The Economic Impact of Precision Medicine in California

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Acknowledgments

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California Initiative to Advance Precision Medicine

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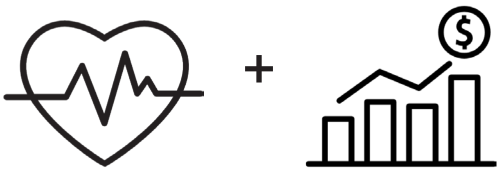
Executive Summary



28,800 employees
across ten industry sub-sectors

70,200 jobs
stimulated in industries outside of precision medicine

$4.0 billion
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$438 million
contributed in state and local taxes.

As envisioned by the National Academy of Sciences, precision medicine aims to use advanced computing tools to aggregate, integrate, and analyze vast amounts of data from research, clinical, personal, environmental, and population health settings, to better understand health and disease, and to develop and deliver more precise diagnostics, therapeutics, and prevention measures.[1] Part medicine, part data science, the approach is being applied to a rapidly expanding number of medicine fields and is poised to usher in a new era of medicine and preventative care. Its importance is also being recognized by policymakers, and in 2015, President Barack Obama and California Governor Jerry Brown each announced the launch of precision medicine initiatives.

In addition to reimagining how medicine is used to save lives, precision medicine also holds promise for the economy. Just like the aerospace[2], high-tech[3], and life science[4] clusters have propelled California's economy and created tens of thousands of high-paying jobs, precision medicine is positioned to expand dramatically. Existing industry clusters in the state along with first class research facilities and higher learning institutions make California a fertile place for precision medicine to thrive.

California's precision medicine industry is already adding significant value to the state's economy. In total, precision medicine is responsible for the annual employment of 99,000 individuals and $30.8 billion in economic activity in the state of California.

Precision medicine will revolutionize medicine and public health as we know it while simultaneously providing substantial economic activity in California for decades to come. However, this success should not be taken for granted, and like other industries that were closely watched and nurtured by investors and policymakers alike, precision medicine will need support if it is to thrive in California.

Introduction

What is Precision Medicine?

Simultaneous advances in biotechnology and high-performance computing, combined with the accumulation of massive amounts of health-relevant data, have enabled the implementation of precise interventions in the medical, personal health, and public health arenas. The aim of precision medicine is to better understand all health-relevant characteristics of individual patients, from their genetic make-up to their specific behaviors, socioeconomic circumstances and environmental exposures, and to use that information to ensure that medical and social health interventions are maximally effective.

As such, the precision medicine approach does not just include traditional biomedical activities like genomics and pharmaceutical development. It also encompasses a wide range of related fields that allow for the collection and storage of health data, analysis of the data, and use of the data for more precise diagnosis of individual conditions and risk factors. As explained later in this report, precision medicine includes activities across a variety of sectors, as illustrated by several case studies.

Why is Precision Medicine Important?

Precision medicine utilizes advanced computing and data collection to aggregate information about patient health history, molecular processes of disease, and clinical studies. These data can then be used to target specific treatments to a person's particular profile of biology, medical history, behaviors, and environmental exposures, making the therapy as effective as possible for that individual person. Precision medicine can also help researchers to better understand the causes and mechanisms of health conditions, allowing for more precise and effective diagnostics and preventive measures.

CIAPM's Definition of Precision Medicine:

Precision medicine aims to use advanced computing tools to aggregate, integrate, and analyze vast amounts of data from research, clinical, personal, environmental and population health settings, to better understand health and disease, and to develop and deliver more precise diagnositcs, therapeutics, and prevention measure.

Case Study: Artificial Intelligence for Imaging of Brain Emergencies[5]

One example of precision medicine activity that encompasses fields as diverse as neuroscience, artificial intelligence, cloud software, and diagnostic technology is the artificial intelligence for brain imaging project at UCSF.

Every 28 seconds, an American suffers a catastrophic neurologic emergency, most commonly stroke or traumatic brain injury (TBI). Neurologic emergencies affect 15 million U.S. adults and children annually at a cost of $115 billion, which is 7% of total U.S. healthcare spending per year.

Since the brain is susceptible to irreversible injury within minutes, immediate diagnosis and treatment are essential. Computed tomography (CT) scanning is currently the only type of imaging used worldwide to diagnose neurologic emergencies. Immediate diagnosis aided by rapid automated evaluation of head CT could greatly improve care in situations where minutes count.

This project, led by researchers at the University of California San Francisco, will apply state-of-the-art artificial intelligence (AI) technology to automatically recognize life-threatening findings on emergency head CT scans in patients suspected of having TBI, stroke, or bleeding due to ruptured brain aneurysms, with the aim of assisting physicians to make a quicker diagnosis.

Another important advance enabled by this technology is the ability to catalogue clinically significant "digital markers" that are recognizable across scans, which will facilitate future precision medicine research by combining data from quantitative image analyses with other types of data.

The project team will implement this AI system in the cloud so that its use does not remain limited to advanced hospital settings and CT scans can be uploaded for analysis from anywhere in the world.

This project illustrates the diversity in the types of activity and technology that are used in emerging precision medicine applications. Bringing them together to diagnose patients with emergency brain injuries more precisely has the potential to save lives.

How Does Precision Medicine Benefit California's Economy?

