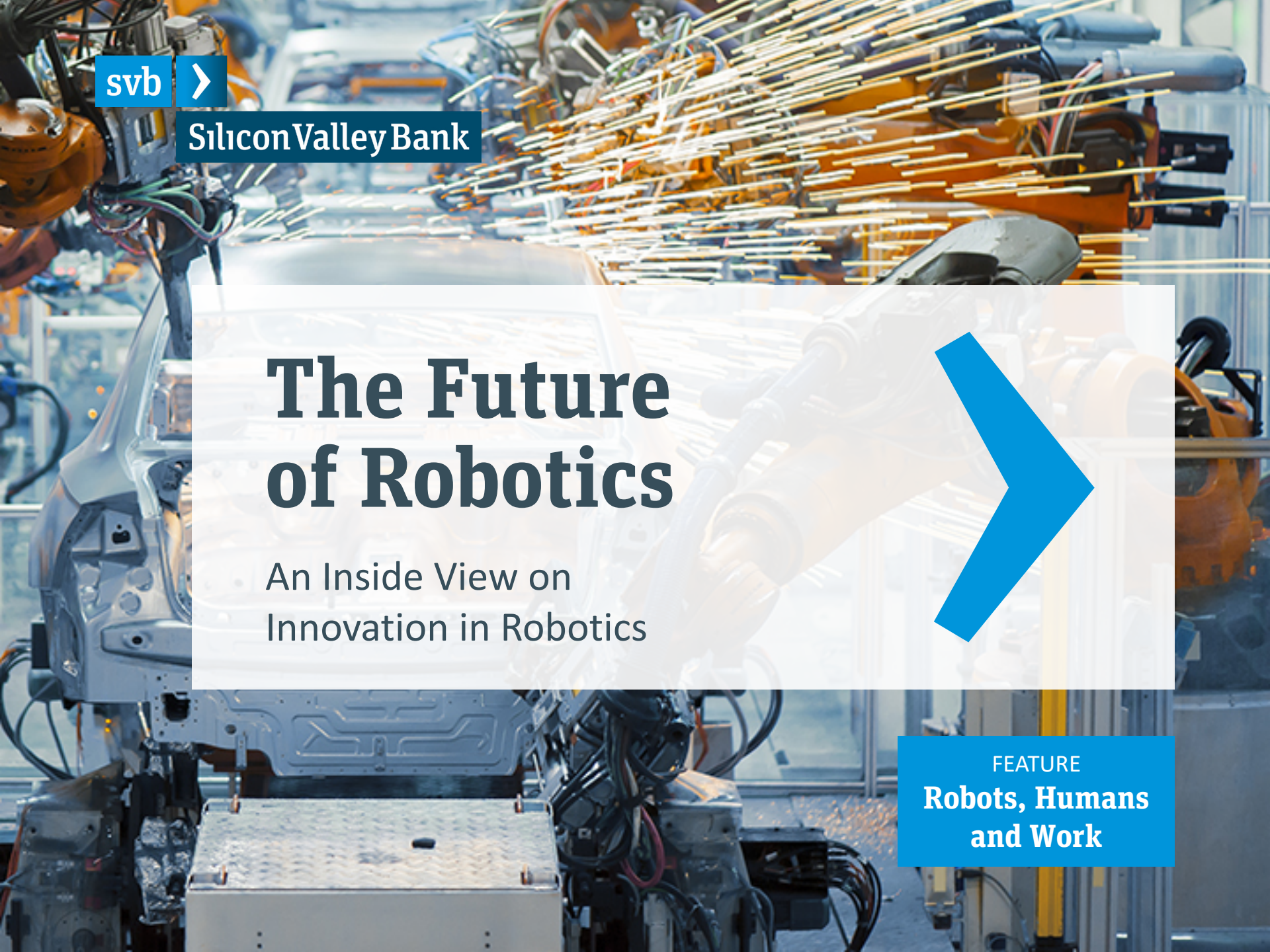

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Silicon Valley Bank

The Future of Robotics

An Inside View on Innovation in Robotics

FEATURE

Robots, Humans and Work

Executive Summary

Austin Badger

Director, Frontier Tech Practice

Robotics in the Startup Ecosystem

The automation of production through three industrial revolutions has increased global output exponentially. Now, with machines increasingly aware and interconnected, Industry 4.0 is upon us. Leading the charge are fleets of autonomous robots. Built by major multinationals and increasingly by innovative VC-backed companies, these robots have already become established participants in many areas of the economy, from assembly lines to farms to restaurants.

