DIVERSIFYING GROWTH IN LIGHT OF ECONOMIC COMPLEXITY

Muhammed Yildirim

Harvard University

EXECUTIVE SUMMARY

A key challenge for countries dominated by extractive industries is to develop other, more productive economic sectors. Analysis from the "Atlas of Economic Complexity" suggests that such transitions are hard to engineer and intuitive steps such as moving down the value-chain can lead to dead-ends. The best strategy for these economies is to attempt larger, more aggressive leaps into new areas that lend themselves to the accumulation of skills and greater diversification.

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Many of the world's poorest economies are dominated by extractive industries. These industries are limited in lifespan by the reservoir size of the country, and countries cannot grow sustainably by just extracting more. These countries need to shift into other productive activities to jump-start growth, but this process is far from trivial. Here, we will use the methodology that is introduced in the Atlas of Economic Complexity by scholars at Harvard and the Massachusetts Institute of Technology to explore this question.

Countries do not grow rich in a sustainable fashion by making more of the same; they change what they produce by moving to activities that are both new and more productive. The diversification process leads to increased sophistication over time. Countries do not move from making coffee beans to making airplanes in one swoop. Countries need to gradually build the capabilities and knowhow to move into ever-expanding set of new and more sophisticated products. This sophistication process cannot be attributed to pure acquisitions of raw materials, capital and labor; instead this is a story of accumulation of capabilities and productive knowledge. These capabilities and productive knowledge have been distributed in the society, whether in individual's brain or in its institutions. The sophistication of the products that a society makes is indicative of the amount of productive knowledge and capabilities they have accumulated. There are products like medical imaging devices or space shuttles that require vast amounts of knowledge. Whereas, harvesting sesame seed require much less. Hence, most sophisticated products will be inevitably produced by the countries holding the vast amount of productive knowledge.

We call the distributed productive knowledge in a country its *economic complexity*. In other words, complex economies are the ones that can bring vast amount of productive knowledge together to generate a diverse mix of knowledge-intensive products. By contrast, simpler economies make fewer and simpler products based on their limited productive knowledge. The more productive knowledge countries have, the more opportunities they have to recombine that knowledge in new ways to develop new products and products that are more complex.

But how can economic complexity be measured? Concepts of productive knowledge and capabilities embedded in a country are abstract and mostly immeasurable. But we know that the economic complexity is also expressed in the products that a country makes. For instance, making a computer would indicate that the country has gathered all the requisite knowledge to make it. On the other hand, we know that the productive knowledge does not survive long when not used in a productive process. Thus, the economic complexity of the country is almost completely revealed through the products the country makes.

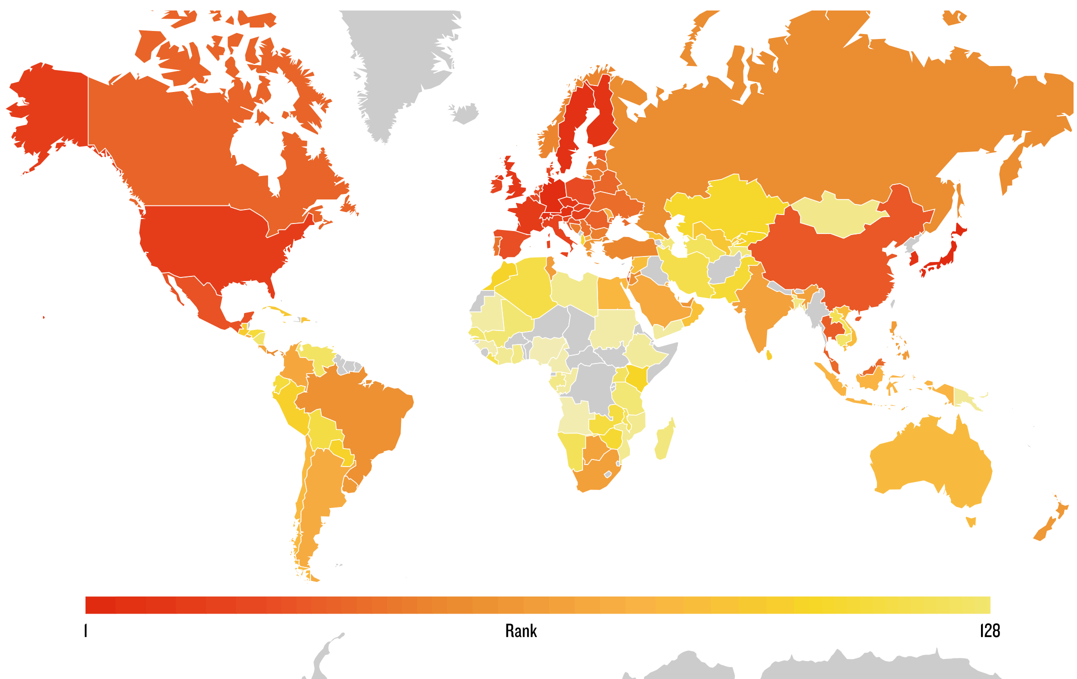
With this insight, to simplify matters, let's use a simple analogy. Suppose that each type of productive knowledge is a letter and each product is a word composed of these letters. Like the game of Scrabble, each country holds a set of letters with plenty of copies of each letter and tries to make words out of these letters. For instance, with letters like A, C and T, one can construct words like CAT or ACT. Then our problem of measuring economic complexity resembles interpreting how many different letters there are in each country's portfolio. Some letters, like A and E, go in many words, whereas other letters, like X and Q, are used in very few. Extending this analogy to the countries and products, only those with a larger diversity of letters will be able to make more and more unique products. On the other hand, words that require more letters will be made only in the countries that have all the requisite pieces.