California is home to many companies and research institutions that have been active on the cutting edge of precision medical approaches. Precision medicine has the potential to encompass a significant portion of medicine and the technology sector, and to have a multi-billion-dollar impact on California's economy, accounting for tens of thousands of jobs in the future. This could be a huge driver of growth in California's economy, propelling the state to the forefront of this rapidly expanding approach to medicine.

Embracing and supporting the emerging precision medicine approach could be very beneficial to California's economy. An instructive parallel example is California's nurturing of the biotechnology industry, which now has revenue of over $100 billion within the state. California supported the industry in its earlier days through programs like the Industry-University Cooperative Research Program, investment in universities, and the passage of Proposition 71 in 2004, which pledged $3 billion in stem cell research and created the California Institute for Regenerative Medicine.[6] The large amount of venture capital in California also played a large role in the growth of the biotech industry.

With similar support from the state and from business leaders, California could be the preeminent location for precision medicine in much the same way it has been for the biotech industry. If properly implemented, widespread use of precision medicine will improve patient outcomes while at the same time creating thousands of jobs and bringing in large amounts of investment to California from sources such as venture capital and National Institutes of Health funding.

Case Study: The UC Health Data Warehouse[7]

Over 15 million patients have received care across the six University of California (UC) health systems over the past 20 years, yielding billions of data points related to patient care. These clinical data are now being standardized, supplemented, and securely stored in the UC Health Data Warehouse to better enable studies of how medicine is practiced and ultimately improve patient care and lower costs.

Researchers are developing tools to use this vast dataset of electronic health records to ask questions and get answers much faster than in the past. Instead of designing and conducting a study to generate new data, researchers and clinicians will increasingly be able to examine what has happened clinically to patients in the existing database. Of course this data must be used only in respectful ways, in a strictly regulated fashion. But it is now possible, for example, to see which patients are using brand name drugs who could be switched to equally effective, low-cost generic drugs–and use this information to save millions of dollars across the UC system. The scope and scale of the questions that can be answered will continue to grow as new data types are added, including patient satisfaction survey data, hospital operations data, medical claims data, and genomic data.

This effort has already yielded some early successes. Recent advances in precision medicine made using UC clinical data include improvements in the ability to predict who may not respond well to the drug used as the typical first line treatment for type 2 diabetes, who may be the best candidates for revision surgery following joint replacement, and who may be most at risk for heart failure among HIV positive individuals with chronic liver disease. Improved risk prediction can in turn be used to improve chronic disease management and clinical treatment decisions.

The possible benefits of leveraging the UC Health Data Warehouse are virtually limitless, and the economic ramifications of this effort are similarly far-reaching. Not only will this work enable improvements in managing health care expenditures without compromising patient care, but the inclusion of non-clinical, operational data can also be used to learn what practices and building designs contribute the most to energy efficiency and carbon neutrality.

Defining An Industry

The U.S. economy is extremely dynamic, and the activities and characteristics of firms operating within the economy are constantly changing. In order to facilitate the measurement and study of the U.S. economy, it is necessary to classify the economic activity of firms into industries. While these classifications change over time, they do so slowly, and oftentimes it takes years to properly classify new economic activities. In some instances, popular colloquial definitions of industries are never codified at all – for example the "High-tech" industry does not have its own designation.[89] For now, the emerging industry of precision medicine is no different.

Classifying Economic Activity

Currently, the classification of economic activity is done by the U.S. Economic Classification Policy Committee, a partnership between the Office of Management and Budget, Bureau of Economic Analysis, Bureau of Labor Statistics, and the U.S. Census Bureau through a set of codes known as the North American Industrial Classification System (NAICS). This system was designed to serve as the standard method of classifying business firms and establishments for the collection and presentation of data among federal agencies. Because of this, NAICS has become the standard method for classifying economic activity and conducting research in both the public and private sectors.

For 2017, NAICS included a total of 1,057 industries, down from 1,065 in 2012. The NAICS system is updated every five years to accommodate changes in the economy, whether that be the creation of new industries or the destruction of old ones. Each NAICS code is intended to be representative of the "primary activity" of businesses classified with that code, though there is no government agency tasked with assigning, monitoring, or verifying codes assigned to firms. Each business is assigned only one primary NAICS code.

A NAICS Code for Precision Medicine?

Like many emerging industries, precision medicine is not yet captured exclusively by any one (or many) dedicated NAICS code(s). Instead, firms active in the precision medicine space are classified under existing NAICS codes such as Research & Development in Biotechnology, Medical Laboratories, or Custom Computer Programming Services.

A helpful example for how NAICS codes evolve over time is the field of Biotechnology. Modern Biotechnology began to develop in the 1970s, though it wasn't until the 2007 update of NAICS that the field finally received its own classification, "Research and Development in Biotechnology."[10] Two revision cycles later, the 2017 update of NAICS refined the classification further, splitting two codes into three and separating out Nanobiotechnology.

Defining Precision Medicine

Precision medicine is an emerging industry, and therefore definitions of what constitutes precision medicine are likely to be as unique as each practitioner is. For the purposes of this analysis, the definition developed in the 2011 National Academy of Sciences' (NAS) report, "Toward Precision Medicine: Building a Knowledge Network for Biomedical Research and a New Taxonomy of Disease," was used. The NAS report envisions precision medicine as aiming to use advanced computing tools to aggregate, integrate and analyze vast amounts of data from research, clinical, personal, environmental and population health settings, to better understand diseases and develop and deliver more precise diagnostics, therapeutics, and prevention measures.

