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Hodjat Ghadimi
West Virginia University, Hodjat.Ghadimi@mail.wvu.edu

Davina Bird
West Virginia University, Davina.bird@mail.wvu.edu

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By: Hodjat Ghadimi, Assistant Professor, Davis College of Agriculture, Natural Resources and Design, West Virginia University and Davina Bird, Ph.D. Candidate, Department of Resource Management, West Virginia University

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Website address: rri.wvu.edu

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Hodjat Ghadimi* and Davina Bird**

*Assistant Professor, Department of Design and Merchandising, Davis College of Agriculture, Natural Resources and Design, West Virginia University 704-O Allen Hall, P.O. Box 6124, Morgantown, WV 26506-6124, Hodjat.Ghadimi@mail.wvu.edu, (304) 293-7517

**PhD Candidate, Department of Resource Management, Davis College of Agriculture, Natural Resources and Design, 2044 Agricultural Sciences Building, P.O. Box 6108, West Virginia University, Morgantown, WV 25606-6108, Davina.bird@mail.wvu.edu

Abstract

Energy rich regions (ERRs) play an important role in the world economy. A knowledge base of energy rich economies on a regional level provides a useful tool for comparative research of sustainable development in ERRs with an interdisciplinary perspective. The purpose of this knowledge base is to present a foundation for understanding the attributes and development processes of various ERRs and the collective role they play in the world's energy, environment, and development debate. The construction of the ERR knowledge base is described, including the steps and data sources, structure, and process. Using two databases on oil and gas giant fields and megaprojects, this article demonstrates preliminary observations and illustrations about the nature and characteristics of ERRs. This research will assist in formulating and addressing interesting questions for future qualitative and quantitative studies.

Keywords: energy rich region, knowledge base, oil, gas

Transitioning to a sustainable energy future is one of the greatest challenges for the 21st century when the earth's exhaustible resources are rapidly depleted to meet the growing needs of growing populations. The International Energy Agency (IEA) calls the current world energy system unsustainable – environmentally, economically, and socially – and considers the pivotal energy challenges of today to be keeping energy available at a relatively low cost while moving quickly to a sustainable and "environmentally benign" energy system (International Energy Agency 2008, 3). These challenges are overwhelming and complex; they are multidimensional in scope– social, ecological, technological, economic, and political – and global in scale.

The IEA has estimated that $26 trillion in new infrastructure investment will be needed by 2030 to ensure the flow of energy to satisfy anticipated worldwide demand (International Energy Agency 2008). Clearly, regions endowed with energy resources receive the bulk of these investments. Which resource rich regions start off or continue to attract these investments in energy projects? What are the regional, national, and global development impacts of these investments? Are there identifiable patterns of development within regions that attract energy investment? Are these developmental patterns and investments aligned with the science of sustainability?

In order to initiate answering such questions, the objective of this research is to utilize a basic information system, or knowledge base, to analyze and derive development patterns of a region—the focus in this article is on economies rich in energy resources of oil and gas. The motivation for this research is the exploration and analysis of data and information contained within a comprehensive knowledge base of ERRs around the world. This article's specific objective is to present the construction and components of a knowledge base of ERRs while demonstrating some preliminary observations utilizing a basic knowledge base for the world's energy regions.

The multifaceted nature of development on any regional scale implies it is an issue that crosses many disciplines and fields of study, and has given rise to many interdisciplinary approaches and perspectives. The creation of a knowledge base provides a conceptual tool for any discipline to utilize in promoting regional development, and so it is truly interdisciplinary. By defining a 'region' as a flexible unit of analysis, as is done in this paper, it is possible to aggregate and disaggregate to different levels of information in order to make best use of the data available. Lastly, this basic knowledge base for the world's regions is a tool to place regions within a national or global context.

