

Microbrewing the Bioeconomy:

Innovation and Changing Scale in Industrial Production

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The future of the U.S. economy might be found in a pint of beer. The rise of craft brewing in the United States is a fascinating test case of distributed biological manufacturing emerging in a market dominated by large scale industrial production. Microbreweries today compete successfully in a commodity market with the largest of multinationals, suggesting that small scale biological manufacturing may be even more successful in higher margin markets. Over the coming decades advances in biotechnology will improve the feasibility and competitiveness of manufacturing firms of all sizes.

How Big is the Bioeconomy?

Biotechnology is often associated with just two markets: medicine and agriculture. Yet the role of biology in the economy is pervasive and there are many more markets and many more dollars at stake. For example, the bio-fuels industry is concerned not just with liquid fuels and agricultural feedstocks, but also with producing enzymes, metabolic pathways, and organisms that convert biomass to fuels. More broadly, industrial biotech uses biology to replace industrial processes in the manufacturing of the products of everyday life. Revenues from industrial biotech in the U.S. are already larger than medicinal or agricultural biotech and are growing roughly twice as fast. In 2010, total U.S. revenues from genetically modified (GM) drugs were roughly \$75 billion, total revenues from the three largest GM crops were approximately \$80 billion, while revenues from GM industrial biotechnology were about \$100 billion.¹

A low regulatory burden clearly contributes to the high growth rate of industrial biotechnology. Whereas new drugs or crops require years of testing, which increases both cost and time to market, new bioplastics, biofuels, or industrial enzymes face little or no regulatory barriers to the marketplace. The critical role of regulation can also be seen in the history of

the brewing industry in the U.S. Understanding the interrelated roles of technology, regulation, and demand in brewing serves as an excellent starting point for thinking about the future of the bioeconomy.

Microbrewing the Bioeconomy

Fermentation is an example of a widely distributed biological technology used to produce everything from laundry enzymes, to vitamins, to beer. The evolution of brewing economics and technology in the United States provides an example of meeting market needs via distributed biological manufacturing.

Before Prohibition, the vast majority of beer produced in the U.S. was brewed by relatively small operations and distributed locally. Refrigeration was uncommon, as were motorized trucks, reducing the amount of beer that could be produced, stored, and shipped in large quantities without spoilage. During the years 1920–1933, the official count of breweries was forced to zero by government policy and enforcement.

After Prohibition, regulatory structures kept small businesses out of the brewing market. With the aid of refrigeration and transportation, large scale breweries proliferated. Subsequently, industry consolidation set in and the number of breweries in the United States shrank. In 1979, the passage of the Cranston Act allowed individuals to brew 100 gallons a

¹ Carlson, Robert H. *Biology Is Technology: The Promise, Peril, and New Business of Engineering Life*. Harvard University Press; 2010.