The California Initiative to Advance Precision Medicine (CIAPM) also operates using the definition of precision medicine developed by NAS, and over several years has been working to develop an inventory of precision medicine assets in California based on that definition. The goal of the inventory is to identify public and private precision medicine assets in the state – including companies, projects, databases and infrastructure, clinical implementations, expertise, and funding – to inform policy, coordinate resources, and engage patients. The inventory, through providing a baseline set of examples to calibrate from, proved invaluable in identifying companies during the sampling conducted in this report.

Case Study: California Kids Cancer Comparison[11]

Each year 500 California children with cancer either lack or fail to respond to standard therapies. Clinical trials currently underway at UC Medical Centers are starting to employ genomic analyses, many of which are obtained from California-based companies, to identify new therapies for these incurable tumors. So far, these efforts have yielded new treatment possibilities for less than 10% of these patients, in part because each tumor is analyzed on its own—a labor-intensive and inefficient process.

The California Kids Cancer Comparison (CKCC) project, led by researchers at the University of California Santa Cruz, provides the power of large-scale bioinformatics to improve this outcome. Bringing together activity in software, biotechnology, genomics, and data storage, among other fields, it is another good example of the type of project that falls within precision medicine.

CKCC analyzes each patient's tumor in the context of thousands of pediatric and adult tumors that have undergone similar characterization. To help rapidly bring state-of-the-art analyses to its clinical collaborators, CKCC's team includes biotech and computer companies in partnership with UC researchers and physicians. Through the CKCC, researchers aim to at least double the number of kids that can benefit from a targeted cancer treatment. The concept can be scaled and applied to other genetic diseases and to all 147,000 Californians diagnosed with cancer each year.

As part of the CKCC project, the team is developing MedBook, a social network designed for medical research and medical decision support. MedBook tools upload, manage, and visualize both clinical and genomic data, handling this information in a manner that protects patient privacy. Clinicians and researchers will collaborate using MedBook to find the best treatment for each patient, while patients and their advocates will be able to access this information and communicate with health care providers through this network.

This project exemplifies the potentially huge scale of precision medicine initiatives and interventions. If scaled, the approach behind the CKCC could improve the prognosis for hundreds of thousands of people, while also generating large economic impacts on the state of California. MedBook, too, could revolutionize all kinds of medical research and treatment decision making. These sorts of technologies are at the cutting edge of the precision medicine approach, and if pursued successfully, could solidify California as the nation's leader in precision medicine.

Measuring Precision Medicine

Given that precision medicine spans health care, research and development in biotechnology, manufacturing, software, as well as data analysis and processing, identifying precision medicine firms is challenging. In the absence of an official industry designation, this report developed a methodology that measures the activity associated with precision medicine firms.

The methodology produces "weights" for existing NAICS codes based on the share of firms within each code engaged in precision medicine activities. Doing so significantly reduces the need to manually classify firms while also enabling the use of existing economic data for employment and output. Additionally, identifying NAICS codes that contain precision medicine firms will provide future research a strong foundation on which to build.

The methodology used here can be distilled into the following components:

1. Identify industries potentially containing precision medicine firms;
2. Sample firms from the identified industries;
3. Classify sample firms as precision medicine, or not;
4. Generate weights for each industry based on classifications;
5. Apply weights to existing economic data and prepare inputs to an economic impact assessment tool; and
6. Use the tool to generate estimates of economic impacts.

Identifying the Industries

Two primary methods were used to identify an initial list of industries for further analysis. The first leveraged the inventory of precision medicine assets developed by CIAPM, and the second updated and expanded a model used by the San Diego Regional Economic Development Corporation (EDC) to estimate weights across sectors. Together, the two methods produced a broad set of industries. Later in the process, erroneous industries were easily eliminated if sampling found no precision medicine firms.

The CIAPM inventory provided a pre-classified list of firms that had already been thoroughly vetted, and from which primary NAICS codes were collected. Previous research on life sciences, biotechnology, and genomics conducted by the San Diego Regional EDC supplemented this list, providing a robust set of initial NAICS codes.

Sampling, Classifying Firms and Generating Weights

The initial list of NAICS codes served as the starting point from which sampling began and, in turn, was used to develop a final list of industries containing precision medicine firms.

As discussed above, most of the firms in each of the identified NAICS codes do not fall under the category of precision medicine. Therefore, the share of activity related to precision medicine must be established. Because the number of firms in each code ranges from 11 to 9,886 (see Appendix A) – totaling 40,561 firms – it is not practical to classify each one. Instead, a random sample of firms from each NAICS was taken to facilitate the creation of the industry weights. Sample sizes were based on the necessary number of firms required from each code to ensure a confidence level of 90 percent with a margin of error of 5 percent.

Once a sample from each NAICS was taken, each firm in the sample was classified either as a precision medicine firm or not a precision medicine firm (see Appendix B). A firm was only classified as being precision medicine if over half of its business activities qualified as precision medicine, following a long-held practice of the classification of industries by U.S. Government agencies.