This article next provides a more detailed discussion of ERRs including their defining characteristics, defines what distinguishes ERRs as regions, and identifies a fundamental challenge to defining ERRs' boundaries. Subsequently, the second section of this article describes the construction of a regional and spatial knowledge base of regions rich in energy resources with ESRI's ArcGIS. Then the knowledge base of ERRs is utilized in a third section to demonstrate some statistical 'snapshots' and illustrations that offer insights into development within and around ERRs. This article concludes with a few remarks concerning further quantitative and qualitative analyses.

DEFINING ENERGY RICH REGIONS (ERRS)

There exist a range of ways and means to define or delineate the boundary of a region and a diverse set of perspectives on which method is the best for determining regions. Edgar Hoover and Frank Giarratani (1984, 243) state that "common to all definitions of a region is the idea of a geographical area constituting an entity, so that significant statements can be made about the area as a whole." However, the extensive literature on regional issues offers no agreed upon unique or specific definition of regions other than suggesting that the choice of regional definition often depends on the object of inquiry (Isard 1975; Richardson 1979; Guttenberg 1993). While the three classical types of regions are generally known—homogenous, nodal, and administrative—John Meyer (1963, 22) makes the argument that these types of regions are not mutually exclusive and "all regional classification schemes are simply variations on the homogeneity criterion". Many authors have advanced their own definitions of regions ranging from very spatially specific to more abstract definitions (Nourse 1968; Schaeffer and Bukenya 2001). Regional delimitation is further made difficult by the fact that regional economies are often more open to external trade, migration, and institutions than national economies (Meyer 1963). While the challenge of defining regions in a meaningful way for the object of inquiry is daunting—especially when data is limited to larger aggregations or does not exist—perhaps the real challenge is sifting through the wealth of data and knowledge already available and providing a means through which to translate the information for stakeholders.

In defining an energy rich region (ERR), the application of the homogeneity criterion initially determines the world's ERRs as those with reserves of oil and gas as the common denominator across all disaggregated constituent ERRs. The main characteristic of ERRs is that they depend primarily on the extraction of exhaustible resources for economic growth and livelihood; therefore, the exploitation of energy resources has played an important role in their development path. In this study, the ERRs considered are administratively defined regions that contain amounts of oil and gas resources greater than 500 million barrels of ultimate recoverable oil or gas equivalent (mmboe)—this includes the onshore and the closest off shore reserves. ERRs have two distinguishing features. First, no other commodity's presence or absence has the potential to impact the global economy as significantly as the lack or abundance of these energy resources would. The strategic and heavy dependence of the world on oil, and increasingly on natural gas, has created a market advantage that no other exporter enjoys.[1] Secondly, oil and gas—like a number of other natural resources—are exhaustible. These regions cannot consider resource revenues as a permanent stream of income, though they may last well beyond a host of political administrations and quite a few human generations. Most often ERRs have the common development challenge of converting their valuable—but exhaustible—natural resources into reproducible physical and human resources, e.g., infrastructure and education or skills given the ‘local’ political, cultural, ecological and economic environment.

ERRs have very diverse climates and are located across the globe. They fall within a wide spectrum of economic systems, from command to market economies, and their reserve size varies as well as levels of dependence on resource revenues. The base spatial unit of analysis for an ERR could be a state or province within a country but at a larger scale—and depending on the focus of the study—an ERR can cross the borders of two or more countries or continents. There is significant variability in economic, political, ecological, geographical and social characteristics both within and between these ERRs. The flexibility of regional spatial size is helpful in capturing and isolating patterns and characteristics that a country or national level analysis alone may be ill-suited to illustrate. Given availability and access to data, one can use varying aggregations of ERRs to show different information. For instance, a province level ERR may capture cultural or social effects while at a country level one could show political information; depending on the energy related objective, the scale and/or scope of the region may change.