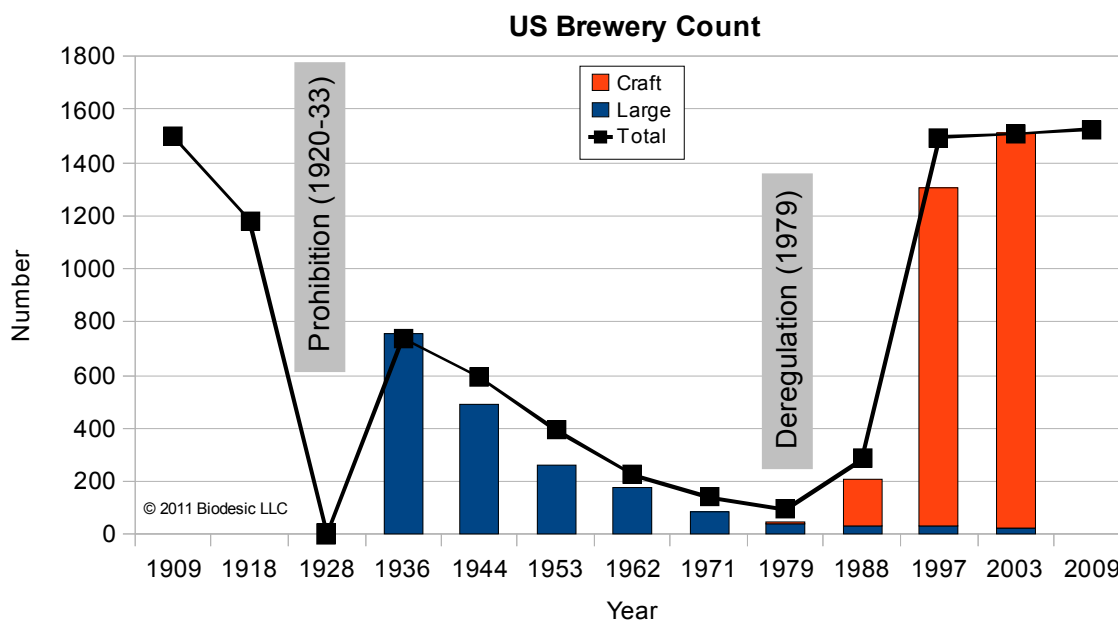


Figure 1: Historical Beer Production (Solid Line: Tremblay et al., Bars: Brewers Assoc.)

year for personal use. Contemporaneous changes to federal and state excise taxes enabled those individuals to sell their beer, and in fact granted small scale brewers a lower excise tax rate, thereby facilitating market entry for small brewers.² This deregulation reopened the market to craft brewers and the industry blossomed through organic growth and the preferences of consumers.

The growth in the United States of a new industrial sector shows that small scale, distributed production can compete against an installed large scale infrastructure base. According to the Brewers Association, as of the middle of 2009 there are about 1,500 craft brewers in the United States, about 20 large brewers, and about 20 “others”, with brewpubs accounting for about 2/3 of the craft brewers (Figure 1).

Conclusion 1: Emerging small scale, distributed production can compete against an installed large scale infrastructure base.

The definition of a “craft” brewer varies across the various interested organizations. From the Brewers Association: “An American Craft Brewer is small, independent, and tradi-

tional.” “Small” here means less than 2 million barrels a year (at 31 gallons per barrel); “independent” means less than 25% owned by a non-craft brewer; “traditional” means either an all malt flagship beer or 50% of total volume in malt beer. There is a profusion of other requirements to qualify as a craft brewer, some of which depend on jurisdiction, and which are important for such practical concerns as calculating excise tax.

Beer generates retail revenues of about \$100 billion in the United States (we estimate revenues to breweries at less than half this figure), and provides direct and indirect jobs totaling 1.9 million³. But craft brewers account for only a small fraction of the total volume of beer brewed in the United States; just three brewers now supply 50% of the world market and 80% of the U.S. market.⁴ In 2007, only 5% of beer brewed in the United States was produced craft brewers, but they took in a disproportionate 9% of revenues. Crucially, this demonstrates not only the ability to survive in a commodity market, but also

2 Tremblay VJ, Iwasaki N, Tremblay CH. The Dynamics of Industry Concentration for U.S. Micro and Macro Brewers. *Rev Ind Organ.* 2005;26(3):307–324.

3 Beer Institute “Economic Impact”. Available at: <http://www.beerservesamerica.org/economic/default.aspx>

4 Beer Institute “Craft Brewers Conference Statistical Update - April 2007” (PPT). Available at <http://www.beerinstitute.org/statistics.asp?bid=220>.

to outperform larger brewers by winning higher margins.⁵

Conclusion 2: Small scale producers can command a premium in a commodity marketplace.

Labor & Innovation

Growing markets and high profit margins are important demand-side considerations. However, businesses are also concerned with supply-side considerations such as the availability of skilled labor and a steady flow of innovation to avoid commoditization. Home brewing had been rare in the United States prior to 1979, which points to an important feature of the market; namely, that the skill base for brewing was quite limited. Yet another effect of legalizing home brewing was that people could practice and build up their skills; they could develop new recipes and explore new business models.

The craft brewing movement developed a culture of innovation which extends to technology development. Homebrewers are now incorporating advances from the open source hardware and software communities into their projects. For example, the Brewtroller Project is an “open source community focused on developing and supporting control systems for brewing beer”.⁶ The hardware is based on the open source Arduino microcontroller and the associated community makes available schematics, parts lists, process code, and recipes. Notably, the goal of the software portion of the project is a program that “will walk through a series of stages (some optional) such as filling, preheat, dough-in, protein rest, acid rest, saccharification rest, mash out, sparge, boil and chill.”⁷ This is a complicated process that is presently directed toward producing the per-

fect pint. However, the instrument is complex enough to grow a wider variety of organisms than just yeast and to produce a wider variety of substances. The Brewtroller also reduces the skill level required to use fermentation enabling a greater number of individuals to brew beer, produce recombinant proteins, or in other ways join the bioeconomy.

