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### The Wealth of Nations

#### A country's competitive edge can spread industry to industry, like a disease

**Davide Castelvecchi**

The economies of poor and developing countries often depend almost exclusively on a single product—perhaps timber or coffee—or on a handful of products at most. That's hardly a startling observation, but what's puzzled economists over the years is why it's been so difficult for these countries to start up new activities in the hope of spurring economic growth and lifting themselves out of poverty.

While there have been a few success stories, such efforts have often ended up consuming heaps of money to little lasting effect.

A team of economists and physicists is now proposing a new way to look at development. The researchers have shown that a country's competitive edge can spread from one kind of product to another along a well-defined network of links, much as disease epidemics tend to spread among people who are socially connected.

The newly charted map of products could help countries design good policies by indicating the most promising paths to creating new industries. The network's structure also presages the hurdles that many developing countries will face along that path.

Traditionally, economists have tried to link a country's commercial expansion to "factors of production," such as reliable transportation infrastructure or the availability of skilled and unskilled labor, explains Ricardo Hausmann, an economist at Harvard University. For example, says Hausmann's colleague and graduate student Bailey Klinger, conventional economic theory predicts that a country with the capacity for making computer chips should also be competitive in other industries that require skilled labor, such as vehicle manufacturing.

But when the two economists looked at actual data, such correlations often failed to show up. Many countries that export computer chips don't export cars, and vice versa. Building and shipping cars requires very different skills and infrastructure than making computer chips does, the researchers point out.

Instead, the two found correlations that standard economic reasoning didn't predict. For example, fish exporters are often successful at exporting fresh produce as well. That's because both activities require similar infrastructures—good roads, ports with refrigerated storage facilities, and bureaucracies able to monitor food safety—Hausmann and Klinger suggest. A country that has developed the means to generate and export one product can easily branch into the other.