There are several challenges and limitations to delineating the boundaries of a region that is both efficient in scale and scope, but capable of identifying a common development pattern across all ERRs. Global data is frequently only available at a national level and disaggregation beyond state, province or municipality level of government is limited and/or unreliable; the data and information may be unverifiable or difficult to obtain, particular when the information is considered important to national security. This requires that any definition for an ERR be consistent with the spatial and temporal data; this limitation exists because a knowledge base cannot be created without knowledge. A related challenge to data provided by some institutions is that the available data is already aggregated two or three times and the underlying disaggregated data are unavailable or costly to aqcuire.[2] While the challenges and limitations considered are substantial, they are not insurmountable.

Within this article, the simplest way to think of an ERR is to liken it to a spatial unit within which there are *significant* exploitable, profitable and exhaustible energy reserves. This section of the article is predominately focused on providing a definition for ERRs wherein the boundaries are neither too expansive nor too restrictive. Since an ERR depends upon a flexible spatial scale, the best use was made of provincial, national, and international data and information to create a knowledge base for ERRs.

A BASIC KNOWLEDGE BASE

While there are other approaches to constructing an energy or environmental information system or knowledge base (Drozdz 2003), this section of the article is the first to describe an applied step-by-step process for the formation of a regional knowledge base focused on energy rich regions. The compilation of information and construction of the regional knowledge base included four steps:

i. Base components

ii. Complementary information

iii. Queries and templates

iv. Visualization

The inputs, base data, the general procedure used, and the output of each step are briefly described.

The first step uses base data components to specify the geography of ERRs and to lay out the foundation of the basic knowledge base. The information derived from two databases was used in an ArcGIS-based world map to identify and map out ERRs around the globe.[3] The first database contains information on 877 global oil and gas giant fields discovered between the years of 1868 and 2003. The source for this data was a CD database "Giant Fields 1868-2003 (CD-ROM)"(Horn 2003). The oil and gas giant fields' database includes the latitude and longitude, name of the giant field, location (state or province and nation), class (oil or gas), year of discovery, age of geologic features, giant field depth, and the ultimate recoverable volume of oil, gas and condensate.

The second database contains energy megaprojects[4] and is maintained by an oil megaprojects task force (WikiProject Energy 2010). While there are several previous attempts at a megaproject database—like the one created by Chris Skrebowski, an expert in global oil projects, for peak flow analysis—this article used the one that was most accessible to the public and freely available.[5] The oil megaprojects database used here contained information on 318 megaprojects that started up between 2003 and 2010. Megaproject information was provided at the country level and included the following: year startup; project name; operator; area; country; type (oil or gas); peak year; peak; discovery year; and capital investment. To determine the state and province location of each megaproject, the project name and country were used to search the internet and other resources for information to associate the megaproject with a state or province; only 213 megaprojects were located utilizing this method. Since not all megaprojects were identified at a provincial level, there may be regions that actually have a higher number of megaprojects than reported in the knowledge base.[6]

The latitude and longitude for the identified giant fields were used to determine a spatial point location using the ESRI ArcGIS program. Then, the point locations were used to determine the state or province that contained oil and gas giant fields. While the megaproject information did not contain latitude and longitude information, data was linked to the state and province polygons. The state and province level ERRs were thus determined from the combined locations of the giant fields and megaprojects which produced the "basemap" for ERRs. Each region was assigned a unique numerical code as a key to link the region with the input in all other data tables. This format allows for storing and sharing of tabular data as well as linking to spatial for the purposes of map production. As shown in the base map, 234 individual ERRs were identified and directly tied to oil and gas fields at a provincial level. The base data available for each ERR includes: population, land area, oil and gas (ultimate recovery) reserves and other identifying characteristics for that site like if the ERR country is a member of the Organization for Economic Co-operation and Development (OECD) or Organization of the Petroleum Exporting Countries (OPEC).