Share of NAICS Codes Found to be Precision Medicine Firms

NAICS	NAICS Description	All	90/5 Sample	Multiplier
621498	All Other Outpatient Care Centers	793	202	0.00
334516	Analytical Laboratory Instrument Manufacturing	114	81	0.44
423430	Computer & Peripheral Equip/Software Mrchnt Whlsrs	253	131	0.00
541511	Custom Computer Programming Services	4,783	255	0.01
518210	Data Processing, Hosting & Related Services	3,683	251	0.00
334510	Electromedical & Electrotherapeutic Apparatus Mfg	27	25	0.38
541330	Engineering Services	9,886	262	0.00
325413	In-Vitro Diagnostic Substance Manufacturing	11	11	0.39
621511	Medical Laboratories	1,910	236	0.19
541519	Other Computer Related Services	1,978	237	0.00
541690	Other Scientific & Technical Consulting Services	2,821	246	0.00
424420	Packaged Frozen Food Merchant Wholesalers	629	189	0.00
325412	Pharmaceutical Preparation Manufacturing	288	140	0.11
541714	Research-Devmnt In Biotechnology (Except Nanobio)	4,202	253	0.10
511210	Software Publishers	5,297	257	0.00
511210	Surgical & Medical Instrument Manufacturing	893	207	0.03
541380	Testing Laboratories	1,057	215	0.12
425120	Wholesale Trade Agents & Brokers	1,936	237	0.00

Economic Institute and San Diego Regional EDC staff conducted the classification of firms in close discussion with CIAPM. Each firm was examined using company websites, publicly available data, news reports, and any other available source. Firms were examined for characteristics of precision medicine activities outlined earlier in this report, including a reliance on advanced computing techniques for data collection and aggregation and the ability to target specific treatments to a person's particular profile.

Each sample was independently reviewed twice to increase precision, and if a firm was in dispute, staff made a joint decision to include it or not based on all available information and thorough discussion. Counts were then weighted by employment to yield the weights used to prepare the inputs. The weights represent an estimate of the proportion of employees with precision medicine jobs in the industry.

Applying the Weights and Preparing the Inputs

Once the NAICS code weights were developed, they were applied to the total employment of their respective industries. Total employment counts were drawn from the Quarterly Census of Employment and Wages (QCEW), which produces a comprehensive tabulation of employment and wage information for all workers covered by state and federal unemployment programs, broken down into detailed NAICS codes.

MIG IMPLAN, a widely accepted tool for economic impact assessment, was used to assess the indirect and induced impacts on employment, value added (gross regional product), labor income (wages), and taxes. Total employment was used as input into the model, and each NAICS code was converted into a corresponding IMPLAN sector using the built-in code bridge in the IMPLAN software.

Precision Medicine Employment by IMPLAN Sector

IMPLAN Sector	NAICS	Description	Total Employment at Prescision Medicine Firms
174	325412	Pharmaceutical Preparation Mfg	3,873
175	325413	In-Vitro Diagnostic Substance Mfg	2,927
314	334510	Electromedical & Electrotherapeutic Apparatus Mfg	5,292
320	334516	Analytical Laboratory Instrument Mfg	3,917
379	339112	Surgical & Medical Instrument Mfg	690
422	511210	Software Publishers	243
451	541511	Custom Computer Programming Services	1,355
456	541714	R&D in Biotechnology (Except Nanobiotechnology)	3,381
479	541380	Testing Laboratories	7,110
Total			**28,788**

IMPLAN Input-Output Methodology

The IMPLAN modeling system combines the U.S. Bureau of Economic Analysis' Input-Output Benchmarks with other data to construct quantitative models of trade flow relationships between businesses, and between businesses and final consumers. From these data, we can examine the effects of a change in one or several economic activities to predict its effect on a specific state, regional, or local economy (impact analysis).

IMPLAN's Regional Economic Accounts and Social Accounting Matrices are used to construct state-level multipliers that describe the response of the economy to a change in demand or production because of the activities and expenditures related to precision medicine. Each industry that produces goods or services generates demand for other goods and services and this demand is multiplied through an economy until it dissipates through "leakage" to economies outside the specified area. IMPLAN models discern and calculate leakage from local, regional, and state economic areas based on workforce configuration, the inputs required by specific types of businesses, and the availability of both in the economic area. Consequently, economic impacts that accrue to other regions or states as a consequence of a change in demand are not counted as impacts within the economic area.

Impact studies operate under the basic assumption that any increase in spending has three effects. First, there is a direct effect on that industry itself. Second, there is a chain of indirect effects on all the industries whose outputs are used by the industry under observation. Third, there are induced effects that arise when employment increases and household spending patterns are expanded.

There are generally several aspects of the overall economic impact. First, there is an effect on value added – the take-home pay of all the people affected will be supplemented by that amount. The secondary and tertiary effects of the industry on the rest of the local economy are not very large. Second is the employment effect, with jobs created in the industry itself, and others spread throughout the California economy. Third is the output, which differs from value added in that that it includes the costs of intermediate inputs, whereas value added includes only people's paychecks. National income accounting avoids double counting by excluding the costs of intermediate inputs.

It is also important to note that capital investments made on different types of investment can lead to different multipliers. Why? A sector can have a large multiplier if it induces economic activity in industries whose employees have a high propensity to spend from take-home pay. Also, if the sector does not import many materials from abroad or from out of state, then its multiplier effect on the local economy will be high. In essence, some of the spending in the local economy may ``leak out'' into other states and countries. If raw materials are imported, then a shock to a local sector will result in decreased economic activity abroad. The same is true if a California business buys inputs from firms in different states.

