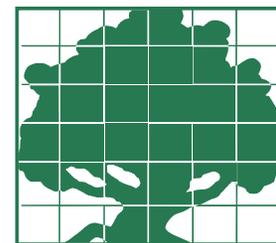


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Beer: A Poster Child of the Bioeconomy

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The bioeconomy includes agricultural sectors that rely on farm inputs and biological processes to produce a wide array of products. The traditional bioeconomy relied on fermentation to produce cheese, beer, etc., while the modern bioeconomy relies on biotechnology. The history of beer used as a case study suggests that over time, the bioeconomy evolved to produce differentiated products with elaborate supply chains. Its evolution depended on investments in research and a balanced regulatory environment.

The bioeconomy has been promoted in recent years. It is viewed as a large sector of the economy that relies on biological processes to produce various end products, including food, fuel, chemicals, etc.

The recent interest in the bioeconomy stems first from concerns about climate change and the need to move away from nonrenewable resources. It also stems from the new capability developed in recent years through modern techniques in molecular biology. While the bioeconomy seems to be a modern concept, this paper argues that it has been with us for millennia and was part of our oldest industries.

We use beer as a case study, beginning with its origin in the traditional bioeconomy and drawing out what lessons it holds for the new bioeconomy. The first section elaborates on the bioeconomy, the second tells the story of beer, and the third provides some of its implications. This history of beer suggests that technological development will lead to the expansion of the bioeconomy, which will lead to new types of farming and new differentiated products. The development of the bioeconomy will also be dependent on the ability to capture new opportunities and introduce reasonable regulations that balance concern over safety, with opportunities for creativity and innovation.

The Bioeconomy and Supply Chain

The bioeconomy includes many sectors such as food, agriculture and

forestry, fisheries and aquaculture, biotechnology, biofuels, and fine chemicals. The bioeconomy is part of the renewable economy (which also includes solar energy and the recycling sector) that will allow humanity to deal with the increasing monetary and environmental cost of nonrenewables and climate change.

Agriculture is a crucial element of the bioeconomy as the source of its raw materials. The notion of the bioeconomy suggests that outputs of agriculture will contribute to a larger range of products consumed. This new range of products provides new opportunities for agricultural production; and the growing importance of these products affects the way that we understand the economics of agriculture.

Understanding the performance of the bioeconomy is a new challenge for agricultural economists. One key element in this challenge is understanding the supply chain of each of its sectors. These supply chains consist of at least two elements: the production of feedstocks and their processing to a final product. For example, the biofuel sector is an important element of the bioeconomy. In the case of biofuels, the supply chain includes the production of feedstocks on farms (e.g., corn and sugar cane) and processing to produce multiple by-products in refineries (e.g., ethanol and dried distilled grains). The modern bioeconomy also includes companies that produce enzymes, farms that produce feedstock for medical products,

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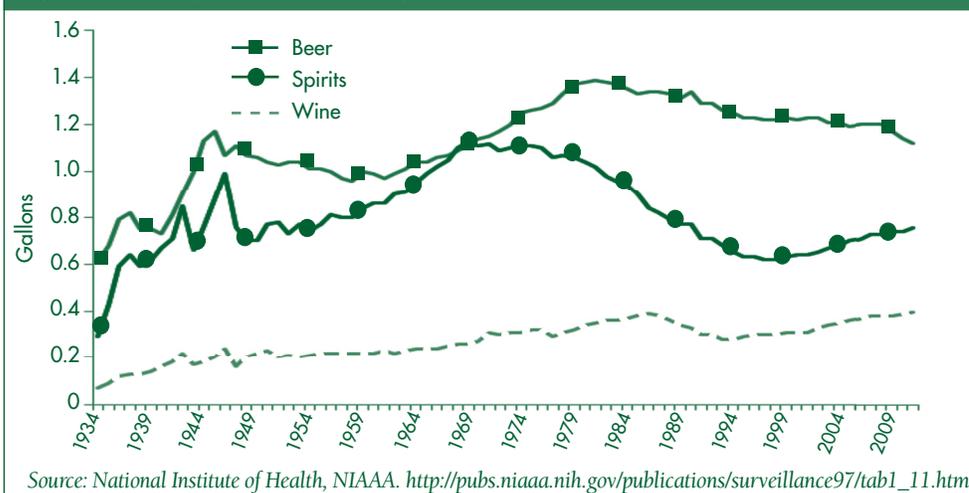
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Figure 1. Per Capita Alcohol Consumption, United States, 1934–2009



and factories that use forest and food residue to produce building materials.