In the second step, a wide range of complementary data and information from various sources and institutions was collected and categorized according to four main categories of data representing ERR regional developmental potential: 1) Geographic 2) Geologic 3) Geo-economic 4) Geo-political. Geographic data may include land cover, land use and type, location of facilities and infrastructure, other built environment features, and population. The main geologic pieces of data for this project are the depth and size of the oil and gas giant fields, while other data not included could pertain to the quality and accessibility of the resource. The geo-economic data can include the oil and gas sectors' production, labor force, and a host of other economic data gleaned from national and international level data sources. The final indicator, geo-political, involves the structure of power and the nature of formal and informal institutions in countries where ERRs exist and national and global energy flows that are impacted by those power structures.

The third step involved designing a set of queries and templates to facilitate data manipulation and derive needed information from the knowledge base. With the flexibility of 'region' as a unit of analysis, different queries of interest can be created at different levels of regional aggregation from a single subnational unit to larger regions, e.g., province to country to OECD. By designing templates based on regions and objects of interest, this research is able to show some basic information, statistics and features of the world's ERRs. By crafting queries and templates targeted at revealing patterns of development, it will be possible to more effectively analyze and illustrate the concentrations and networks within the knowledge base through correlations and similarities across and within regions.

For the final step, queries and templates were used in combination with visualization tools like Google Earth Pro to produce and portray selected information on ERRs. The overall goal for the ERR knowledge base is to provide a cohesive data and information infrastructure for qualitative and quantitative analyses of development in these regions within a global context. The advancement and refinement of this knowledge base construction process will allow researchers to compare and contrast specific regions, derive patterns of development, and address multidimensional issues prevalent to the world energy system.

Preliminary Observations from a Knowledge Base of ERRs

ERRs with oil and gas comprise thirty percent of the world's land surface and twenty percent of the world's population; however, out of total global area (including water), they comprise 8.7 percent. Geographically, these ERRs are located in 68 countries all over the world and on every continent. ERRs are spatially dispersed and non-homogenous, e.g., each region may have different political, ecologic, cultural and economic systems. This makes identifying patterns and information more challenging and it also broadens the scope of what an ERR may include and delineate because of the capability to not just aggregate, but also disaggregate geographically.

While identifying development patterns is beyond the scope of this article, there is a commonality across giant fields within ERRs in that most (94 percent) are less than four kilometers in depth. In modeling or cost-benefit analysis, depth could serve as a parameter in evaluating the costs for the oil or gas extraction for an average giant field in the region of interest. Other interesting trends may be meaningful if analyzed within the context of an increasingly globalizing world and the rising demand for transportation, technology and energy:

- Seventy four percent of giant fields were discovered in the twenty years before and after 1973—a pivotal time for energy production. Before 1950 there were only 152 giant fields discovered, but this jumped to 323 giant field discoveries over the next twenty years. From 1971 to 1990, 304 giant fields were discovered. During the 1990s and up until 2003, only 97 giant fields were discovered.
- Most of the early discoveries took place in North America with some in Eastern Europe and South America, while the more recent discoveries are heavily concentrated in the North Sea and Persian Gulf.
- Offshore oil and gas giant fields account for thirty two percent of giant fields discovered, while oil and gas offshore reserves are respectively 14 and 20 percent of total ultimate recovery of all oil and gas giant fields.
- Total ultimate recovery of all oil and gas giant fields within the ERRs in this knowledge base is 2,070,719 mmboe.[7]

While it is possible to conjecture based off this information, what is safe to say is that most of the easier large discoveries in oil and gas are made by now and there are some uncertainties over how much longer current reserves will last.

There are four mega giants that contain more than 50,000 million barrels of oil equivalent (mmboe). There are an additional 75 super giants which contain more than 5,000 mmboe that are scattered around the world. Altogether, the mega and super giants account for about 58 percent of total reserves where the four mega giants alone account for 19 percent with 14 percent residing in the three gas mega giants in Iran, Qatar, and Russia.

OPEC countries with ERRs have 55 percent of total oil and gas reserves compared to the OECD countries with ERRs that have 13 percent. This leaves the other 119 countries with ERRs with 32 percent of total reserves. The top fifty oil and gas companies in the world in 2007 owned an estimated 83% of the oil and gas reserves contained in this knowledge base (PetroStrategies Incorporated 2010).

