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Energy: The missing link in globalization

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ABSTRACT

Energy resources are transported long distances and create powerful interlinkages between countries. Energy thus contributes to the globalization of the world, but has received little attention in the globalization literature. This article hypothesizes that energy globalization is growing and accelerating. The hypothesis is tested by developing an index to measure changes in the extent of energy globalization during the 20-year period from 1992 to 2011. The following sub-indicators are included in the index: number of energy trade relationships, average distance of energy trade relationships, and energy dependency of the countries in the world. The development of the index encounters a number of conceptual and methodological challenges related to globalization, which, it turns out, have not been addressed properly in the broader literature. Clarification of these issues can help improve the analysis of globalization.

1. Introduction

During most of human existence, people would go outside their house, tent, or cave; gather some dead branches or chop down a tree; and that was their source of energy. Only during the past few hundred years have growing numbers of people obtained their energy from further afield, and its supply has thus become entangled in faraway locations and events. This is particularly true of oil, but also of all the other energy types that can be moved across borders: coal, electricity, natural gas, and nuclear fuel—all of which this article deals with. These energy interlinkages are a form of globalization that contributes to increasing interaction between different parts of the world.

The Middle-East oil crises of 1973 and 1979 and the Russian–Ukrainian gas crises of 2006, 2009, and 2014 illustrate the dependency aspect of energy globalization [29,p. 13]. Had importing countries such as the United States and Ukraine been energy self-sufficient, these events could not have occurred. On the other hand, energy resources are unevenly distributed and if all countries in the world were to make do with their own resources, there would be even more energy poverty in the world than there is now. Currently, 1.4 billion people are not connected to an electricity grid, and 2.7 billion people rely on traditional biomass for cooking, with the resulting fumes causing large-scale pulmonary health problems [34,p. 1] [37,p. 153].

The globalization literature covers a large number of sub-topics, including economics (e.g., [20,26,28]), politics (e.g., [39,6,7]), culture (e.g., [8,57,23]), social relations (e.g., [40]), technology (e.g., [41,25,74]) and migration (e.g., [63]). However, energy is a missing link. A seminal analysis of over 4000 articles about energy identified 15 main energy topics and 71 sub-topics, but globalization is not among them ([60,p. 6], cf. [61]). This is also confirmed by a series of searches in the Thomson Reuters Web of Science database [64]. As shown in Table 1, there are many publications on energy and many on globalization, but hardly any touch on both energy and globalization. None are a systematic analysis of energy globalization per se. Many concern irrelevant topics, such as nutrition or dental care, while others are on relevant but narrower topics: the consequences of globalization for the energy sector in a single energy-rich country or region (e.g., [2,55,65]); energy challenges at the global level, such as climate change or energy security (e.g., [10]); or the internationalization of markets for specific energy types (e.g., [4,5]). Only a single publication is about the process of globalization in and through the energy sector itself [30], but it is actually largely devoted to energy security, US interests and the rise of Asia. A search including related terms such as "transnationalism" and "internationalism", which were used more before "globalization" came into widespread use in the 1970s, does not give different results. Never has a systematic analysis providing an overall assessment or measurement of energy globalization at the global level been published.

In addition, an examination of the six main composite indices of globalization finds that none include an energy sub-indicator.

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Table 1
Bibliographical database search; titles, abstracts and keywords; published between 1900 and 2015; limited to social sciences [64].

Search terms	Hits
"Energy"	81 332
"Globali*ation"	27 957
"Energy and globalization"	251
"Energy globali*ation"	0

This includes the Kearney Foreign Policy Globalization Index [70], the Konjunkturforschungsstelle (KOF) Index [56,15,16], the Centre for the Study of Globalisation and Regionalisation (CSGR) Index [71,36,49], the Maastricht Globalization Index (MGI) [17,24], the New Globalization Index [76], and the G-Index [75]. For an overview of these indices, see [59].

As Yatchew [68,p. 74] formulated it, "the pursuit of energy is a fundamental driver of human history" (cf. [62,p. 65]). Energy underpins the economic growth and military might of countries [51,p. 1]. It is seen as a potential driver of international conflict—over political influence in major oil-producing countries, military control over transport choke points and rights to continental shelves [48,p. 1]. Oil companies are some of the world's largest multinational corporations. The largest international oil companies typically operate in scores of countries across all continents, with investments of tens of billions of USD in several of them and tens of thousands of employees spread around the world (e.g., [22,9]).

Energy must therefore be central to globalization, and its absence from the globalization literature is an important omission. It is difficult to say why there has been so little attention to energy in the literature. Perhaps many of those who have studied globalization see energy as a set of simple commodities and overlook its crucial role in the functioning of societies; and perhaps many those who have engaged in the study of energy, many of whom have a preference for hard data, have associated the globalization topic with authors such as Rosenau [58] and see it as wishy-washy. In any case, the purpose of this article is to contribute to filling the gap at three levels: conceptually, empirically, and methodologically.