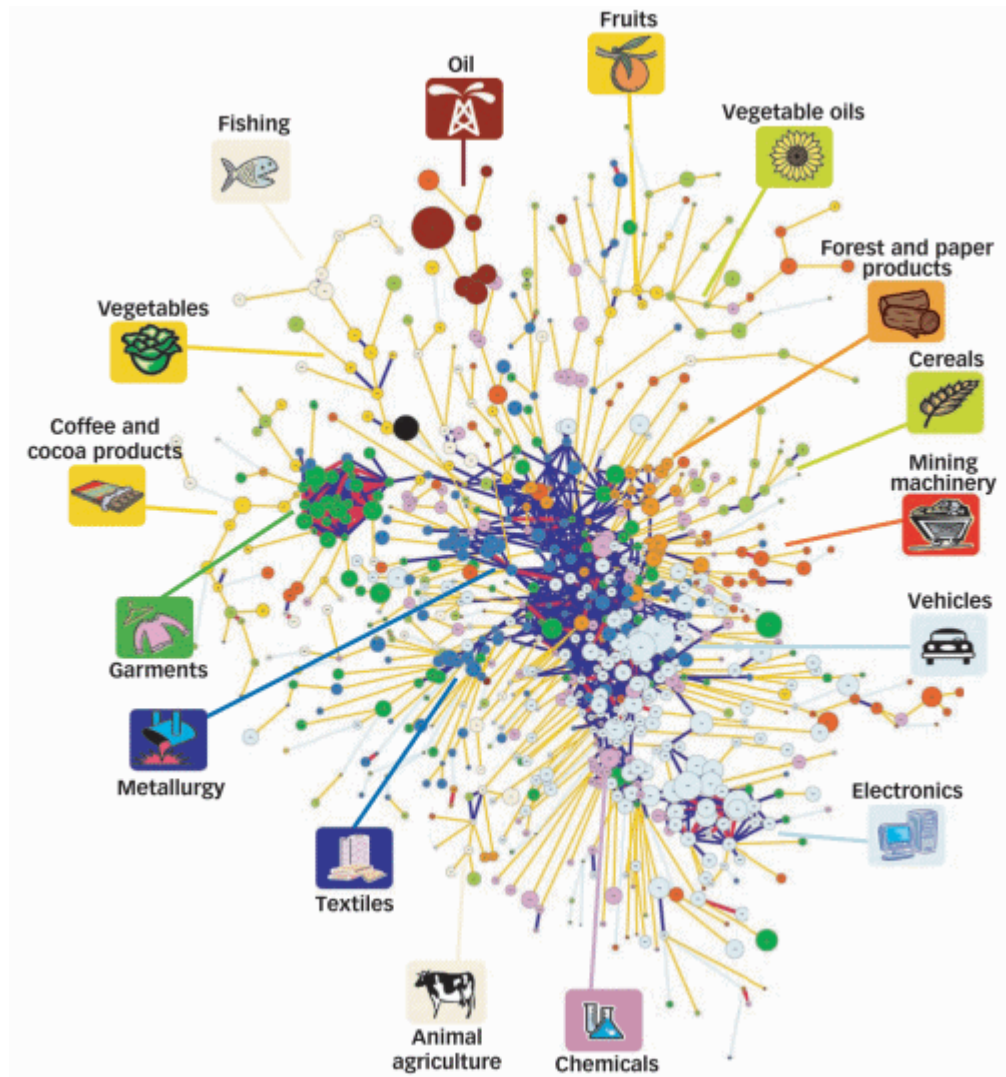


*An entrepreneur traffics in empty oil drums in the Nigerian port of Warri. Mathematical analysis of the connections among industries explains some of the difficulties that face developing countries trying to expand and diversify their economies.*

George Steinmetz/Corbis

## Path to success

To refine their perspective on economic linkages, Hausmann and Klinger developed a new notion of closeness between products. By analyzing global export data on numerous categories of goods, the two economists calculated, for each pair of categories, the probability that if a country is good at exporting one type of product, it will also be good at exporting the other. When that probability is high, those two products have a short "distance" between them. When the probability is low, the products are far apart.



*HIDDEN LINKS. In the product space network above, nodes represent products. The more closely products are linked, the more likely they are to be produced and exported by the same countries. Each node's size represents the total world trade in that product, and the nodes' colors follow an older classification of products.*

Hidalgo/Science

The researchers focused on export data because they are good indicators of high-quality production, and because they are the best global data available. While many countries don't compile reliable data on domestic production and consumption, exports are carefully recorded worldwide.

Hausmann and Klinger created a table listing the distance between each pair among 775 types of goods. To make sense of this mountain of data, Hausmann sought the help of Albert-László Barabási, a physicist at the University of Notre Dame in Indiana. Barabási specializes in applying the abstract theory of networks to real-life situations, such as the structure of the Internet or the degrees of separation between people.

Cesar Hidalgo, a graduate student working with Barabási, translated the distance data into a network. He represented each category of goods as a node and drew links between nodes only when they were close

according to Hausmann's metric. Nodes that were strongly connected to many other nodes formed clusters, whereas those that had only a few connections straggled out toward the edge of the diagram. Hidalgo chose an arrangement of the nodes to spread out the network on a page as clearly as possible.

The resulting network, which the four researchers call the product space, maps out world exports. But it represents a kind of cartography that has nothing to do with the geography of the countries involved. Instead, the map shows how industries gather in clusters according to how likely it is that those industries thrive in the same countries. The team's findings appear in the July 27 *Science*.

In the middle of the product space lies a large "continent" of products tightly connected to each other. These include the vast majority of industrial products, from machinery and steel to chemicals. Garments, textiles, and electronics form their own, smaller, clusters.

Farther out, almost in isolation at the network's periphery, are products such as oil, minerals, cereals, and coffee.



*REGIONAL DIFFERENCES.* In these illustrations, black squares mark products successfully exported. The industrialized countries' products (left) occupy the highly connected core of world trade. Goods from Southeast Asia and the Pacific region (center) cluster in the garment industry and in electronics, while sub-Saharan Africa's products (right) are mostly peripheral.

Hidalgo/*Science*

The rich countries of the industrialized world tend to have broad portfolios of industries, and accordingly occupy large areas of the product space, usually including much of the network's core. Fast-growing developing countries such as China, Thailand, and Hungary are strong in some of those central, well-connected regions. The poorest countries, especially those in sub-Saharan Africa, tend to specialize in a few of the peripheral products—such as oil for Nigeria and copper for Zambia.