Investors, founders and policymakers are all still working to conceptualize a framework for these companies and their transformative technology. In this report, we take a data-driven approach to emerging topics in the industry, including business models, performance metrics, and capitalization trends.

Finally, we review leading theories of how automation affects the labor market, and provide quantitative evidence for and against them. It is our view that the social implications of this industry will be massive and will require a continual examination by those driving this technology forward.

Table of Contents

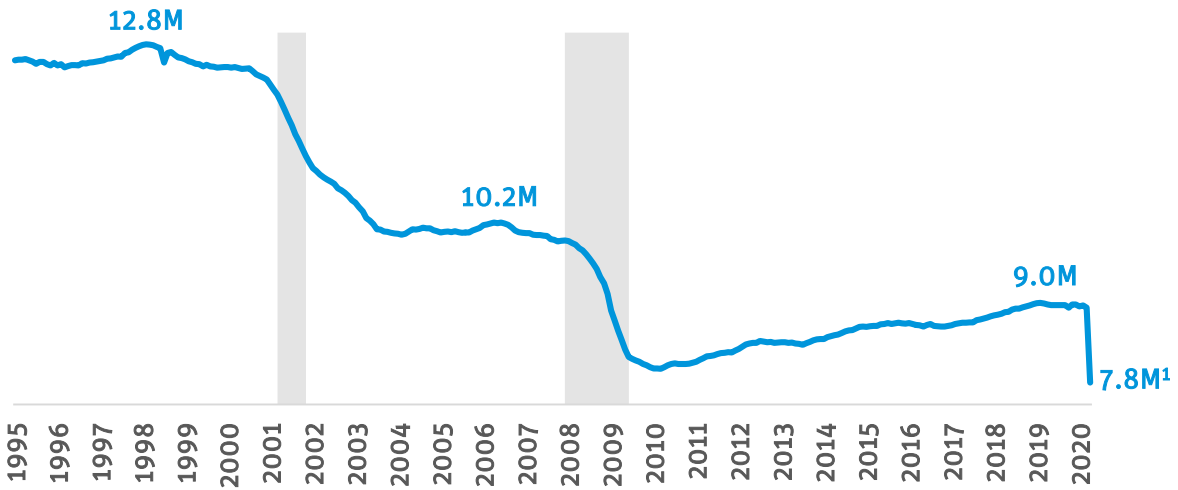
The Landscape

Industry 4.0 and the Robotics Ecosystem

COVID-19 and the Next Automation Wave

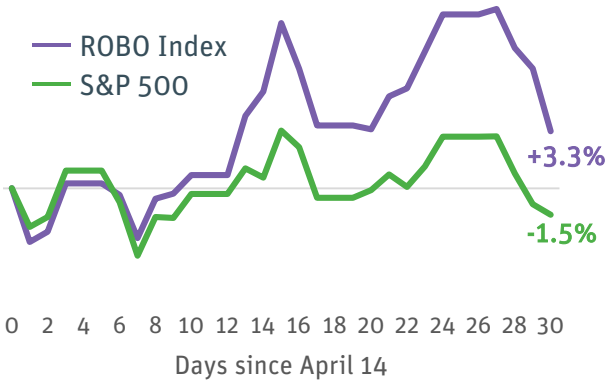
Recessions tend to reduce employment, and some jobs don't come back. This trend is glaring for US manufacturing in the prior two downturns as businesses reconsidered their supply chains and looked to move production offshore or to automate. The pandemic's effect on global supply chains has made the offshoring option problematic, increasing the likelihood that this cycle will see an increase in investment in automation. Executive surveys and robotics stock performance indicate this has started.