2. Hypothesis

One of the few works that touches on the topic of energy globalization is Keohane and Nye's [38] book *Power and Interdependence*. The backdrop and inspiration for their book was the oil crisis of 1973, which was precipitated by increasing imports of oil from the Persian Gulf to Western countries, where private car ownership was on the rise. Since Keohane and Nye wrote their book, there have been many new developments that may have accelerated energy globalization. One example is the building of the China–Turkmenistan gas pipeline. By connecting Turkmenistan to China's domestic grid, this pipeline makes it possible to transport gas some 7000 km from Turkmenistan to Shanghai [3]. Turkmenistan is already connected 4000 km westwards via Russia and Ukraine and the European pipeline grid, which in turn extends from Finland in the north to central Algeria in the south. In parallel developments, the EU is working to dissolve old national monopolies and to liberalize, and thus integrate, the European gas market; interconnectors have been created between the various national grids of European countries [54,p. 124], and regasification terminals have been constructed along the European seaboard to receive liquefied natural gas (LNG) by ship from other parts of the world (see Fig. 1). Such developments create new connections between the markets for natural gas in different parts of the world.

A more comprehensive overview of developments that point toward a hypothesis of rising globalization is provided in Table 2. Taking into account the developments listed in Table 2, I hypothesize that energy globalization is growing and accelerating. This hypothesis is echoed by Goldthau and Boersma [29,p. 13] as well as Harris [30,p. 272]: "Today... energy market globalization is unprecedented in its pace, range, and depth." One way of assessing the hypothesis is to create an index of energy globalization to measure flows of energy between different countries and track changes in these flows. The rest of this article is about how such an index can be composed and the interesting conceptual and methodological questions that it gives rise to.

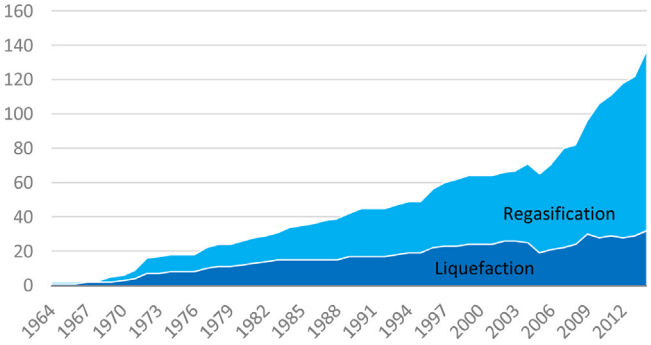

Fig. 1. The growing number of LNG terminals in Europe.

3. Defining globalization

There are many definitions of globalization. In 2006, Al Rodhan [1] gathered 114 definitions, and more have been added to the literature in subsequent years. I have selected four texts as the starting point for an energy-specific definition of globalization. The texts were selected because they emphasize interconnectedness, interdependence, and interrelations, and it makes sense to put such aspects at the center of an analysis of how energy creates interlinkages around the world. In addition, they represent the full breadth of the topics covered by the globalization literature, including criminality, culture, economy, finance, geography, politics, and spirituality. The four texts define globalization as:

> "...the widening, deepening and speeding up of worldwide interconnectedness in all aspects of contemporary social life, from the cultural to the criminal, the financial to the spiritual..." [73,p. 2].

> "...the growing economic interdependence of countries worldwide through the increasing volume and variety of cross-border transactions in goods and services and of international capital flows..." [74,p. 45].

> "...the intensification of economic, political, social and cultural relations across borders..." [31,p. 1].

> "...the intensification of worldwide social relations which link distant localities in such a way that local happenings are shaped by events occurring many miles away and vice versa..." [27,p. 64].

Drawing on these four general definitions of globalization, energy globalization can be defined as the growing interconnectedness of the world's energy supplies through the movement of growing volumes of energy over greater distances across international borders. This definition will be operationalized through the selection of sub-indicators for the energy globalization index in the following sections of the article.

Table 2
Some factors contributing to energy globalization, 1995–2015.

Development		Consequences
Growing energy consumption in emerging economies	>	Makes the global consumer picture more complex and multipolar, less centered on the West
Emerging/expanding petroleum-producing regions	>	Makes the global production picture more complex and multipolar (e.g., the Arctic, East Africa, East Mediterranean, the Russian Far East and Brazilian deep water)
New natural gas pipelines and interconnectors	>	Expands and connects the regions within which natural gas is traded
Unconventional oil and gas technology	>	Increases the number of locations where oil and gas are extracted
Increased LNG capacity	>	Makes it possible to trade gas around the world rather than only within national and regional markets connected by pipelines
Liberalization of trade in energy-intensive commodities	>	Liberalization of trade in energy-intensive commodities such as steel, aluminum and cement leads to greater indirect competition between coal, hydropower and natural gas markets around the world
Expanding regional energy markets	>	The areas within which electricity, coal and firewood are traded have expanded geographically, promoted by free-trade agreements, especially in the EU
Global climate policy	>	Many actors aim to create a unified global framework for all energy use, promoting some energy types and discouraging others
Growing number of electric machines	>	Electric cars, bicycles, garden tools, household appliances, etc., use electricity that can be generated by many different primary energy sources (nuclear power, natural gas, coal, wind power, solar energy), thus bringing these energy sources into competition with each other via the expanding electricity market
Growing number of NGVs	>	Natural gas vehicles (NGVs) lead to increased competition between oil and natural gas in the transport sector, thus connecting oil and natural markets with different geographical coverage
Globalization of news flows and public opinion	>	Affects patterns of energy use across national borders through attitudes toward nuclear power, renewable energy, diesel, sports utility vehicles, electric cars, windmills, etc.