The supply chain of the various sectors of the bioeconomy may give rise to interesting industrial structures. For example, in the poultry sector, Tyson Foods supplies feedstock to farmers who raise chickens. In turn, Tyson processes the chicken into various products. The interaction between Tyson and the chicken farms is through contract farming. Other chicken processors such as Foster Farms use vertical integration—and own the chicken farms.

Further, the development of the bioeconomy is subject to government regulations on acceptable technologies. For instance, genetically modified crops are banned in many parts of Europe but used in some parts of the United States. It is interesting to understand the factors that drive the emergence of supply chains and the different ways they are regulated.

The potential of the bioeconomy has been enhanced immensely by the discovery of DNA and new technologies that utilize modern molecular biology, genetics, and information technology. While the bioeconomy seems like a new and modern system, actually the old bioeconomy is one of the oldest industries. The old bioeconomy relied on fermentation to produce alcoholic products like

wine, beer, vodka, pickled foods (like kimchi), and cheeses of various types.

The old bioeconomy provides some valuable lessons for the new bioeconomy. One of the most important case studies is beer, which we emphasize below. A large body of research has focused on beer, including an informative book by Jo Swinnen, *The Economics of Beer*, as well as several other books and websites dedicated to this subject.

The Evolution of Beer

It seems from the blogs that it's unclear which came first: beer or bread. Historians speculate that prehistoric nomads may have made beer from grain and water before learning to make bread. The ancient Egyptians who built the pyramids got paid by beer, bread, and green onions.

Different cultures rely on available grains to produce beer. They use millet, maize, and cassava in Africa, agave in Mexico, and rice in Japan. The Egyptians grew a specific variety of barley for brewing beer, and beers were part of many medical prescriptions in Egypt and many other cultures. Even before people knew about germs, they realized that beer and alcohol protected them against contaminated water.

Also, alcoholic beverages provided nourishment, pain relief, and socializing. People consumed different drinks according to their needs. For

example, in the Middle Ages, low-alcoholic beer was called 'Small Beer' as a safe alternative to water. Higher alcohol content beer (4%) was used as part of regular meals, and even higher content (6%) was used in festivals. This is part of the differentiation that became a characteristic of the beer sector. Concern about quality and market power led to the establishment of a brewing guild in Germany, as well as purity standards in the 15th century.

Production of beer has industrialized. In early times, families brewed beer. Then it shifted to centralized production and became a source of income for monasteries and convents. Eventually, breweries became independent businesses that were selling beer both on the premises and in containers to go.

The production of beer evolved over time. In the early days, it required some grain, water, and the addition of herbals for flavoring. Since the Middle Ages, the use of hops replaced most of these flavorings. In 1876 Pasteur unraveled the secrets of yeast in the fermentation process, and he also developed pasteurization to stabilize beers 22 years before the process was applied to milk.

Currently, there is a specialized industry producing different varieties of yeast for beer. The West Coast, and especially the Yakima Valley in Washington, specializes in hops, which is a high-value crop that is managed effectively through contracts. Brewers operate barley breeding programs to produce malt that will result in beer with specific flavors. However, the barley industry, which is a low-value crop, is declining in both the United States and Canada.

Taxation of beer was a major source of income for governments. Jo Swinnen suggested that the Low Countries (Holland and Belgium) won their independence from the Spanish because of beer. They financed their armies from beer tax, while the Spanish relied on tax on silver. The beer won.

Beer was very important in the history of the United States. In 1620 Pilgrims land at Plymouth Rock because the beer supplies were running low. The soldiers of the Revolutionary Army received a quart of beer a day. Beer was taxed, but James Madison suggested a low duty in order to encourage beer production in the states.

Prohibition in the United States was a traumatic event for the beer industry, when more than 80% of the breweries disappeared. However, those that survived became stronger, according to Carlos Hernandez, an economic historian from UCLA. Survivors switched to other drinks, such as sodas, and I imagine that during Prohibition, they were able to gain a foothold in the black market.

