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Source: BioScience, 62(7) : 631

Published By: American Institute of Biological Sciences

URL: https://doi.org/10.1525/bio.2012.62.7.4

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In 1990, the federal government formally launched an ambitious initiative to sequence the human genome, to identify all the genes in human DNA, and to develop the tools to store and allow access to this information. The effort took 13 years and cost the federal government $3.8 billion. As is evidenced by technological advancements, the cultivation of new lines of research, and countless subsequent scientific discoveries, the Human Genome Project (HGP) was a success by nearly all measures. A question of interest to policymakers, however, is what the economic return on this kind of federal investment is.

The HGP generated great prosperity, according to a 2011 report by the Battelle Technology Partnership Practice. Between 1988 and 2010, human genome sequencing and associated activities by private industry and researchers generated $796 billion in US economic output. This represents a return on investment of $141 for every $1 spent by the government. The HGP has also generated an estimated 3.8 million job-years of employment and increased government revenue. As was reported by the Battelle group, the genomics-enabled industry generated more than $3.7 billion in federal taxes and $2.3 billion in state and local taxes in 2010 alone. "Thus in one year, revenues returned to government nearly equaled the entire 13-year investment in the HGP," states the report.

Beyond economic benefits, the HGP has influenced and benefited numerous disciplines outside genomics. From human health to agriculture and forensics, the discoveries and methods resulting from the project have generated numerous societal benefits. No one could have anticipated how revolutionary the project would be in improving human health, feeding the planet, fueling society, and remediating degraded environments.

"From a simple return on investment, the financial stake made in mapping the entire human genome is clearly one of the best uses of taxpayer dollars the US government has ever made," said Greg Lucier, chief executive officer of Life Technologies, whose foundation sponsored Battelle's analysis. "Now we sit at the dawn of the 'Genomics Revolution' and all humankind will reap the benefits as we transfer what we now know about the human genome into major breakthroughs.… These major advancements are rapidly creating multiple new industries and companies and those companies are creating quality jobs for thousands of people."

Of course, the HGP is just one example of government-backed science. The broader and more important issue is the economic track record for federal research and development (R&D) as a whole.

"R&D is central to economic growth," states Fred Block, a research professor at the University of California, Davis. Block's research on the economic effects of government investments in R&D demonstrates the importance of federally sponsored science. From 1948 to 2007, the output per unit of labor at private businesses grew at an annual rate of 2.5%. More than half of that growth can be attributed to multifactor productivity "or the increase of knowledge that comes from R&D," states Block.

Vijay Vaitheeswaran, an editor for *The Economist* and the author of a new book on the future of innovation, argues that about 80 percent of US gross domestic product comes from services and activities, including R&D—not the physical production of products.

Accounting for the economic outputs of R&D is no easy task. That is why the federal government has launched an initiative to measure the outcomes of research. The Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness, and Science (STAR METRICS) initiative aims to track economic outputs, such as jobs and the creation of new companies, resulting from federally funded research. Scientific outcomes, such as publications and patents, will also be tracked. The project is still in the early stages, but it promises to create the necessary digital infrastructure to link science funding with outcomes.

Even without the detailed information that STAR METRICS aims to provide, ample evidence exists to make a strong case for the economic returns from federally funded science. "We have powerful evidence of R&D, but funding is moving in the wrong direction," said Block. Declining investments in science will impair the nation's ability to innovate and prosper in the future. "We're eating our seed corn."

The economic recession should not be used as an excuse to defer investments in science, according to Vaitheeswaran. The government invested in America during the Great Depression, investments that later fueled the economic growth of the 1950s and 1960s. "Great economies, like great companies, invest during a downturn," said Vaitheeswaran.

Watch a video of a recent briefing for policymakers on the benefits of federally funded research and development. The event was organized by an interdisciplinary group of scientific organizations, including the American Institute of Biological Sciences, which publishes *BioScience*. The video is available at *www.youtube.com/watch?v=5m6y_P2vUfg&feature=youtu.be*.

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doi:10.1525/bio.2012.62.7.4