US Manufacturing, Production and Nonsupervisory Workers



Automation Stock Performance

April 14–May 14, 2020



Share of executives investing in **accelerating automation** due to COVID-19

41 percent[2]

Forecast **2021 robotics market size** after COVID-19

$23 billion[3]

Notes: 1) Preliminary reading. 2) Based on Ernst & Young survey results. released 3/30/2020. 3) Based on ABI Research study results released 4/2/2020.
Source: Bureau of Labor Statistics, S&P Capital IQ, Ernst & Young and ABI Research.

Production Over the Past Two Centuries

Global civilization has grown exponentially wealthier and more productive through three industrial revolutions. A fourth is now underway, one which promises to unlock new opportunity, but may also unleash transformative shifts for labor, industry, and society at large.

US GDP per Capita through Four Industrial Revolutions

First

Watt's steam engine becomes an energy source for industry and transportation. Textile innovations, such as the power loom, drastically increase British output.

Second

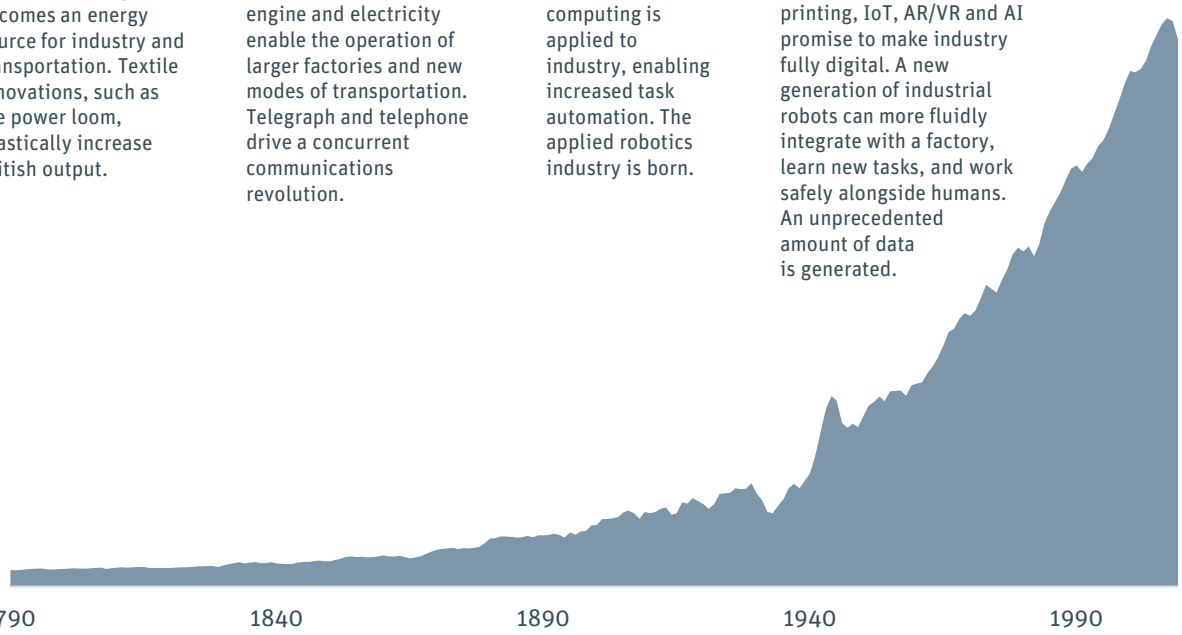
The internal combustion engine and electricity enable the operation of larger factories and new modes of transportation. Telegraph and telephone drive a concurrent communications revolution.