The product space is a snapshot of the status quo in the global trade of goods. It represents empirical data, not an interpretation of the causes of the status quo or of its consequences. However, the researchers also argue that the network can help explain why some economies have grown, while others have not.

By crunching 2 decades' worth of data, the team showed that countries that have expanded into new industries have usually done so by stepping from one node to another one directly linked to it. The process is reminiscent of how information or diseases spread across a social network.

For example, the team looked at Malaysia's and Colombia's exports during the 1980s and 1990s. In those decades, both countries were successful at branching out into new industries close to those in which they were already competitive. Colombia widened its production of garments to include lingerie, while Malaysia expanded into cameras from other electronics products.

On the other hand, economic activities toward the periphery of the product space have fewer links. These tend to be industries, such as mining or the growing of certain crops, that require infrastructure or skills with few alternative uses. Historically, countries that rely on them have had a hard time branching out into new industries. The network's structure is a stark reminder of the difficulties that these countries face, and the four authors admit that it doesn't point to an easy solution. "Nevertheless," Barabási says, "it's important to understand what are the causes and the consequences of where these countries are."

## Treasure hunting

Hausmann and his collaborators say that their new approach might help governments and aid organizations orient themselves when deciding how to invest money, though it won't point to specific policies. "It's kind of like having a map that allows countries to move around from product to product," Hausmann says. "But the map doesn't tell you where to go."

To emphasize the contrast between their model and standard economic theories, the researchers color coded the network's nodes using an existing classification that groups products according to the similarity of the factors of production they require. Nodes of the same color often ended up far apart, meaning that in practice, countries have rarely been able to move directly between them. "It's telling you that these factors of production are not [the factors] that matter" to predict how diversification can succeed, Hidalgo says.

"This is a highly original approach," says physicist Eugene Stanley of Boston University. "What makes it unique is that the network is not a network of countries, but of products."

"The analysis is pretty revealing," says Luis Amaral, a physicist at Northwestern University in Evanston, Ill. "If you just had the data on a table, it would be impossible to see these patterns at all." Amaral says that the team's methods might help economists understand the growth of companies as well as of countries.

Columbia University's Joseph Stiglitz, a recipient of the 2001 Nobel Prize in Economics, says that the team has come up with "a very interesting and appealing idea." He says that he emphasized the importance of product-specific skills over factors of production as early as 1969. That was before network theory and computers enabled economists to tackle extreme complexity.

For Hausmann, the ultimate question is, "Will the world converge, or will it continue to be a world of poor and rich countries?" In the past few months, he has been traveling around the world, invited by officials of developing countries and international organizations to brief them on his team's approach. At least two countries—South Africa and Colombia—have begun reviewing possible policy changes based on the new ideas. His team's research has highlighted how countries' potentials differ. Perhaps it will someday help countries figure out how best to exploit their potentials.

"If you just had the data on a table, it would be impossible to see these patterns."

— LUIS AMARAL,  
NORTHWESTERN  
UNIVERSITY

"Will the world converge, or will it continue to be a world of poor and rich countries?"

— RICARDO HAUSMANN,  
HARVARD UNIVERSITY

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### Further Readings:

Supplemental information about the Product Space and the Wealth of Nations is available online at:  
<http://www.nd.edu/~networks/productspace/index.htm>.

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Luis Amaral  
Department of Chemical and Biological Engineering  
Northwestern University  
2145 Sheridan Road, Room E136  
Evanston, IL 60208

Albert-László Barabási  
Department of Physics  
University of Notre Dame  
225 Nieuwland Science Hall  
Notre Dame, IN 46556-5670

Ricardo Hausmann  
Kennedy School of Government  
Harvard University  
79 JFK Street  
Cambridge, MA 02138-5801

Cesar Hidalgo  
Department of Physics  
University of Notre Dame  
225 Nieuwald Science Hall  
Notre Dame, IN 46556-5670

Bailey Klinger  
Kennedy School of Government  
Harvard University  
79 JFK Street  
Cambridge, MA 02138-5801

Eugene Stanley  
Department of Physics  
Boston University  
590 Commonwealth Avenue, Room 204B  
Boston, MA 02215

Joseph Stiglitz  
Columbia Business School  
Columbia University  
3022 Broadway  
New York, NY 20027

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