In sum, our analysis using input-output accounts is based on three important assumptions. First, there are constant returns to scale. This means that a 10 percent cut in spending will be ten times as severe across every sector in the economy as a one percent cut. Second, there are no supply constraints. This means that any marginal increase in output can be produced without having to worry about bottlenecks in labor markets, commodity markets, or necessary imports. This assumption is quite realistic in a free-market economy like California's where there is some unemployment. Third, the flow of commodities between industries is fixed. This means that it is not possible to substitute in the short run the many different inputs that go into any given industry.

Explaining Economic Impacts: The DNA Test Example

There are multiple aspects to explaining economic impacts. Expenditures associated with a precision medicine company that performs DNA testing, as discussed in this report, have the potential to generate significant increases in economic output, local employment, and government tax revenues. Each of these impacts stem from three separate effects. First, there is a direct effect: how many jobs and how much in tax revenues are directly linked to the company's expenditures. Second, there is an indirect effect: when the company administers and processes 100 DNA tests, this stimulates activity directly for the firm, but also indirectly for the plastic manufacturers that provide the collection tubes and the laboratory equipment manufacturers who provide the tools for analysis. Finally, there is an induced effect that results from the employees of the firm, the plastic manufacturers, and the laboratory equipment manufacturers spending their increased salaries.

Case Study: Early Prediction of Major Adverse Cardiovascular Events Using Remote Monitoring[12]

Cardiovascular disease is the leading cause of death for both men and women in California. Tragically, many people develop a heart attack, stroke or other complication of cardiovascular disease because they were under-treated, not taking their medicines, or not receiving the care they needed in the first place; this is especially common among younger women and racial/ethnic minorities.

One reason for this is that early signs of disease can be easily missed, and also because people spend most of their life far away from a doctor or hospital where it is challenging to monitor disease progression.

In this study, researchers at Cedars-Sinai Medical Center are looking for the earliest signs of impending disease by monitoring patients remotely, outside the four walls of the hospital or doctor's office. Patients will wear a specialized watch that measures activity, sleep, heart rate, and stress levels.

They will also report their levels of anxiety, depression, and quality of life using a smartphone or computer. Finally, they will periodically send a small finger prick blood sample by mail, allowing doctors to measure over 500 different blood chemicals.

By combining these different types of data, the researchers will seek a "signal in the noise" that predicts who may be about to have a heart attack or stroke.

If successful, patients could greatly benefit from more effective prevention and treatment as a result of earlier disease detection, but in order to broadly implement innovative new technologies, it is also important to understand their potential cost impacts on the health care system. The team will therefore perform an economic analysis to estimate the cost effectiveness of this remote monitoring approach.

This study provides insight into the variety of types of economic impact that can be spurred by precision medicine. Not only will this project create direct economic activity through the analysis of blood chemicals, it will also create indirect activity through the manufacturing of the parts that go into the specialized watches and the containers used to transport the blood samples, as well as induced activity through the spending done by those working on the technology.

Economic Impact

Estimating the Economic Impact

Precision medicine adds value to California's economy through a variety of pathways, including increased employment, output, income, and tax revenue. This includes not only the industry's direct economic impact, but also its indirect and induced impacts. As the precision medicine industry grows, so does the production of goods that supports it, and so does the increase in spending that results from greater employment and income.

At a glance, it is clear that California's precision medicine industry adds significant value to the state's economy. Its impact includes:

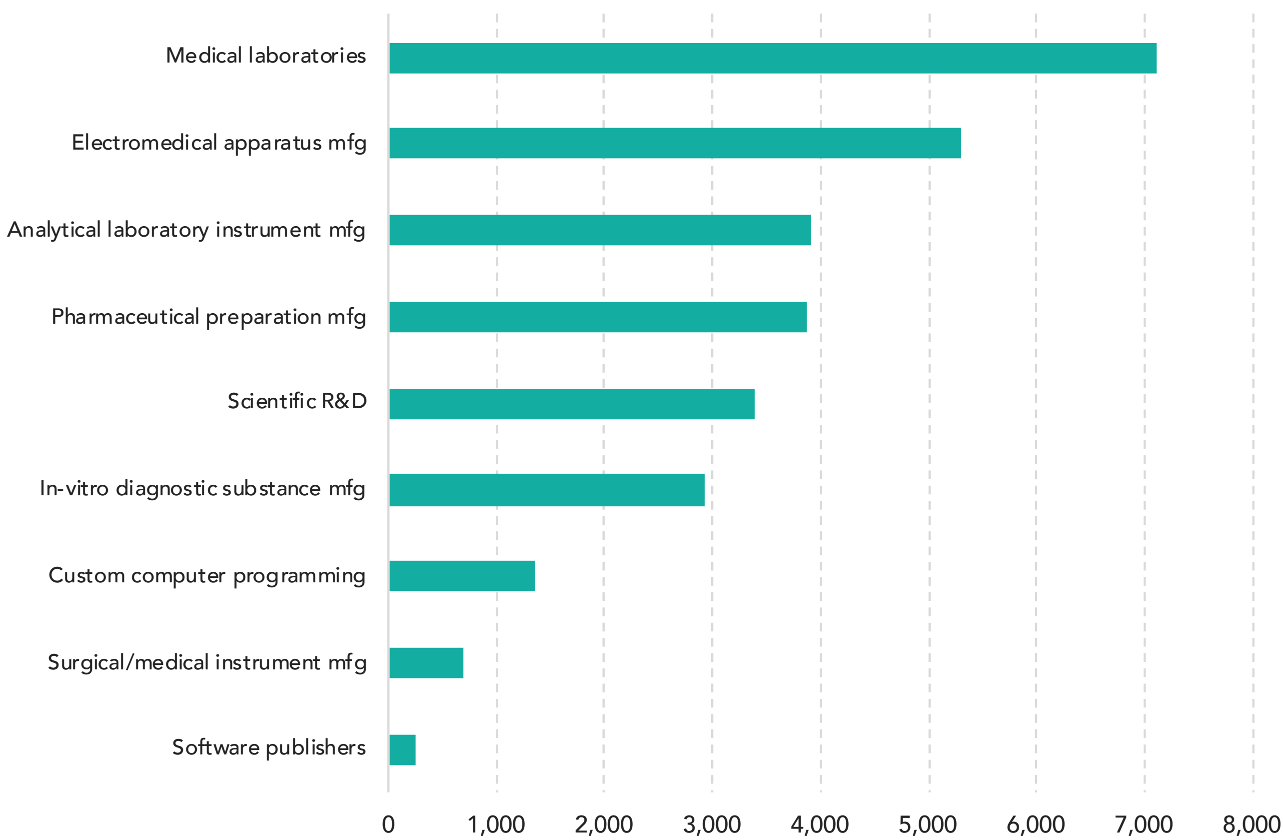
- Directly employed 28,800 individuals across ten industry sub-sectors;
- Stimulated an additional 70,200 jobs in industries ranging from Health Care & Social Assistance, to Finance & Insurance, Real Estate, and Accommodation & Food Services;
- Directly paid $4.0 billion in labor income each year, and stimulated an additional $5.0 billion in labor income;
- Directly contributed $17.2 billion in economic activity in the state each year, and stimulated an additional $13.6 billion;
- Directly contributed $438 million in state and local taxes.