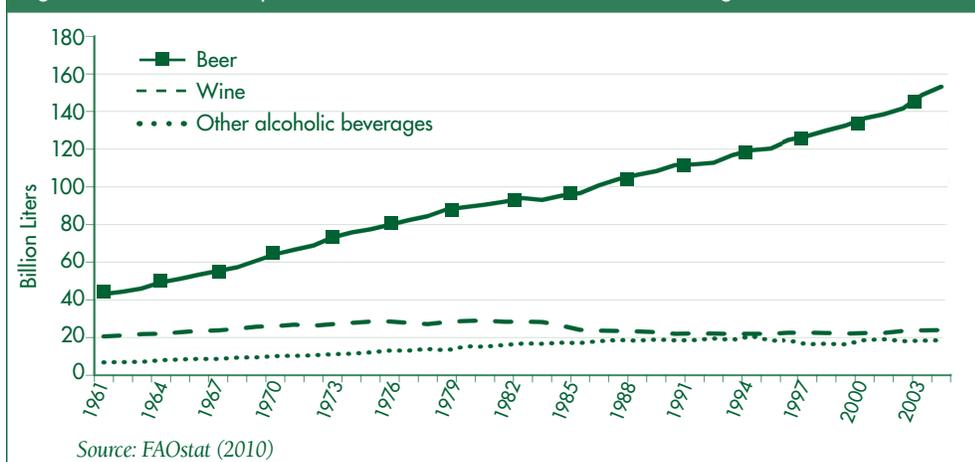
Another economic historian, Martin Stack from Saint Louis University, suggested that between the 1870s and 1950s, the poor were drinking local, unpasteurized beers with many exotic flavors, while the well-to-do middle class was buying more expensive pasteurized, uniform beer. After Prohibition, there was a period during which the big companies provided bland beer accessible to everyone.

And now, we live in a period of the budding sector of craft beers. The difference is that the middle-class pays the extra for the local, exotic beers, while individuals with lower income purchase the standard beers. For example, 46% of millennials claimed not to consume Budweiser.

Figure 1 suggests that beer has been the dominant alcoholic beverage in the U.S. over the past 100 years. Consumption of beer peaked in the 1910s, declined significantly during Prohibition, then slowly recovered until the 1980s—but has since declined. Wine consumption per capita has risen steadily since Prohibition.

Swinnen suggests that beer consumption increases with per capita income but once GNP per capita is

Figure 2. Global Consumption of Beer, Wine, and Other Alcoholic Beverages in Volume, 1961–2005



greater than \$30,000, beer consumption declines—this has been true in Germany, the United States, and Belgium. On the other hand, wine consumption increases with income. While overall consumption of beer is declining, production continues to increase due to export growth.

Figure 2 suggests that globally, on average, people consume more beer than any other alcohol and that the gap is increasing. The reason for the increase in beer consumption is that for most countries in the world, per capita income growth has been significant. However, average income still remains below \$30,000 per person annually and thus beer consumption continues to outpace other alcoholic beverages.

As Figure 3 shows, China overtook the U.S. as the largest overall consumer of beer at the beginning of the millennium, and Russia overtook Germany in overall consumption a couple of years later. Swinnen presents a more surprising finding in that Russians consume more beer than vodka today. He suggests that one reason could be that advertisements of vodka were disallowed in 1995.

Beer and the Bioeconomy

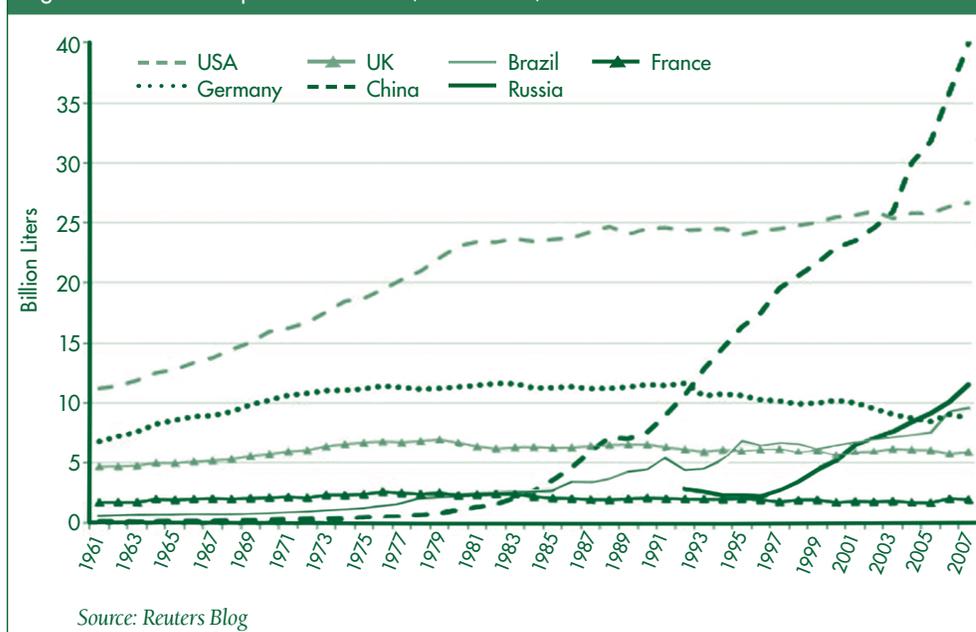
Beer is perhaps the oldest sector of the bioeconomy, and its history has many lessons for the modern bioeconomy. In the case of beer, feedstocks vary across locations and have changed over time.