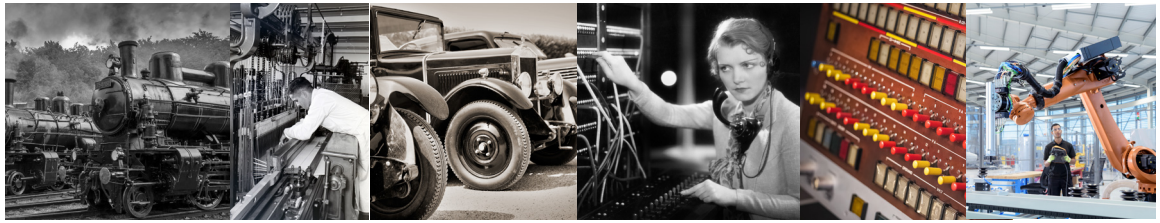
Third

The advent of computing is applied to industry, enabling increased task automation. The applied robotics industry is born.

Fourth

Frontier technologies like 3D printing, IoT, AR/VR and AI promise to make industry fully digital. A new generation of industrial robots can more fluidly integrate with a factory, learn new tasks, and work safely alongside humans. An unprecedented amount of data is generated.



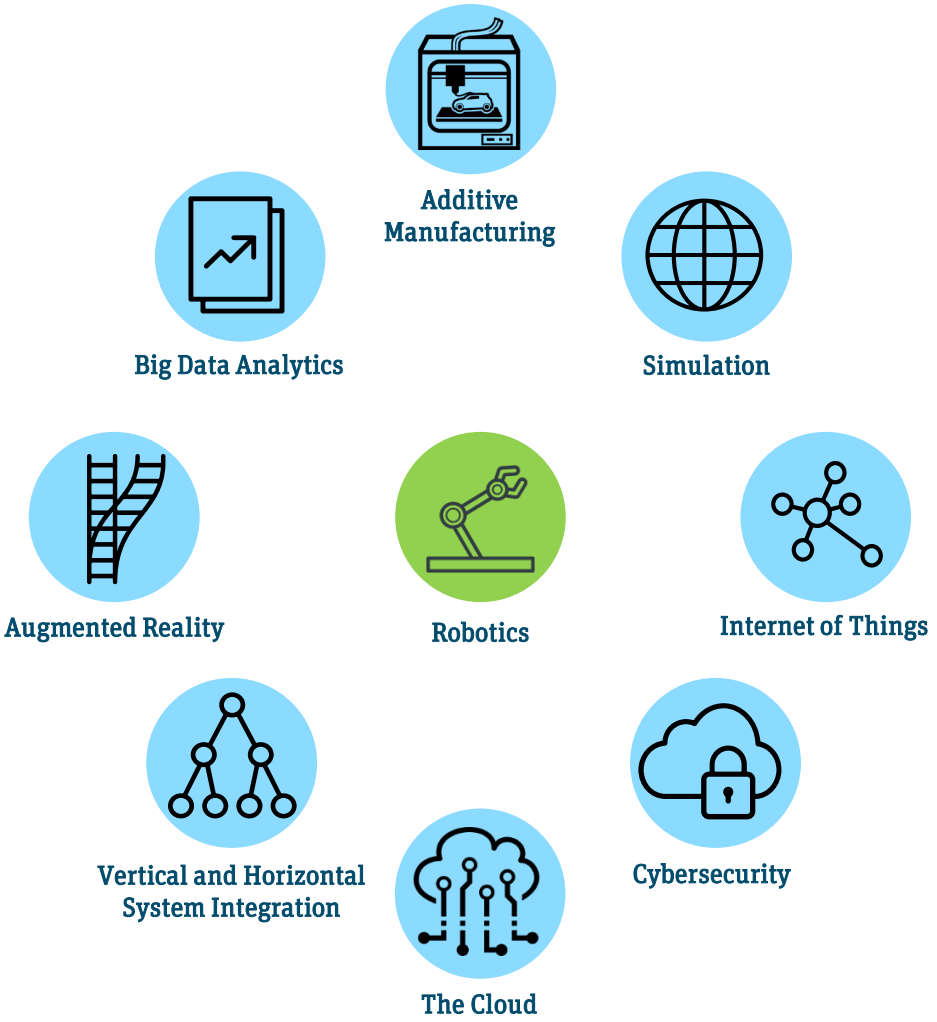


Source: Barro-Ursua Macroeconomic Dataset.