Players who have more letters should be able to make more words. So we can expect the diversity of words (products) that players (countries) can make to be strongly related to the number of letters (productive knowledge) that they have. Thus, diversity is an initial measure of how much knowledge a country has. The number of players that can make a word is indicative of how many letters the word has. Longer words will tend to be less common, since it necessitates players with all the requisite letters. Similarly, more complex products will be less common because only the countries that have all the requisite knowledge will be able to make them. Products that require little knowledge should be more ubiquitous and vice versa.

We define the diversification of a country as the number of different products it can make and the ubiquity of a product as the number of countries that can make that product. Countries with a greater variety of letters will be more diversified. Products that require more letters will be less ubiquitous. Ubiquity by itself is a coarse-grained measure of complexity, since a product can be non-ubiquitous even though it does not require much productive knowledge. Going back to the Scrabble analogy, think of a short word like “Xi.” This word is non-ubiquitous because it involves a rare letter, X. But this word will be easily formed by the countries with letter X, making them not necessarily diverse. But a long word, like "knowledge," can only be formed by diverse countries. Therefore, we can update the complexity of the product by combining the ubiquity information with the diversity of countries that make the product.

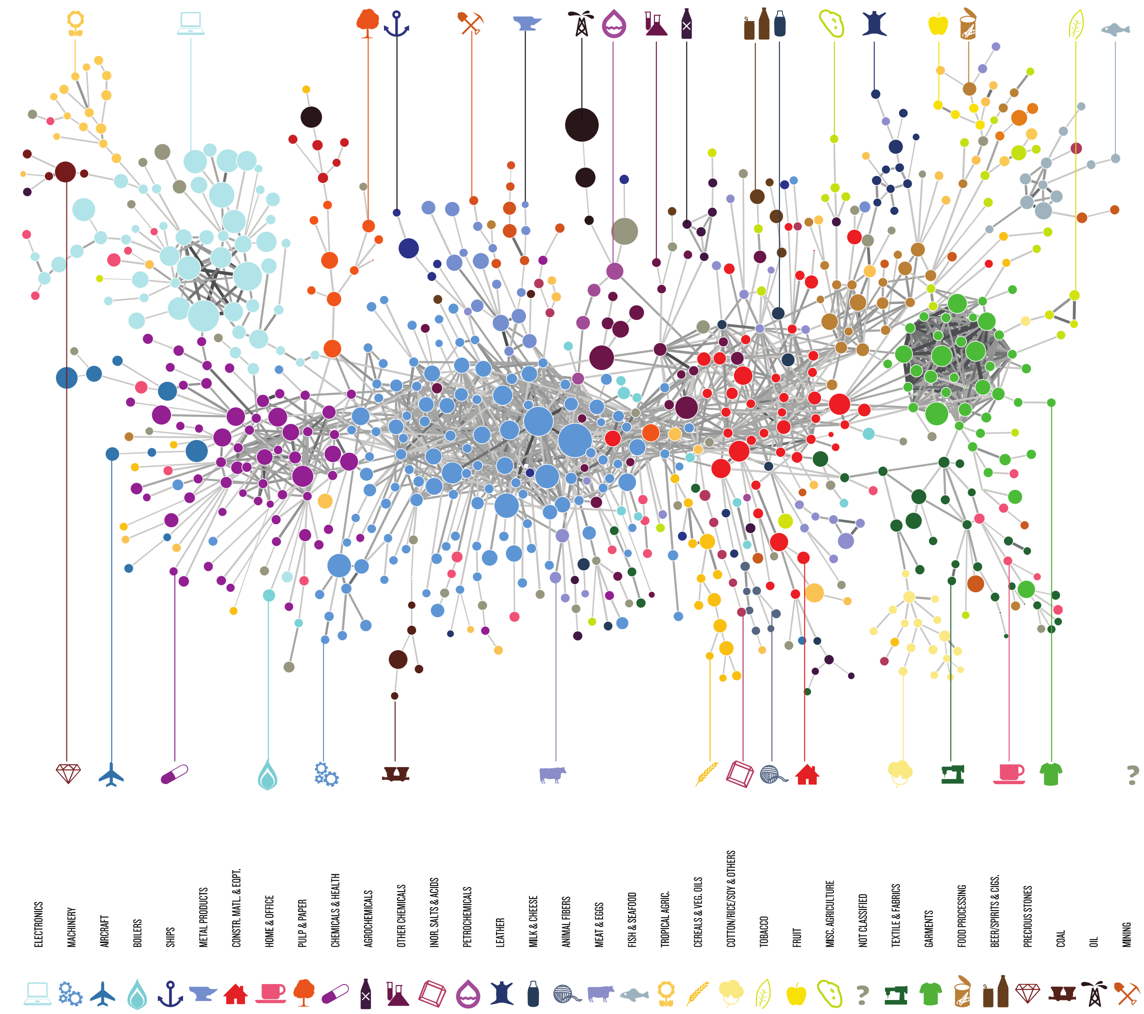
