The Need for Bioeconomy Data and Metrics

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In 2012, I estimate that U.S. domestic revenues from genetically modified systems were greater than $353 billion, or the equivalent of ~2.2% of GDP, and grew at an overall annual rate of 10%[1]. This is intended to be a conservative estimate, and the actual revenues could easily be 10% larger. *Moreover, biotechnology now contributes somewhere between 5% and 8% of annual GDP growth in the U.S. (R. Carlson, Unpublished).* While these figures are impressive, the associated uncertainty is unacceptably large and undermines critically important assessments of investment, employment, and physical and economic security. Improved data collection, classification, and analysis are required to understand the scope and impact of biotechnology in the U.S. and around the globe. The NSF should support efforts to better quantify the U.S. bioeconomy.

Biotechnology continues to emerge as a significant contributor to the U.S. economy. Discussions of funding and policy, of benefit and risk, and of opportunity and threat must be informed by a more detailed understanding of where biotech is and where it is headed. Here I summarize data collected from a variety of public and private sources to assemble an initial picture quantitative estimate of the economic value of biotechnology, which I define as science and industry related to the manipulation of genes, genomes, and metabolism. To that end, I construct a metric, the Genetically Modified Domestic Product (GMDP), composed of revenues from genetically modified systems and the technology used to manipulate those systems. The GMDP enables a comparison of biotechnology with the economy as a whole. This analysis reveals that the U.S. economy, and in particular annual U.S. GDP growth, is becoming increasingly dependent upon biotechnology[2].

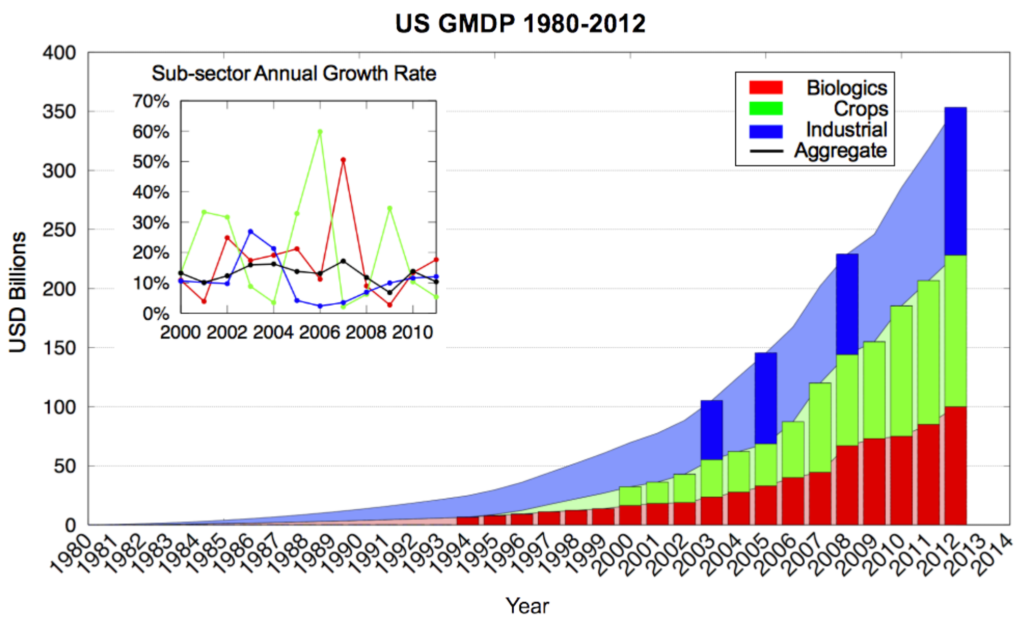

Figure 1. Estimate of annual U.S. Genetically Modified Domestic Product (GMDP) from 1980 to 2012. *Bars*: biologics revenue data and GM crop and industrial revenue estimates. *Shaded areas*: stacked plot of cubic spline interpolation of individual sub-sectors. It is likely that the interpolation overestimates early industrial biotechnology revenues – which were probably no larger than biologics revenues – and thereby underestimates later growth. *Inset*: Sub-sector annual growth rates between 2000 and 2012, calculated from year-on-year data and interpolations.

Due to differences in regulatory structure, financing, and, consequently, pace across the industry, the GMDP naturally breaks down into the sub-sectors of biotech drugs (biologics), agricultural biotech (GM crops), and industrial biotech.