4. Selection of sub-indicators for energy globalization index

For the construction of the index, it is important to find indicators that: say something meaningful about international energy relations; are different from each other; and for which data are available. The three sub-indicators selected according to these criteria are number of energy trade relationships in the world; distance of energy trade relationships; and energy dependency (see Table 3).

An energy globalization index should cover the main energy types that can be transported across borders: coal, electricity, natural gas, nuclear fuel, and oil and oil products. The ideal would be to use data on the actual physical flows of these energy types, measured in barrels of oil equivalent (boe) or British thermal units (Btu). However, because such data either do not exist or are very difficult to access, I instead use financial trade data as a proxy. Economic data are thus used as the basis for the analysis because they are available. However, rather than economics per se, the analysis is about the energy connections between different locations in the world (geography) and between states (political science). In the words of Pasqualetti and Brown [19,p. 122], "if energy and society are parts of the same cloth, geography is the thread that ties them together."

As there is no perfect way of measuring distance for the purposes of analyzing globalization, the number of kilometers between countries that trade energy is used as a proxy. It would not be possible to use the number of kilometers between the exact locations that energy is sent from and to because such data are not gathered. And even if the data did exist, they would not give an entirely accurate picture since energy can travel great distances within a large country such as the USA without much change in context or chance of events along the way; or travel only a few kilometers across a border between two very different locations, for example Norway and Russia. There is also an inaccuracy in using distance between countries while ignoring movement of energy within countries, since some countries such as India or Kenya have far greater internal variation than others. However, since the data are organized by country that is a weakness that we have to live with.

The hypothetical example in Fig. 2 illustrates how the three sub-indicators jointly measure the level of globalization. Country A exports 2 million barrels per day (bpd) of oil to country B. Then, country B becomes poorer while country C becomes richer, so that exports from country A to country B are reduced to 1 million bpd per day and, at the same time, country C starts importing 1 million bpd. The sum of energy dependency in the three countries combined is the same, and the same amount of oil crosses international borders the same number of times; nonetheless, globalization has increased because the number of energy trade relationships has grown.

In addition to the three sub-indicators selected, I also considered including the percentage of energy investment that comes from abroad. Especially in the petroleum sector, and increasingly also in the nuclear and electricity sectors, large companies play important trans-border roles, and this indicator would have brought out the role that these companies play in the energy sector. For most countries, however, it is not possible to find country-level data that distinguish foreign direct investment (FDI) in the energy sector from other FDI. Furthermore, although relevant, this is not the most important potential sub-indicator on energy globalization. For the purposes of this article, the flow of energy itself is more important than the flow of investment in energy.

Table 3
Sub-indicators selected as proxies for energy globalization in index.

	Sub-indicator	Rationale	Source
A.	Number of energy trade relationships in the world	The more other countries a country trades energy with, the more different places in the world it is interconnected with	Comtrade via WITS [66]
B.	Distance in kilometers between countries that trade energy	The further energy travels, the more places, events, and factors it can interact with along the way: wars, shipping costs, storms, pirates, etc. [44,p. 106]	Comtrade via WITS [66]
C.	Energy dependency (ratio of net energy imports or exports to domestic energy consumption)	The more dependent a country is on imported or exported energy, the more connected it is with the world	IEA via World Bank [67]

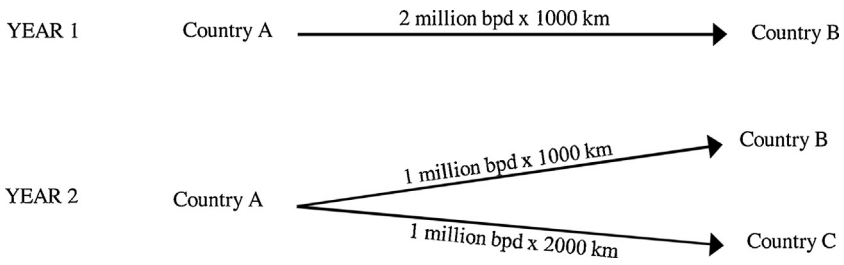

Fig. 2. Hypothetical example of changes in sub-indicators.