Following this logic, we can note that diversity and ubiquity are, respectively, approximations of the variety of productive knowledge available in a country, or required by a product. They can be used to arrive at a summarized measure of knowledge present in a country or knowledge required by a product—the **Economic Complexity Index (ECI)** and **Product Complexity Index (PCI)**. The PCI is a number unique to each product that captures how complex it is. A product is complex if it is made by highly diversified countries that make predominantly rare products. The ECI is a number unique to each country that measures the average complexity of its products (Figure 1). Countries with a high ECI are well- diversified countries exporting, on average, high-PCI products. In Table 1, we show the rank of PCI for some of the extractive industries. Many of these industries are among the top 10 percent of lowest PCI industries, implying that these industries do not require a large variety of productive knowledge.

Figure 1: Ranking of Countries by the Economic Complexity Index (ECI)



Why is complexity important? As we demonstrate clearly in the Atlas of Economic Complexity, the ECI does not only carry information about the productive structure of countries but also income and future growth. Moreover, it outperforms all other measures of country sophistication in its explanatory power, including governance indicators, education and financial quality measures.

Figure 2: Visual Representation of the Product Space

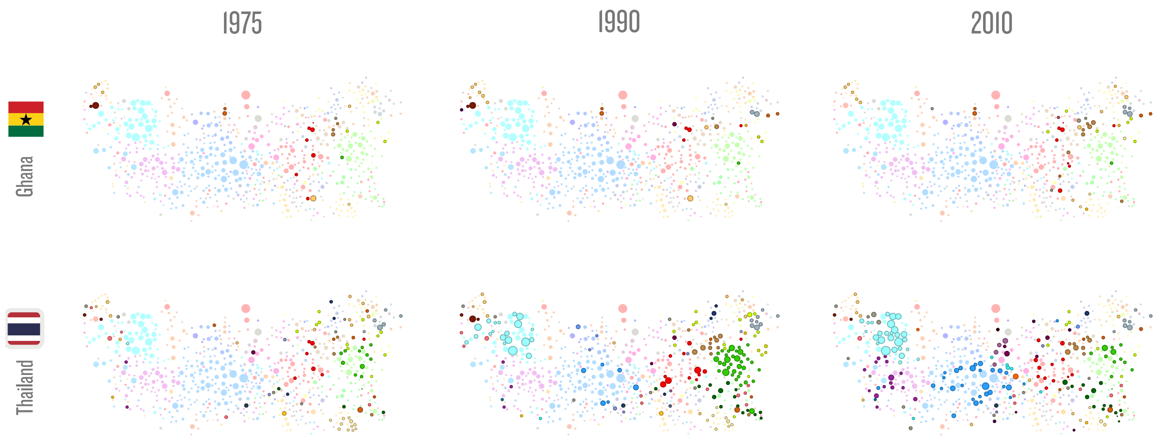


Note: Each node is a product and its size is determined by its share of world trade. Two products are connected by links based on their probability of being co-exported. The higher this probability, the thicker and darker is the link between the products. The color of each product node corresponds to its community, which are the groupings of highly interconnected products that naturally emerge in the Product Space. We interpret the existence of these strong connections as evidence that the products in a community share a specialized set of inputs or knowledge different from that shared by other communities.