In total, California's precision medicine industry has a yearly output of nearly $31 billion. Of this, $17.2 billion is produced directly by the precision medicine sector. The other $13.6 billion is created indirectly by industries like agriculture and construction that support precision medicine, as well as by additional spending induced by the economic activities of the precision medicine industry. When people are employed in precision medicine-related jobs, they do not just pocket the money they make. They spend it on all kinds of goods and services, thereby contributing to the indirect and induced economic impact of the precision medicine industry.

Summary of Economic Impacts

	Output (in millions)	Employment	Labor Income (in millions)
Direct Impact	$17,229	$28,788	$4,042
Indirect and Induced Impact	$13,566	$70,181	$4,975
Total Impact	$30,795	$98,969	$9,017

Direct Precision Medicine Employment by Sub-Industry



Precision medicine directly employs 28,788 people, and it indirectly supports another 70,181 jobs. With this large amount of employment, the industry pays $4 billion in labor income each year, and it indirectly stimulates another $4.9 billion in labor income for a total of $9 billion.

Activity in the precision medicine sector is distributed throughout a fairly diverse range of sub-industries. Direct employment and output are concentrated mainly in the four industry sectors of manufacturing, information, health care and social assistance, and professional, scientific, and technical services. Specifically, within those sectors, direct precision medicine activity was found to largely occur within the sub-industries of:

- Pharmaceutical preparation manufacturing
- In-vitro diagnostic substance manufacturing
- Electromedical and electrotherapeutic apparatus manufacturing
- Analytical laboratory instrument manufacturing
- Surgical and medical instrument manufacturing
- Software publishers
- Custom computer programming services
- Scientific research and development services, and
- Medical and diagnostic laboratories

As to be expected, employment and production stimulated indirectly by precision medicine were spread across a much wider set of industries, ranging from public administration to educational services to retail.

Yearly Impact of Precision Medicine by Industry

Industry	Output (in millions)		Employment		Labor Income (in millions)	
	Direct	Total	Direct	Total	Direct	Total
Agriculture, Forestry, Fishing and Hunting	$0	$47	$0	$292	$0	$16
Mining, Quarrying, and Oil and Gas Extraction	$0	$21	$0	$84	$0	$7
Utilities	$0	$87	$0	$93	$0	$16
Construction	$0	$136	$0	$791	$0	$53
Manufacturing	$14,754	$16,751	$16,699	$20,739	$2,683	$3,085
Wholesale Trade	$0	$1,188	$0	$4,747	$0	$396
Retail Trade	$0	$577	$0	$5,807	$0	$239
Transportation and Warehousing	$0	$516	$0	$3,359	$0	$206
Information	$119	$1,172	$243	$1,909	$50	$374
Finance and Insurance	$0	$952	$0	$3,753	$0	$328
Real Estate and Rental and Leasing	$0	$1,081	$0	$3,144	$0	$144
Professional, Scientific, and Technical Services	$1,436	$2,728	$4,736	$13,615	$695	$1,463
Management of Companies and Enterprises	$0	$1,469	$0	$5,456	$0	$776
Administrative, Support, Waste Mgmt Services	$0	$533	$0	$7,102	$0	$282
Educational Services	$0	$113	$0	$1,564	$0	$71
Health Care and Social Assistance	$920	$1,662	$7,110	$14,081	$613	$1,048
Arts, Entertainment, and Recreation	$0	$148	$0	$1,552	$0	$63
Accommodation and Food Services	$0	$404	$0	$5,660	$0	$168
Other Services (except Public Administration)	$0	$359	$0	$4,662	$0	$219
Public Administration	$0	$848	$0	$560	$0	$65
TOTALS	**$17,229**	**$30,795**	**$28,788**	**$98,969**	**$4,042**	**$9,017**