Hoover and Giarratani (1984) discuss delimiting functional regions using ‘flow’ information and, building upon this. Perhaps what is needed is a functional ERR region that uses flow data, whether quantities of the energy resource, money, migration, etc., in order to classify energy rich regions. The evidence presented here hints at the wealth of knowledge that might be attained through the further development of this knowledge base of ERRs.

CONCLUDING REMARKS

This research expands the literature by taking the first steps in developing a knowledge base for regions to be used as flexible units of analysis to demonstrate patterns of development and assist in the advancement of appropriate 'development metrics' (Baster 1972). With a more comprehensive knowledge base, we could identify energy production stage of a giant field or region or the role of politics and culture in a given cluster of ERRs. A comparative study could be used to look at two ERRs that have the same amount of energy resources, but very different socio-economic and political environments in order to assess perspectives on the relationships between resources, people, and their environment. Alternatively, one could look at the role of energy resources on a local ERR level by controlling for and holding constant, insofar as is possible, the socio-economic or political variables between two or more ERRs.

There are several future steps for this research to consider. The use of better and more recent data will improve the accuracy of any analysis. The amount of reserves at any point in time is relative to the available technology and what can be extracted using this technology. By including reserves made economically viable and technically feasible through advancement of processes like hydraulic fracturing, e.g. oil sands and shale gas, the knowledge base will provide better and more thorough understanding of developmental patterns. The third step for a better knowledge base within this research is expanding the visualization of the patterns, information, and data within the knowledge base. Future efforts to improve visualization will focus on showing wealth and other capital forms, e.g., natural, physical, and intangible (World Bank 2006); this will include better visuals on the stocks and flows of energy within and between regions. Careful analysis of the regional patterns of development of these energy rich economies and polities will help to more clearly identify the critical 'nodes' and 'linkages' that are crucial to regional and global energy systems.

From a global perspective, the emphasis on development of ERRs is critical in terms of maintaining and extending the current energy system indefinitely. To achieve development in ERRs is a spatially complex and context-sensitive process. Although ERRs have the common problem of converting their valuable but exhaustible natural capital - particularly oil and gas - to other forms of reproducible capital, they have otherwise very diverse economic, political, social, and spatial characteristics. This diversity reflects the multifaceted nature of development in ERRs and highlights the need for a multiregional and multidimensional global context to study economic development in these economies that goes beyond economic factors to include other socio-ecological dimensions. By using a comprehensive knowledge base of energy resources, flows and relationships, policy and decision makers can have a means to make the best choices not only for today, but also for tomorrow.

ENDNOTES

1. Certainly, the development of a cheaper and more efficient renewable source of energy could replace oil and gas as the world's preferred sources of energy, as once oil replaced coal. Whether this occurs sooner or later in a given region may

depend on the emphasis placed on social versus technological advancement within a local context (Pasqualetti 2011).

2. For example, most data available using the North American Industry Classification System (NAICS) codes in the U.S. report oil and gas data aggregated together in order to protect the identities of the businesses.

3. A project is typically only considered a megaproject if the investment is greater than one billion U.S. dollars.

4. For future research, purchasing more complete oil and gas megaproject data may be necessary through a source like the *Oil and Gas Journal*.

5. An additional issue with the data is the difference in time as the megaprojects data covers a different span of years than the giant field data.

6. According to the IEA's 2008 World Energy Outlook, total ultimate recovery of conventional reserves, including remaining proven reserves and undiscovered resources, amounts to about 4.5 trillion barrels of oil equivalent (International Energy Agency 2008). The U.S. EIA estimates that proven oil and gas reserves in 2009 were about three trillion barrels of oil equivalent.

7. This knowledge base does not include the recent significant estimations of the availability of unconventional oil and gas resources through technological advancements in the exploitation process.

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