The Fourth Industrial Revolution Is Upon Us

A confluence of technological advancement in various fields has allowed entrepreneurs to develop solutions to common problems in industry. These solutions are far from isolated and cross the digital and physical realms. Robotic performance of tasks is a key element in this interplay. In a recent cross-industry McKinsey study, 70% of surveyed executives said they expect advanced robotics to become a very important productivity driver by 2025.

BCG Constituent Technologies of Industry 4.0



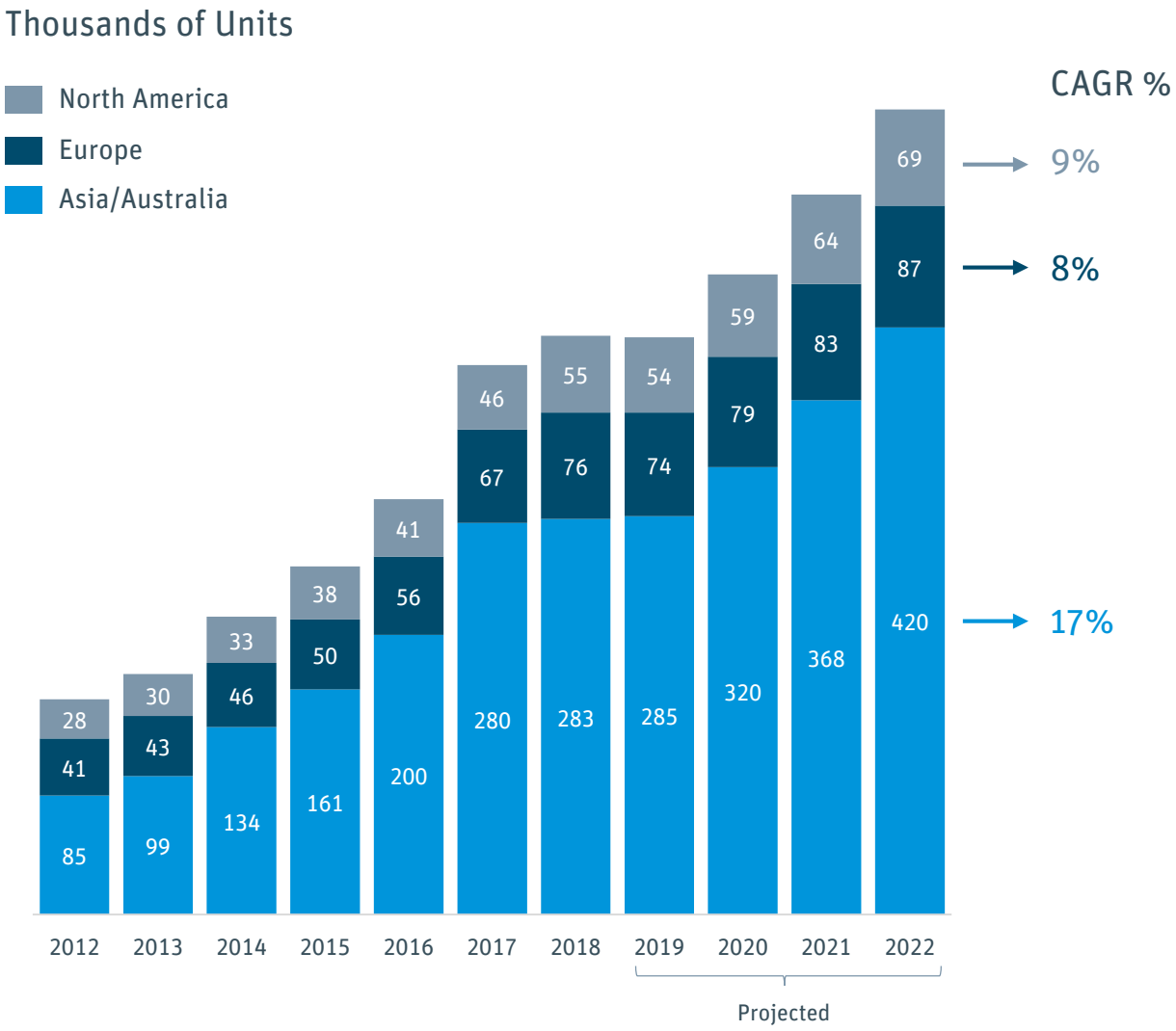
Source: Boston Consulting Group.