5. Temporal cut-off points

For all three selected sub-indicators, data are available from the early 1960s, and my initial intention was to extend the index back to 1960 in order to provide a long-term perspective on energy globalization. However, weaknesses in the data militate against this. The further back in time one goes, the more countries for which data are missing. One might limit the index to those countries that have reported for all years, but this would lead to bias, as the industrialized countries of the OECD are heavily overrepresented among this group. One of the most interesting aspects of the development of the global energy sector is the rise of emerging economies as consumers and importers of energy, and they would be left out because they had limited capacity for recording statistics during the first years of the dataset.

In addition, the further back in time one goes, the more misreporting there is among the countries that did report. According to Melchior [46,p. 5], this leads to an error of up to 12% in terms of trade volume and 35% in terms of number of trade relationships in some years. Some countries entirely failed to report during some years of the first decades of the data. For example, Saudi Arabia, one of the world's largest energy exporters, did not report between 1969 and 1974. Such lacunae make the data unreliable for the 1960s, 1970s and 1980s.

Further challenges are posed by the dissolution of Czechoslovakia, the Soviet Union and Yugoslavia as well as the unification of East and West Germany. If a time series spanning those events were used, it could have made it difficult to know how to interpret the globalization data. With the breakup of states, integrated energy systems for single countries are disrupted by the newly erected international borders of multiple successor states. In the case of the Soviet Union, there were as many as 15 successor states. This leads to energy crossing more international borders, a higher count of international energy trade relationships and an increase in energy dependency. For example, the same amount of oil transported annually from the same field in Russia through the same pipeline to the same refinery in Belarus before and after the dissolution of the Soviet Union would be registered by the index as increased globalization. The question is whether that would be correct. One might argue that it is correct because globalization is not only about physical distance but also about what might be thought of as political distance. The dissolution of the USSR led to a more complex world with a larger number of distinct political units, and thus, the total amount of globalization increased.

The growing integration between the EU member states raises the opposite question: although the countries interact across their borders with increasing ease, they are also less separate than before. Does the world become less globalized due to EU integration? One could emphasize that the EU is not a country but still many separate sovereign states, and therefore, the greater integration between them brought about by the EU should correctly be counted as increased globalization. But what if the EU were to be transformed into a fully integrated state—should its contribution to globalization then suddenly be counted as negative? Or to make the problem starker, what if the whole world became fully integrated under a UN government? Would that make the world less globalized? Intuitively one might argue the contrary, that it would be a highly globalized world.

If one juxtaposes state disintegration and integration, it is difficult to make the logics add up. If the dissolution of the Soviet Union meant more globalization according to the logic of political distance, then according to the same logic the integration of states in the EU or other regional organizations should mean less globalization. This paradox may be caused by an underlying contradiction. On the one hand, states are used as proxies for different locations on the planet, and thus, sometimes the use of states as the unit of analysis can lead to misleading results insofar as one is actually interested in locations and the distances between them. On the other hand, state boundaries and the separateness of sovereign states as independent political entities *are* also a relevant factor in their own right, so they also have to play a role in the analysis.

This contradiction and the other problems with data described above are not easily resolved, but they are partly obviated by starting the time series in 1992. By the end of that year, the Soviet Union had dissolved, Germany had been reunited, and Czechoslovakia and most of Yugoslavia had dissolved. With the dataset starting in 1992, it is still possible to capture the many interesting developments of the 1990s and 2000s that might contribute to globalization, such as longer pipelines, intensified efforts at market liberalization, the growth in LNG and the rise of the BRICs and other emerging economies.

After the data were truncated in 1992, there were still some countries for which data were incomplete. Most of these were microstates, which were simply removed from the dataset. This left a dataset of 197 countries, covering the vast majority of the planet's economy, population, and surface. However, data were still lacking for a few major countries for occasional years after 1992—for example, Russia, which happens to be the world's largest energy exporter [53,p. 6]. For these countries, it was assumed that no change occurred in the years with missing data.

The next three sections discuss the sub-indicators separately. Each of them makes a contribution to the overall picture of energy globalization and raises different methodological issues.

6. Sub-indicator A: number of energy trade relationships

If a country engages in both the sale and purchase of energy with another country, should this be counted as one or two energy trade relationships? For example, if one country exports crude oil to another country and re-imports refined gasoline from the same country, the two countries are more dependent on each other than if the country had only exported crude oil and not imported anything in return. I therefore count a unidirectional relationship as one relationship and a two-way relationship as two.