How do countries move into making new and more complex products? Countries tend to move from products that they are making to new products that are "nearby": products that use—to a large extent—productive knowledge that already is utilized to make other products. This reduces the amount of new productive knowledge that needs to be coordinated with the development of the new industry. Here we can use the insight that if two products require very similar productive knowledge, they will either be simultaneously present or absent in most countries. For instance, if artichokes require knowledge similar to that required by asparagus, but different from that required by engines, then for most countries producing artichokes, asparagus production will also most likely be observed, but the same will not apply to engines. So the probability that pairs of products are coproduced by countries carries information about how similar these products are. If two goods require roughly the same knowledge they will be produced by the same countries. Hence, we can define a similarity measure between products based on the probability of co-appearance of the products and depict it as the "Product Space" (Figure 2). In this visualization, two products (represented by circular nodes) are connected if they are likely to be co-exported by many countries. It is important to keep in mind that the Product Space is a technological feature of products, not of countries. There is therefore one Product Space in which countries evolve, rather than a Product Space for each country.

One striking feature of the Product Space is the core-periphery structure. Products in the periphery of the Product Space are only weakly connected to other products, and many of these products are mineral or agricultural products including petroleum (large dark brown circle on top). This heterogeneous structure of the Product Space has important implications for the diversification process. If a country is producing several goods in a dense part of the Product Space, for example the central machinery cluster, then the process of export diversification is easier. That is, because, the set of productive knowledge used in current machinery products can be more easily used to produce other nearby products. However, if a country is specialized in peripheral products, for example petroleum, then this redeployment is more challenging because there are few nearby products that use the productive knowledge used for the peripheral products made by the country. Thus the ability of countries to diversify is crucially dependent on their initial location in the Product Space. All else equal, countries that have many products at short distances from their current capabilities face an easier path toward future diversification. We can observe striking differences between evolution of Ghana and Thailand on the Product Space between 1975 and 2010 (Figure 3). Although, both countries had similar average years of schooling and per capita income at the beginning of 1970s, Ghana's economic complexity and income stagnated as it remained an exporter of cocoa, aluminum, fish and forest products and only added gold to its portfolio. By contrast, due to its more advantageous position on the Product Space, Thailand underwent a massive diversification process and increase in economic complexity, between 1970 and 1985 that gave rise to a sustained economic boom after 1985. Currently Thailand's per capita income is more than three times higher than that of Ghana.