Each of the main inputs to beer has its own supply chain. Grains, like wheat and especially barley, are major commodities. A small fraction of the overall output is directed to the production of beer. But, there hasn't been much effort to identify specialized grain varieties for the production of beer.

The emergence of the craft-beer industry—with its emphasis on product diversity and quality—provides the opportunity to establish a specialized malt-barley sector. In particular, the new tools of crop breeding could be employed to develop special varieties of barley that will provide improved flavors resulting in better beers. The case of beer illustrates how new technologies provide new opportunities and the importance of product differentiation in generating value in various segments of the bioeconomy.

The fermentation process has become a science based on increased selection and better management of yeast. The production of hops, which is a high-value crop, is done through elaborate contractual agreements that emphasize quality and there are ongoing processes to develop new varieties of hops. Beer companies also compete to upgrade the quality of their product by securing access to high-quality water. As the willingness to pay for beer increases, there will be continuous efforts to increase the quality of inputs. Furthermore, the supply chain of beer

Figure 3. Beer Consumption in the World, Billion Liters, 1961–2007



includes two modes: (i) large breweries that emphasize distribution through retail stores, and (ii) small breweries that focus on local markets and make much of their income on the premises of selling both beer and food items.

Technology and regulations are two drivers of the various sectors of the bioeconomy. The discovery of the use of hops in beer production around the 14th century improved quality and taste, as hops contribute bitterness (to counter the sweetness of barley), add flavor and aroma, and contribute to the preservation of the beer.

Refrigeration, gradually introduced in the 19th century and improved ever since, redefined brewing. In the 1870s, Adolphus Busch pioneered the use of double-walled railcars and a network of icehouses to make Budweiser the first national brand. Refrigeration improved production processes and created new types of beer, assured uniform products, and expanded the reach of breweries becoming a major source of economies of scale in beer production.

The history of beer at various locations was affected by its taxation, as well as regulation on alternative products such as wine. Regulations of production practices and

distribution were introduced for safety, as well as to serve the interests of various groups such as brewers.

The negative side effects of alcohol led to an excessive reaction in the form of Prohibition in the United States. But by 1933, society realized the folly of excessive regulation and bans, and repealed Prohibition. But even after Prohibition, breweries were denied the right to sell beer to the public. However, in 1982, State Assembly Bill 3610 passed, which legalized brewpubs in California. It was followed by similar legislation elsewhere and spawned the craft beer industry in the United States, which became the most creative and dynamic segment of the beer industry.

The rich history of beer illustrates the potential and the unpredictability of the nascent sectors of the bioeconomy. It demonstrates the expanding revenue potential originated in the agricultural sector as feedstock for new products. It also highlights the importance of cleverly designed supply chains for marketing differentiated, high-value, specialty products. These products can be sold through stores or through specialized outlets that can be controlled by the brewer. The future of the bioeconomy also depends on the capacity

of science to increase the diversity and safety of the product, and the necessity of creative regulations that ensure safety but don't impede creativity.

The story of beer suggests that expansion of the bioeconomy to other fields will provide many opportunities to expand farming to other high-value products. The structure of the industry that will produce this new source of feedstock will be unveiled over time; it is likely to emphasize use of contracting as well as vertical integration.

The new sectors of the bioeconomy may compete with traditional agricultural sectors for resources such as land and water. Recent concerns over availability of resources to produce both food and biofuel is an indicator of the potential for conflict. Thus, one of the challenges of traditional agricultural crops is to increase productivity to increase the production of non-conventional, high value-added products and develop safe, cost-effective ways to produce new feedstock.

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