For each unidirectional relationship, the data are registered twice in the statistics, by the exporting country and by the import-

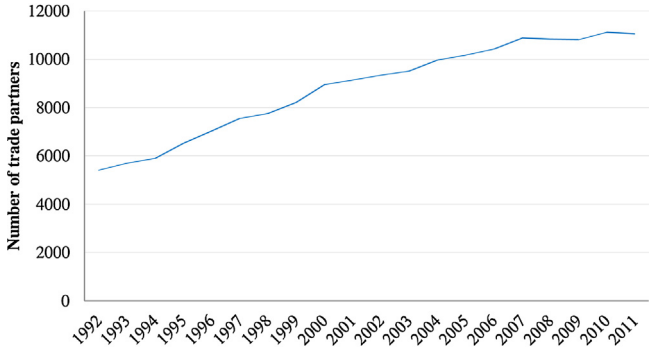

Fig. 3. Sum of number of energy trade partners of 197 countries.

ing country. Often, these data diverge (cf. [46,pp. 4–5],[33]). Which of these should one use? Because importing states have an interest in levying tariffs and in stopping illegal goods, I assume that their statistics are more reliable and I therefore use them. Thus, if two countries only trade one way, it is registered as one importing relationship; if they trade both ways it is registered as two importing relationships.

I also decided to count each trade partnership as one relationship regardless of how many energy types the two countries traded. This was partly because it was easier to do with the data downloaded from the WITS website and partly because in a globalization perspective it is more important how many other countries a country has energy trade relationships with, than the specific types of energy traded.

Having decided on these basic questions about how to interpret the statistics, I turned to a more complex issue. My initial plan was to simply count the change in the number of energy trade partners over time: the greater the number of trade partners, the more globalized the world. However, this raises some complex questions, which can be exemplified with the following hypothetical cases. If a country's population is 10 million and it has 100 energy trade relationships, but then the population grows to 11 million and the number of energy trade relationships grows to 110, is the country more globalized? As a state, it has more energy trade partners, but per capita, the number is the same. Most people I presented this example to concluded that the index should simply measure globalization relative to countries, not the size of their population. However, this problem can also be conceptualized with a different example. If country x has a population of 5 million and has 10 energy trade relationships, while country y has a population of 1 billion and has 12 energy relationships, which is more globalized? Here, one might be tempted to conclude that country x is more globalized than country y, but then the logic is inconsistent with that in the previous example.

If the aim were to compare the degree of energy globalization of different countries, this could be an intractable problem. However, as this study is instead aimed at tracking change in the world as a whole over time, the question is slightly less problematic and boils down to a choice between whether one wants to measure globalization per capita (or per USD of income); or globalization of the world as whole without regard to the number of people who inhabit it or the size of the world economy. A control question here could be whether one considers more globalized a world inhabited by one million people and with few international linkages less globalized and a world inhabited by one billion people and with many international linkages. My answer to that question is "yes", and I therefore conclude that for the purpose of this index, I am interested in the globalization of the world as whole rather than per capita.

The development of sub-indicator A from 1992 to 2011 is illustrated in Fig. 3. It is worth noting that at its peak in 2010, it shows that there were over 11 000 energy trade relationships, which also says something about the large size of the dataset used for this analysis.

7. Sub-indicator B: average distance of energy trade relationships

The ideal sub-indicator for the index would have been the energy equivalent of the aviation industry's passenger miles, i.e., the number of miles over which each unit of energy travels—what one might call "energy miles". This would, however, have depended on having access to data on physical volumes of energy flows. Because such data either do not exist or are too difficult to get hold of and it is necessary to use trade data in USD instead, energy miles is not an option. If one multiplied the distances that energy is moved by the available trade data, variations in energy prices between different locations and over time would seriously distort the calculations. The prices of natural gas, coal and electricity are particularly prone to geographical variation, while the price of oil is particularly prone to temporal variation—but the prices of all energy sources vary in both dimensions. This means that changes in the trade statistics do not necessarily reflect an increase or decrease in the amount of energy traded. In an energy trade relationship, energy flows in one direction and money flows in the other direction. Although the two are connected, changes in the flow in one direction are not necessarily reflected proportionately in the flow in the other direction. In particular, the price elasticity of demand for oil is considered to be low [11,13,47], but inelasticities exist in many parts of the energy sector. My interest is in the global energy interlinkages as such, rather than the money that is paid for them; therefore, it is important to make sure that the financial trade data are only used as a proxy and do not become the objective of the analysis in their own right.

An alternative might be to calculate an energy miles indicator for only the subset of countries for which data on the actual physical volumes of energy traded are available, but how would one then select a representative group of countries? Those countries with most complete datasets will again be the most industrialized countries, and then one would again miss out on much of the energy globalization driven by emerging powers such as China and India and even more so on the many smaller countries with rapidly growing economies but a history of weak statistics.

After much experimentation, I concluded that the solution to this problem is to instead estimate the average distance over which each country trades in each year, weighted by the financial value of each trade relationship of that country. Although this approach remains vulnerable to variations in energy prices, it is less problematic than the initial concept of energy miles, as the financial values are now only used to select the average distance over which individual countries trade and within one year at a time. To obtain the global sum for a year, I add up all of the country averages in the world for that year.