Driven by Asia, the Industrial Robo-force Swells

Annual installations of industrial robots have more than doubled since 2013, growing at 18% CAGR[1]. This is expected to slow in the next four years to 9%. China has led the way, increasing its stock of industrial robots nearly fivefold.

While impressive, this rate of growth is not tremendous. Innovating the existing stock of robots is a compelling opportunity, as is expanding that stock.

Annual Installations of Industrial Robots by Region



Notes: 1) CAGR = Compound Annual Growth Rate.
Source: International Federation of Robotics.

Robotics Enjoys Unique Advantages

There are three key features that set robotics apart from other thriving sectors. Unlike other autonomous hardware such as AVs, many applied robotics use cases occur in closed and well-mapped environments, thereby reducing engineering problems. In many industries, robots can add immediate value and unlock visibility into new productive data.

Three Virtues of Modern Applied Robotics

Closed Environments

Innovation can occur without physical interaction with an end customer. Robots safely operate within constrained and less-trafficked environments. This significantly reduces engineering problems, and allows machines to learn faster while producing insightful data.

Immediate Value

The boldest applications may seem distant (e.g., humanoid robot assistants), but startups and corporates are finding immediate success deploying robots to achieve specific tasks. ROI can be immediately achieved for repetitive tasks, such as agtech use cases, or in scenarios where overnight work enables step-ups in productivity.