Biologics. In 2012 domestic U.S. revenues from biologics reached nearly $100 billion[3]. Beyond drugs that are produced biologically, the development and testing of virtually all small molecule prescription drugs are highly dependent upon biotechnology. Of the approximately $337 billion in total 2012 U.S. pharmaceutical sales, a large fraction of the small molecule revenues were clearly reliant upon biotechnology[4]. Accounting for this contribution could add tens of billions of additional revenues to the biotechnology tally. Here, however, in the name of simplicity and of sticking to data that are relatively easy to come by, I have chosen to only include "nameplate" biologics revenues that are directly attributable to biological production.

GM Crops. By combining the fractions of crops planted in GM seed with average crop revenue figures compiled by the USDA, I estimate that the sum of farm-level domestic U.S. revenues, seeds, and licensing revenues reached $128 billion.

Industrial Biotechnology. U.S. revenues from industrial biotech (fuels, enzymes, and materials) reached at least $125 billion in 2012. The accuracy of this estimate continues to suffer in comparison to revenues from biologics and GM crops due to the quantity and quality of available data. My previous estimates have involved reverse engineering reports from private consulting firms, who rarely describe data sources and methods[5]. For the 2012 datum, here I rely on an estimate provided by Agilent Technologies in late 2013[6]. The internal breakdown of the $125 billion in these *business-to-business sales* is transformative for understanding the state of the bioeconomy: $66 billion in chemicals, $30 billion in biofuels, $16 billion in biologics feedstocks, $12 billion in food and ag, and $1 billion in emerging markets. (Agilent did not provide any greater specificity regarding how these areas were defined or how the data were gathered.) Notably, it appears that chemicals have eclipsed fuels as the largest component of industrial biotech revenues. Finally, the ultimate consumer level economic impact of industrial biotechnology is larger by an unknown factor of somewhere between 10% and 30%, depending on the actual retail margin over business-to-business transactions. The total 2012 consumer-level impact on the U.S. economy could therefore easily have been in the neighborhood of $160 billion, bringing the total 2012 GMDP to as much as $390 billion.

The overall paucity of relevant data is due largely to the lack of national reporting mechanisms that capture biotech revenues. While the North American Industrial Classification System (NAICS) includes an optional secondary code for biotech R&D, the vast majority of biotech product and service revenues fall into generic categories such as chemicals, agriculture, and pharmaceuticals. This is particularly problematic when biotech can be used to produce a molecule identical to one derived from petroleum; the biological product may displace the petroleum product from the market on the basis of price or preference, yet revenues are still attributed to a category including petrochemicals. More generally, this misattribution obscures the raw economic contribution of biotechnology and impedes quantitative assessment of key features of sector growth and health such as firm number, firm creation, employment, and the overall impact of federal research dollars. A more aggressively optimistic interpretation of biologics and industrial revenues could easily bring the total 2012 GMDP to more than $400 billion, or more than 2.5% of GDP. And yet there is no official measurement of this sector. This voluntary ignorance has subsequent impacts, for example confounding an understanding of national security that surely must include the economic role of biotechnology. It is my hope that, by calling attention to these shortcomings, this analysis will encourage both private and public sector efforts to gather and share data that supports a more detailed understanding of the biotechnology sector and its contributions to employment, innovation, and physical and economic security.

Notes:
[1] Initially reported in a Congressional briefing on 5 November, 2013, I have revised 2012 GDMP slightly upward, and its contribution to GDP slightly downward, as a consequence of updated data from the U.S. Department of Agriculture the U.S. Department of Commerce. See http://www.synthesis.cc/2014/01/the-us-bioeconomy-in-2012.html
[2] To be published in full in Nature Biotechnology in late 2014.
[3] Computed from "Blockbuster Biologics 2012", *R&D Pipeline News*, La Merie Business Intelligence, 7 May 2013.
[4] "The Pharmaceutical Industry and Global Health: Facts and Figures 2012", International Federation of Pharmaceutical Manufacturers & Associations.
[5] Robert Carlson, *Biology is Technology: The Promise, Peril, and New Business of Engineering Life*, Harvard University Press, 2010, Cambridge, MA.
[6] Darlene Solomon, "Tooling the Bioeconomy", U.S. Congressional Briefing, 5 November 2013.
[7] Robert Carlson, "The Pace and Proliferation of Biological Technologies", *Biosec Bioterr*, 2003; Carlson (2010); Robert Carlson, "The Causes and Consequences of Bioeconomic Proliferation: Implications for U.S. Physical and Economic Security", *Biodefense Net Assessment*, Homeland Security Institute, 2012.