When calculating the average distance of energy trade relationships, I have again wondered whether it is correct to count each trade relationship twice, once for the exporter and once for the importer. I decided that it is appropriate to do so because I want to know the average distance of trade relationships for each country in the world, and for that, I need to use all of its relationships because each trade relationship has a different effect on the average of the exporting and importing country, which depends on the other trade relationships of the specific country in question. Thus, the distances were calculated in a different way from the number of trade relationships, where each bilateral relationship was counted

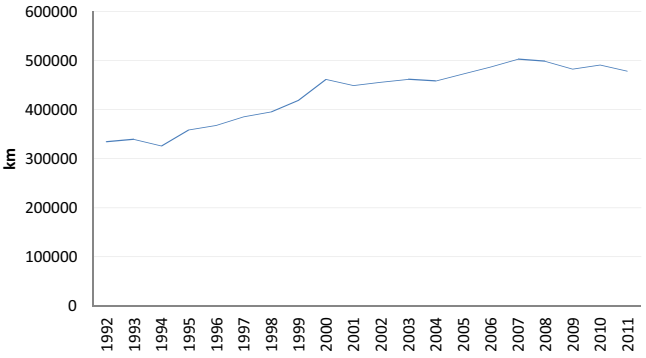

Fig. 4. Sum of average distances of energy trade relationships of 197 countries.

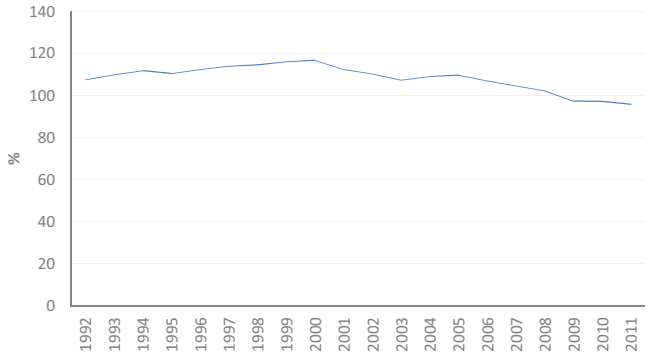

Fig. 5. Average energy dependency of 197 countries.

only once, from the side of the importing country. The evolution of sub-indicator B from 1992 to 2011 is illustrated in Fig. 4.

8. Sub-indicator C: energy dependency

This last sub-indicator puts the other two in context and reflects the saliency of energy globalization. A country engages in a certain number of energy trade relationships over a certain distance, and the country's energy dependency says something about the importance of the other two sub-indicators to that country. A country may trade energy with many remote countries, but if those relationships play a small role in the country's own energy supply, the country can be considered less globalized than if they play a large role.

As with the other sub-indicators, the data on energy dependency give rise to some methodological issues. First, they do not distinguish between energy import dependency and energy export dependency. Although exporting countries have tried to argue that the two are the same concern, or at least equally important concerns, there are clearly important differences between them [72,pp. 540,541],[43,p. 32],[69]. Whereas security of supply relates specifically to basic human energy needs—such as heating buildings, cooking food and the continued functioning of the state—security of demand is a general economic concern similar to the concerns of any country that makes money from exporting something. For example, if South Korea loses access to the market for mobile phones and Russia loses access to the market for natural gas, these two events are comparable. However, if Ukraine loses access to the imported gas that it depends on in the middle of winter, this is not only an economic problem but also a more direct and physical (though not necessarily irresolvable) threat to the Ukrainian population's survival.

While fully recognizing this difference between security of supply and security of demand, this article is not about energy security per se or about the consequences of energy globalization, but about energy globalization in its own right. For the purposes of this article, exports and imports are therefore considered equivalent in terms of representing connections with other parts of the world.

The second methodological issue related to this sub-indicator is that the ratio of net energy imports or exports to domestic consumption is only a partial indicator of dependency. For example, imagine a country that consumes 10 000 bpd of oil, and 100% of it is imported. The country gets richer and starts consuming 20 000 bpd, still 100% from imports. In this case, the ratio of energy imports to domestic consumption is stable at 100% and the sub-indicator registers no change, but in fact, the dependency has increased. This is a possible weakness of this sub-indicator, but it is also worth noting again that the purpose of the index is to measure globalization and not energy security and that this sub-indicator does not stand alone but is combined with two others that cover other aspects of globalization. The development of sub-indicator C from 1992 to 2011 is illustrated in Fig. 5. Interestingly, and in contrast to the steady rise of the two other sub-indicators, this one declines.

9. Combining the sub-indicators

The next step is to combine the three sub-indicators into one index. Because the sub-indicators are different types of values, they cannot simply be added up (cf. [42,p. 507]). One sub-indicator is measured in 1000s of kilometers, one in 10s of trade partners, and one as a percentage of energy dependency. In addition, energy dependency for most countries is net import dependency ranging 0–100, but for a substantial minority of countries, it is net export dependency, which can range from zero to several hundred percent. In order to overcome these differences and make the sub-indicators compatible with each other, I took the natural logarithm of the sub-indicator values. That way, each sub-indicator becomes a normalized percentage-change from the base year.