Figure 3: Evolution of Ghana and Thailand on the Product Space

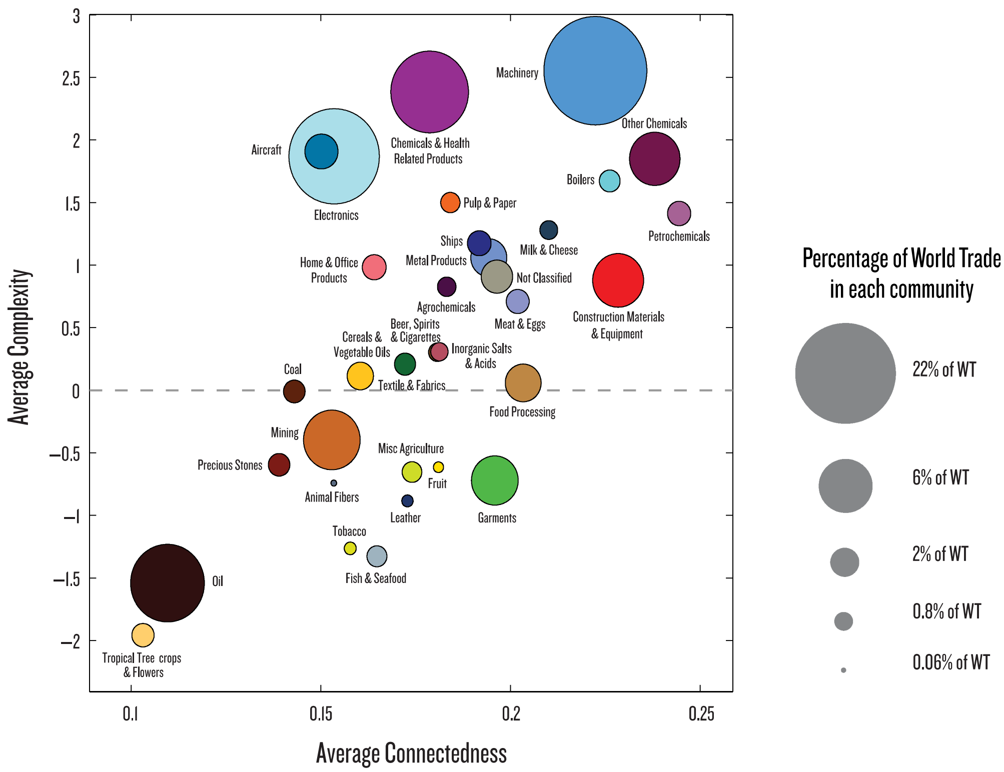


Note: Fully colored nodes are the products that these countries have comparative advantage in.

Peripheral products can be identified through how well they are connected to the rest of the product space. Figure 4 reveals a positive relationship between how centrally located the product communities are in the Product Space and how complex these products are. Not surprisingly, peripheral products with low connectedness values are also the products with least average PCI, indicating that these products do not need require large amounts of productive knowledge and the required productive knowledge by these products cannot be used in other products. Mining and agricultural products are poorly connected and they are also low in complexity. Machinery, on the other hand, is very complex and is highly connected to the rest of the Product Space. Garments, textiles and food processing are in an intermediate position. Electronics and health-related chemicals are very complex but not as highly connected as machinery implying that they use specific productive knowledge to the products within these clusters. Table 1 shows the ranking of connectedness of individual extractive industries among 773 products in the Product Space. Most extractive industries are also very peripheral, ranking in the bottom 10 percent of the connectedness scale. If we examine two proximate products to the extractive industries, they are either other extractive industries or downstream products in the value chain.

It is important to recognize that the path by which countries diversify their product portfolio does not necessarily follow an input-output or value chain relationship. For example, countries that produce cotton do not necessarily hold comparative advantage in making garments, or vice versa. Countries diversify by leveraging the productive knowledge that they possess. Thus they move into making products that use similar productive knowledge to what already exists. Input-output relationships in a value chain do not necessarily indicate shared productive knowledge. There are some cases where these relations coincide. For example, we find that refined petroleum products and petrochemicals are relatively "close" in the Product Space but that "cotton yarn" and "knitted undergarments of cotton" are not close, although they are directly linked in the value chain. The idea of moving up the supply chain might not result in many diversification options. For instance, in Saudi Arabia, where most of the upstream industries of oil production are present, only 1.1 percent of all jobs are within this sector. And Saudi Arabia has been struggling to diversify into other industries.

Figure 4: Community Characteristics



Note: Average complexity of the products in each community as a function of the community's connectedness. Bubble size is proportional to the community's participation in world trade.

Our focus here is countries that have lagged behind in the economic development and whose economies have been hitherto dominated by the extractive sector. Many of these countries find themselves in the sparse and peripheral parts of the Product Space with few nearby opportunities for diversification. In these cases, enhancing production possibilities around existing industries will not produce the leaps that are desired—from petroleum to cars, from garments to electronics, etc. Such leaps call for more aggressive industrial policy. It entails selecting a number of new industries or products, call them strategic bets, at which to target public inputs. The aim of such support is to provide temporary public support that will attract and facilitate private investment to the new products and sectors. Diversification is a risky enterprise that must tolerate failure. The point is not to always pick winners—an impossible goal—but to have the discipline to let losers go.

But what kind of diversification is desirable? Improving the economic complexity and achieving prosperity should be the goal. To this end, countries should be moving into products that are not just increasing their immediate income, but rather they should encourage moving into products that will enable them to move up in the complexity ladder. This can be achieved by maximizing the capabilities and productive knowledge useful for many other industries. These industries can be identified with the Product Space as one can quantify how much closer each industry brings the country's productive base to the complex products. The key idea is to maximize spillovers onto other industries. For instance, the United Arab Emirates strategically diversified away from oil by moving into the financial, tourism and construction sectors, which have large spillovers on each other. A large airport, golf courses, shopping malls, business centers and industrial clusters were all part of an elaborate plan that depended on each other. Whereas, moving into petroleum refineries or other mineral processing activities require huge amount of capitals and generally do not generate knowledge spillovers.