Yearly Tax Impact of Precision Medicine (in millions)

	Federal		State and Local	
Type of Tax	**Direct Impact**	**Total Impact**	**Direct Impact**	**Total Impact**
Employee Compensation	$442	$924	$23	$48
Proprietor Income	$3	$31		
Production and Imports	$24	$90	$189	$716
Households	$361	$809	$157	$352
Corporations	$354	$527	$69	$103
TOTALS	**$1,183**	**$2,380**	**$438**	**$1,219**

Implications for Tax Revenue

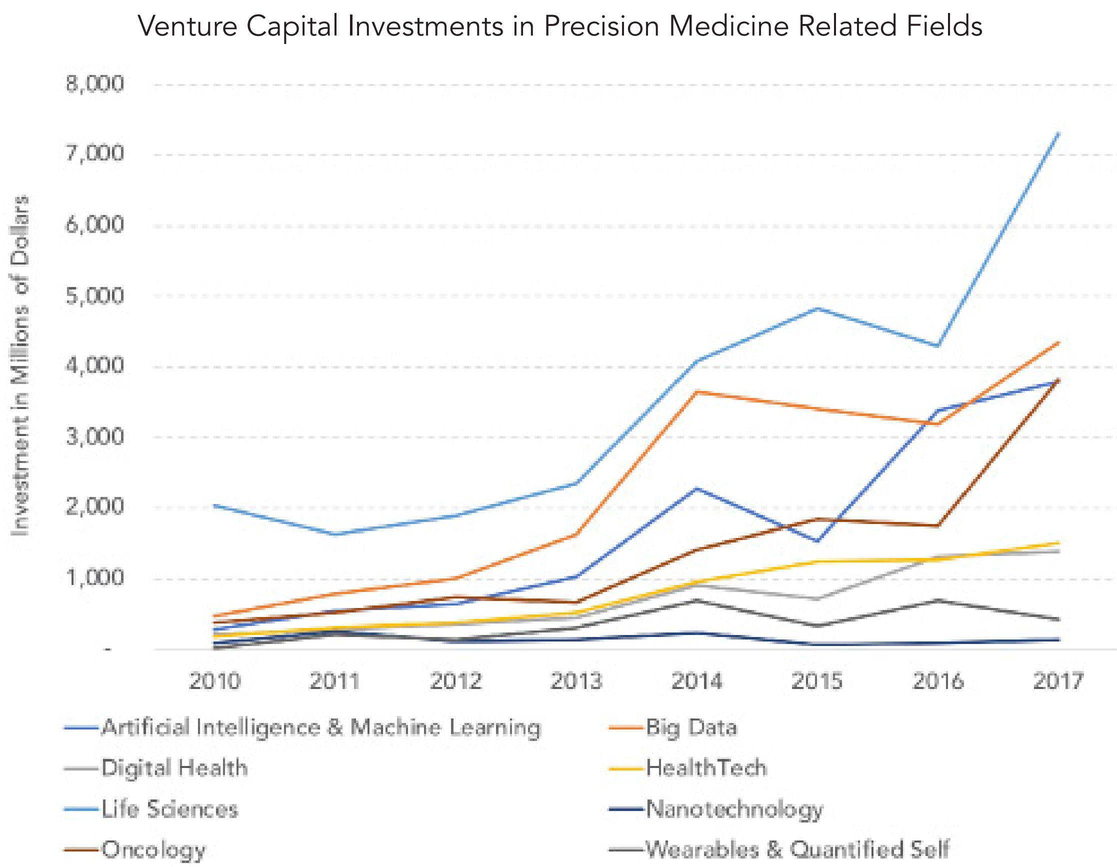
Another important economic impact of California's precision medicine industry is its large contribution to federal, state, and local tax revenue. The industry directly creates federal tax revenue of $1.18 billion each year, through a combination of taxes on employee compensation, proprietor income, production and imports, households, and corporations. This comes from the goods and services produced by the industry in addition to its revenue and employee incomes. California's precision medicine industry also creates a large amount of tax revenue for state and local governments, totaling over $438 million in direct taxes paid each year.

In addition to direct taxes, the precision medicine industry also creates a large amount of tax revenue indirectly, through taxes on activities that support the industry and that are induced by the industry's output. This comes out to another $1.2 billion in federal taxes and $780 million in state and local taxes.