Historical Lessons

In summary, the proliferation of distributed biological manufacturing that followed the legalization of craft brewing in the United States provides three general lessons relevant to considering investment in the future bioeconomy. First, it is clear that, given access to tools and skills, entrepreneurs can innovate and change markets even when those markets are dominated by large companies. Craft brewing emerged in the United States amidst an already established large scale, industrial infrastructure for producing and distributing beer. Second, small scale, distributed production can command a premium at the cash register. Third, the largest shift in the transformation of the U.S. brewing industry came about 10 years after deregulation (See Figure 1). Revolutionary change may have a long lead time, but the ensuing market transition can be quite sudden.

Structural Changes in the Marketplace

It is often said that greater efficiency is found in greater scale or, in other words, that economies of scale always favor large production facilities. This is true for many industrial activities, for example all throughout the petroleum industry, in which both thermodynamics and surface-to-volume considerations favor larger ships, larger storage tanks, and larger refineries. Consider also steel making, where one large blast furnace is more efficient than a hundred smaller smelters. This is an assertion that China unwittingly tested during the Great Leap Forward of the 1950's when peasants were directed to create backyard smelters and promptly cut down 10% of China's trees for fuel in just a few months, while producing only piles of useless low quality ore that still

5 Brewers Association. Brewers Association | Facts. Available at: <http://www.brewersassociation.org/pages/business-tools/craft-brewing-statistics/facts> [Accessed October 17, 2010].

6 *BrewTroller Project*. Available at: <http://www.brewtroller.com/wiki/doku.php> [Accessed October 17, 2010].

7 Parekh A. BrewTroller - Brewing Control System. *Hacked Gadgets*. 2009. Available at: <http://hackedgadgets.com/2009/04/09/brewtroller-brewing-control-system/> [Accessed October 17, 2010].

litter the countryside.⁸ In contrast, large organisms are relatively uncommon; the biosphere is dominated in both mass and number by small organisms. In other words, biological processes rarely display the same returns to scale as industrial processes. Competing successfully may not require that companies that employ biological processes be large in order to succeed. Consequently, the bioeconomic marketplace may not be dominated by a few large producers. Instead, there may be numerous participants and a great diffusion of skills and knowledge.

Those participants will have access to an increasingly mature marketplace. Even a decade ago, to attempt a genetic experiment required a monolithic, vertically integrated, strategy. Producing a product based on a genetically modified organism required in-house expertise in a wide range of skills spanning biochemistry, molecular biology, and microbiology. Yet within the last few years every one of these specialized skills has become available for purchase as a service in a competitive marketplace. Specialization creates new niches where companies can thrive; it also facilitates proliferation and competition. It is now quite simple to find an interesting gene sequence in an online database, electronically submit this to a DNA foundry to be fabricated, and have the resulting molecule shipped to a protein expression house for manufacture and delivery to your doorstep. This protein could be used as a tool in house or could be immediately re-shipped as a product. That the skill base for genetic modification has recently seen a rapid proliferation suggests we may soon see an economic disruption analogous to the transformation of the brewing industry. However, given the great breadth of application of genetic modification, the resulting disruption could lead to far greater change within our economy

or agriculture will be transformed through the adoption of biological technologies. Technological change always brings the possibility economic disruption and produces new winners or losers. One significant aspect of biotechnology is that the economies of scale are very different from those of previous technology revolutions, such as chemistry, and may favor smaller, distributed production rather than enormous centralized facilities. The historical example of microbrewing demonstrates that these ideas are not just theoretical, but very real. Intense small scale innovation, coupled with biotechnology, has allowed microbrewers to gain a share of the beer market and be more profitable than traditional macrobrewers. The transition to a bioeconomy is just beginning and the years of disruptive change are still ahead.

Conclusion

The bioeconomy is much bigger than recombinant insulin or genetically modified corn. Increasingly, ordinary industries outside medi-

⁸ Economy EC. *The River Runs Black: The Environmental Challenge to China's Future*. illustrated edition. Cornell University Press; 2004.