When the logged sub-indicators are finally combined into the index, another issue is encountered, namely whether to take into account the difference in size of countries. For example, should the globalization of Lichtenstein count as much as that of China or the United States? If the countries are not weighted, a change in Lichtenstein would have equal weight as a change in China or the United States. Since Lichtenstein is a very small part of the world, that would give a distorted view of what is going on in the world. I therefore weighted the contribution of each country to the global index by its share of the world's GDP in that year. Thus, the formula for the final index is as follows:

$$\text{Index}_t = \Sigma \left(\ln a_{gt} + \ln b_{gt} + \ln c_{gt}\right) \times \frac{\text{GDP}_{gt}}{\Sigma \text{GDP}_{gt}}$$

where a is the global sum of the average of the distances of the energy trade relationships of each country, weighted by the financial value of each trade relationship; b is the sum of the number of energy trade relationships in the world; and c is the average of the energy dependency of all of the countries in the world. The final composite energy globalization index is graphed in Fig. 6.

10. Energy globalization counter-trends

Fig. 6 shows that the index does rise over time, in accordance with the hypothesis at the beginning of this article. However, it is not accelerating as hypothesized. Furthermore, the decline in the index in 1998, 2001, 2004, 2008, and 2009 shows that energy globalization can also go up and down and may not always increase over time, further weakening the hypothesis.

There are several factors that could counteract the trend toward energy globalization and lead to a falling index. Firstly, rising domestic consumption in major petroleum-exporting countries

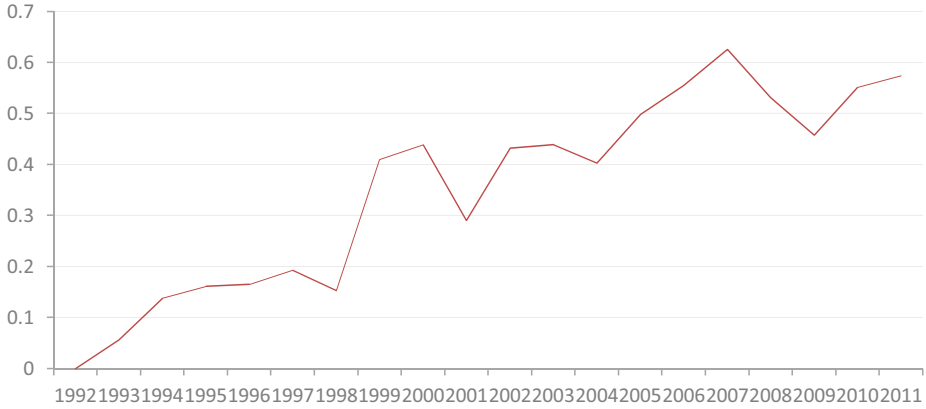

Fig. 6. Energy globalization index 1992–2011.

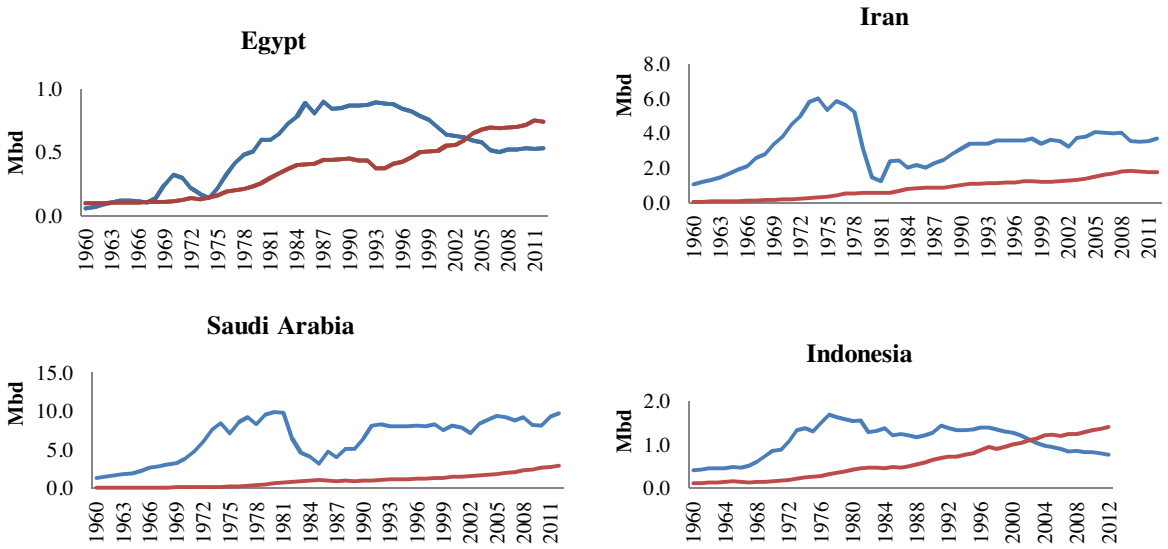

Fig. 7. Energy exports (blue lines) gradually being eaten up by domestic energy consumption (red lines). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source of data: [50].