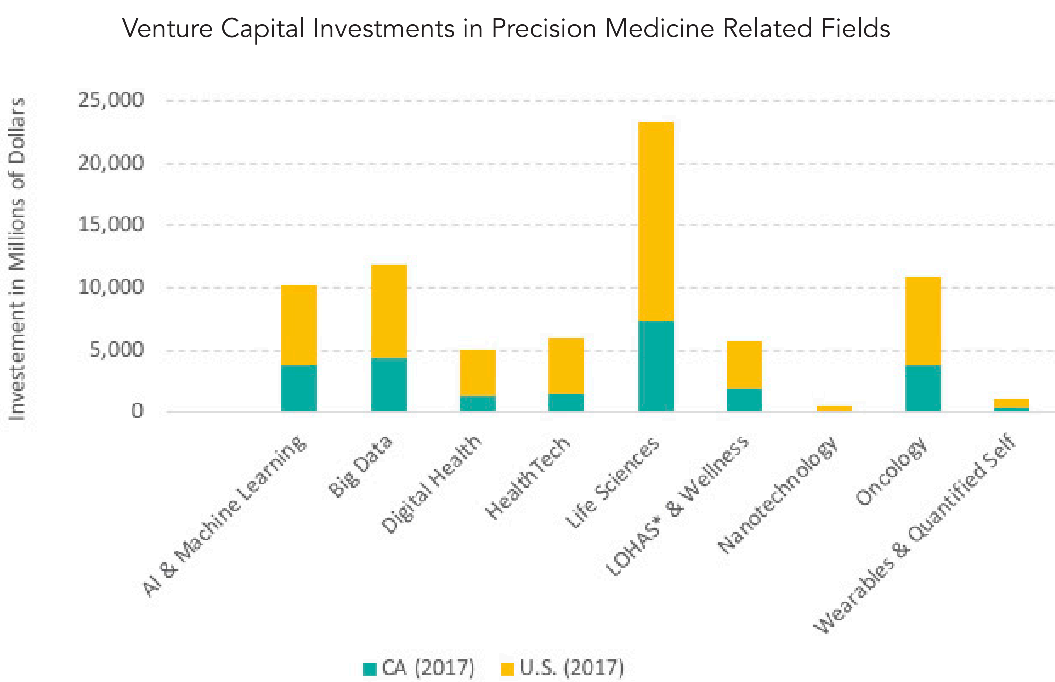
Venture Capital

As demonstrated above, precision medicine is already generating a significant amount of economic activity in California. However, robust investment in precision medicine and the technologies that enable it are critical in keeping its momentum. Venture capital data from Pitchbook show increased investment in precision medicine-related categories since 2010, with sharp growth in some industries since 2013. Overall, $49.6 billion was invested in the U.S. in these categories in 2017, with just under 50 percent ($24.6 billion) of that coming to California.

Four areas in particular saw the largest gains since 2010 in California, including: Wearables & Quantified Self (+2,444%), Artificial Intelligence & Machine Learning (+1,238%), Oncology (+941%), and Big Data (+829%). The remaining categories also posted strong growth, ranging from 61 to 723 percent. While each of these investments may not directly be in precision medicine companies, the collective progress in each field means more powerful tools can be brought to bear in the future.



Venture Capital Investments in Precision Medicine Related Fields
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
Investment in Millions of Dollars
2010
2011
2012
2013
2014
2015
2016
2017
Artificial Intelligence & Machine Learning
Big Data
Digital Health
HealthTech
Life Sciences
Nanotechnology
Oncology
Wearables & Quantified Self



Venture Capital Investments in Precision Medicine Related Fields
25,000
20,000
15,000
10,000
5,000
0
Investement in Millions of Dollars
AI & Machine Learning
Big Data
Digital Health
HealthTech
Life Sciences
LOHAS* & Wellness
Nanotechnology
Oncology
Wearables & Quantified Self
CA (2017)
U.S. (2017)

Case Study: Rapid Sequencing for Rare Genetic Diseases[13]

Along with creating jobs and adding economic value, precision medicine also has the potential to reduce the costs of certain types of healthcare for patients while at the same time improving outcomes.

It is estimated that somewhere between 10 and 15 percent of newborns in the U.S. are admitted to neonatal or pediatric care units at birth; many with rare genetic diseases. With over 8,000 known genetic diseases, diagnosing and implementing the correct course of treatment for a critically-ill child can be a daunting and expensive process. Many families spend years navigating the diagnostic odyssey, bouncing from specialist to specialist in search of answers.

At Rady Children's Institute for Genomic Medicine, Dr. Stephen Kingsmore and his team are revolutionizing the standard of care in diagnosing and treating childhood genetic diseases through their use of genomic medicine. Dr. Kingsmore is credited with the world record for fastest genetic diagnosis. Using sequencing technology developed by Illumina, Dr. Kingsmore and his staff work to quickly and accurately diagnose critically-ill newborn infants with unknown conditions.

Since its inception, the Institute has assisted more than 150 families with critically ill children through their rapid genome sequencing process. By sequencing and decoding the genome of each patient they treat, Dr. Kingsmore's team is able to diagnose the rarest of diseases in a matter of hours or days, improving health outcomes and changing the life trajectory for each patient they treat.

Today, the average cost to sequence each patient's genome at Rady is roughly $8,000. However, a recent analysis of 42 patients treated by Dr. Kingsmore's team indicates that receiving an accurate diagnosis sooner results in enormous cost savings over a patient's lifetime. The cumulative health care cost savings associated with these patients is an estimated $1.8 million dollars, or nearly $43,000 per patient. Rady continues to invest in fundamental genomic research and is building a body of evidence to demonstrate the cost effectiveness of using rapid genome sequencing as the standard of care in diagnosing and treating rare genetic diseases.

Conclusion

Precision medicine is already changing lives and making contributions to California's economy. The state's vibrant economy, unique concentration of existing assets, and robust innovation ecosystem mean it could become the preeminent hub for precision medicine in the nation. With it would come additional billions of dollars in economic activity, thousands of high-paying jobs, and millions in local and state tax contributions. The industry's eventual success however, should not be taken for granted and will be dependent on continued public and private investment, the availability of talented workers with a wide variety of expertise, and the thoughtful use of industrial land near job centers.

End Notes

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