In the countries which are in dire need of jump-starting growth, government support should focus on stimulating new products. Potential entrants into a new product face considerable uncertainty as to its cost and productivity under local conditions. Breaking into new sectors typically requires a pioneer investor, who signals to other investors the profitability of these new products. This process is ripe with information externalities and spillovers because followers can benefit from the information revealed by the pioneer. As a result, markets tend to under-provide entrepreneurship in new products.

Therefore, targeting public resources at new products might be a good strategy. This is bound to generate information that is valuable to other potential producers, who will benefit from these efforts. Government should focus on providing missing public inputs and limit support, which distorts the price mechanism. Here the government is well advised to focus on providing the inputs that businesses need but cannot supply or purchase in private markets. These can include public inputs like infrastructure, regulation, certification, labor training, coordination of potential investors and suppliers, etc. But all these infrastructure developments should be available for all industries. For instance when a rail line, a port or a power plant is built, they should not be dedicated to one industry. Indirect subsidies such as artificially low cost of energy or water are often not the most effective tools of government support. Indeed, such support can distort market incentives by pricing intermediate inputs below their long-run marginal costs. This can lead to inefficiency, misallocation and unsustainable budget pressures for governments.

Beyond benefitting the immediate employer, investments in labor training have positive externalities as workers move from one firm to another or set up their own businesses. Subsidizing labor more than capital also helps to avoid generating incentives for excessive investment in capital-intensive activities—an outcome which runs contrary to the government's priority goal of employment creation. Industrial zoning can be a useful tool to ease problems of coordination and to facilitate provision of key inputs. Around the world, industrial parks tend to provide high-quality infrastructure, friendly and competitive business environment, and deliver services at lower costs due to economies of scale. They can also coordinate the supply of additional requisite inputs and provide ecosystems in which productive knowledge can easily diffuse between firms.

Where can extractive activities take us? Here we introduced use of the methodology of the Atlas of Economic Complexity to explore. We show extractive sectors are in a peripheral part of the Product Space, are badly connected to the rest of the Product Space, and have low product complexity values. In addition, the idea of moving up the value chain will at best create a narrow path in the Product Space and will not create type of knowledge spillovers to jump into more lucrative parts of the Product Space. The best strategy is therefore larger, more aggressive leaps into the areas of the Product Space that are denser and more connected to push a country closer to the higher-complexity products. This is hard to pull off but the most viable route toward sustained development and economic transformation requires such an aggressive strategy.

A more detailed description and many data visualizations can be found at http://atlas.cid.harvard.edu/.

Table 1: Some Extractive Products and their Rankings in Complexity and Product Space Centrality

Product Name	PCI Rank (out of 773 Products)	Connectedness Rank (out of 773 Products)	Proximate Products	
Crude Petroleum	770	758	Natural Gas	Nitrogenous Fertilizers
Natural Gas	741	741	Crude Petroleum	Nitrogenous Fertilizers
Agglomerated Iron Ore	595	715	Not Agglomerated Iron Ore	Pig & Cast Iron
Aluminum Ore	675	717	Not Agglomerated Iron Ore	Agglomerated Iron Ore
Copper	746	691	Zinc	Other Non-Ferrous Base Metals
Manganese	745	764	Aluminum Ore	Other Coal
Natural Calcium Phosphates & Aluminum	704	762	Phosphate Fertilizers	Asbestos
Not Agglomerated Iron Ore	681	736	Agglomerated Iron Ore	Aluminum Ore
Nickel	677	748	Other Coal	Asbestos
Tin	766	767	Unwrought Copper & Copper Alloys	Other Coal
Uranium & Thorium	629	773	Manganese	Radioactive Chemical Elements
Zinc	584	590	Lead Ore	Unwrought Silver
Industrial Diamonds	618	671	Not Mounted Diamonds	Precious Jewelry
Crude Natural Potassium Salts	481	771	Phosphate Fertilizers	Natural Calcium Phosphates & Aluminum
Roasted Iron Pyrites	505	765	Pig & Cast Iron	Unwrought Nickel & Nickel Alloys
Asbestos	663	750	Unwrought Nickel & Nickel Alloys	Other Coal
Anthracite	602	727	Pig & Cast Iron	Solid Fuels
Lignite	498	720	Other Coal	Agglomerated Iron Ore
Other Coal	583	711	Lignite	Asbestos