changes the balance between how much energy they consume domestically and how much they export to other countries. The rising domestic consumption is driven by a combination of three main factors: population growth, economic growth, and energy subsidies. Fig. 7 exemplifies the reduction in net energy exports over time for several major energy exporters, all of which are major energy subsidizers. These changes contribute to a lowering of the energy dependency sub-indicator, until the countries become zero net energy exporters. As they gradually become bigger energy importers from there on, they contribute more and more to globalization again.

Secondly, rising production of unconventional oil and gas have reduced the dependency of the United States on energy imports, especially after 2004 (see the turnaround in US oil import trends in Fig. 8).

Thirdly, the 2008 financial crisis, improvements in energy efficiency, and increased use of locally produced renewable energy and coal all contributed to reducing European and US dependency on imports.

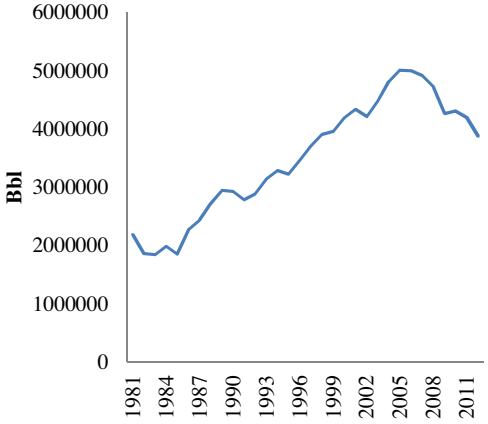

Fig. 8. US imports of oil and oil products.
Source of data: [21].

11. Conclusions

At the beginning of this article, it was hypothesized that energy globalization has been growing and accelerating in recent decades. During the course of the article, an index was constructed to assess the progress of energy globalization. The constructed index indicates that energy globalization has indeed grown, but neither as steeply nor as smoothly as expected expected, and without accelerating. On the other hand, it is still possible that in the longer term,

there will be a trend toward steadily increasing energy globalization with some ups and downs along the way.

It is also possible that energy globalization will abate and even be reversed if a renewable or nuclear energy technology revolution takes place and results in an abrupt re-decentralization of the global energy supply [51]. Unconventional oil and gas have already made a dent in international energy linkages by reducing US energy import dependency [32,p. 55]. Such developments provide support for Clark's [12] critique of globalization conceptualized as an inexorable, unidirectional, technologically determined process, while introducing a rather different force of fragmentation from that envisaged by Clark, who focused on nationalism.

However, as mentioned in the introduction to the article, 1.4 billion people are not connected to an electricity grid, and 2.7 billion people rely on traditional biomass for cooking [34,p. 1] [37,p. 153]. As these people strive to gain access to modern energy, the long-term trend toward energy globalization may easily continue unabated.

Energy dependency was included as one of the sub-indicators for the index, and energy globalization and energy dependency are connected. However, although a rise in energy dependency leads to a rise in energy globalization as measured by the index, a rise in energy globalization does not necessarily lead to a rise in energy dependency—if energy dependency is conceptualized as vulnerability (on the distinction between energy security and vulnerability, see [14,p. 211]. When energy globalization is due to diversification of suppliers and/or consumers, it actually leads to *lower* vulnerability.

In addition to the spatial or horizontal energy globalization examined in this article, there are also changing vertical linkages between different energy types in individual locations. For example, the growth in natural gas vehicles (NGVs) creates interaction between the markets for natural gas and oil, and the generation of electricity from coal, natural gas, nuclear power, hydropower and small-scale renewable energy sources for the same grid bring all of these energy types into contact with each other. These interactions chain together the geographical spans of different energy types. For example, in the EU electricity market(s), American coal competes against Russian natural gas, and both of these are affected by other factors in the United States (for example, shale gas, see [35] and Russia (for example, subsidies for natural gas, see [18,52]. This interface between geographical extent of energy linkages and changing interlinkages between different energy types is not captured by the index in this article. The reason for this is that there are no data that could obtain a systematic handle on the interaction between all different energy types.

The methodological issues that arose in connection with the design of the index also serve to highlight how many basic questions remain unaddressed in much of the globalization literature—in particular, how to interpret the impact of changing state boundaries due to state dissolution or unification and whether globalization should be thought of in relation to the planet or per capita. These issues go to the very heart of the concept of globalization, and it is surprising that they are not more widely discussed in the literature. Further exploration of them would help clarify what globalization is, how it is evolving, and how it can be analyzed.

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