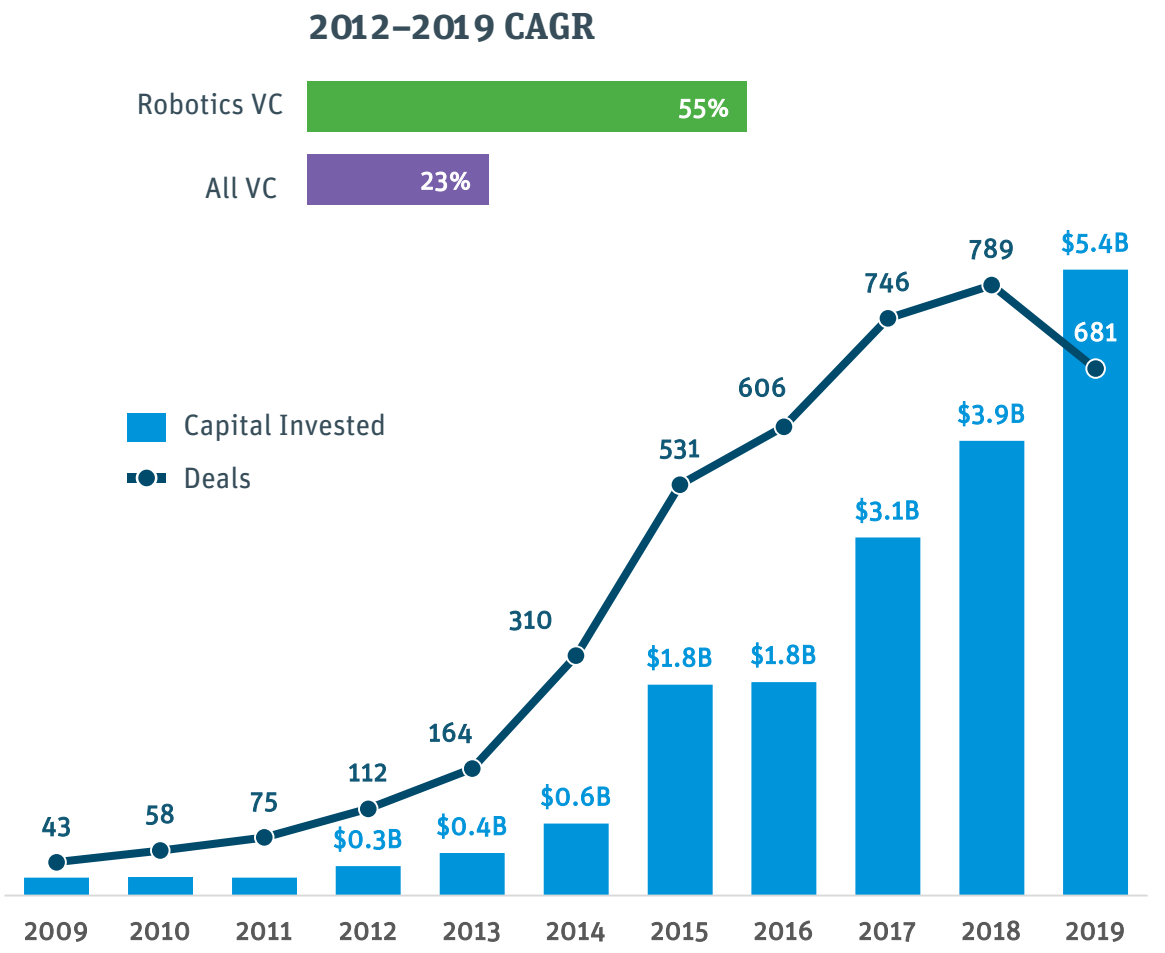
Data Acquisition

Many industries have grown used to an abundance of data; the primary and secondary sectors are behind this curve. Inserting robots into production environments unlocks new streams of physical data, catalyzing positive feedback loops that further optimize production.

VC Appetite for Robotics Growing Fast

Venture investment in companies building robots or related hardware has exploded over the last business cycle, topping $2B in the first quarter of 2019. Investment in robotics has significantly outpaced the rest of venture, making robotics one of the hottest sectors of the decade. Near the beginning of 2018, growth in deal count stalled, while dollars invested continued to rise. This suggests that category leaders are beginning to be established.

Global VC Investment in Robotics and Related Hardware



Source: PitchBook.

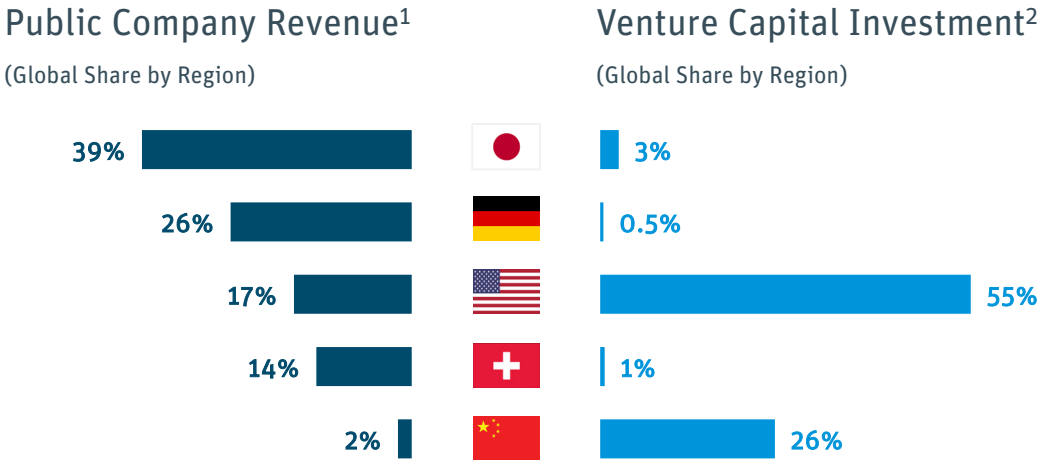
VC Challenges Incumbent Strongholds

The market for industrial robots is dominated by large public companies, with a handful of Japanese conglomerates ahead of the pack.

VC investment in robotics startups is, by contrast, concentrated in the United States and China.

This is both an indication of where the larger industry may shift in the future and a competitive risk for incumbent firms, which has already motivated several strategic acquisitions.

Public Robotics Business Revenue and Robotics VC Investment



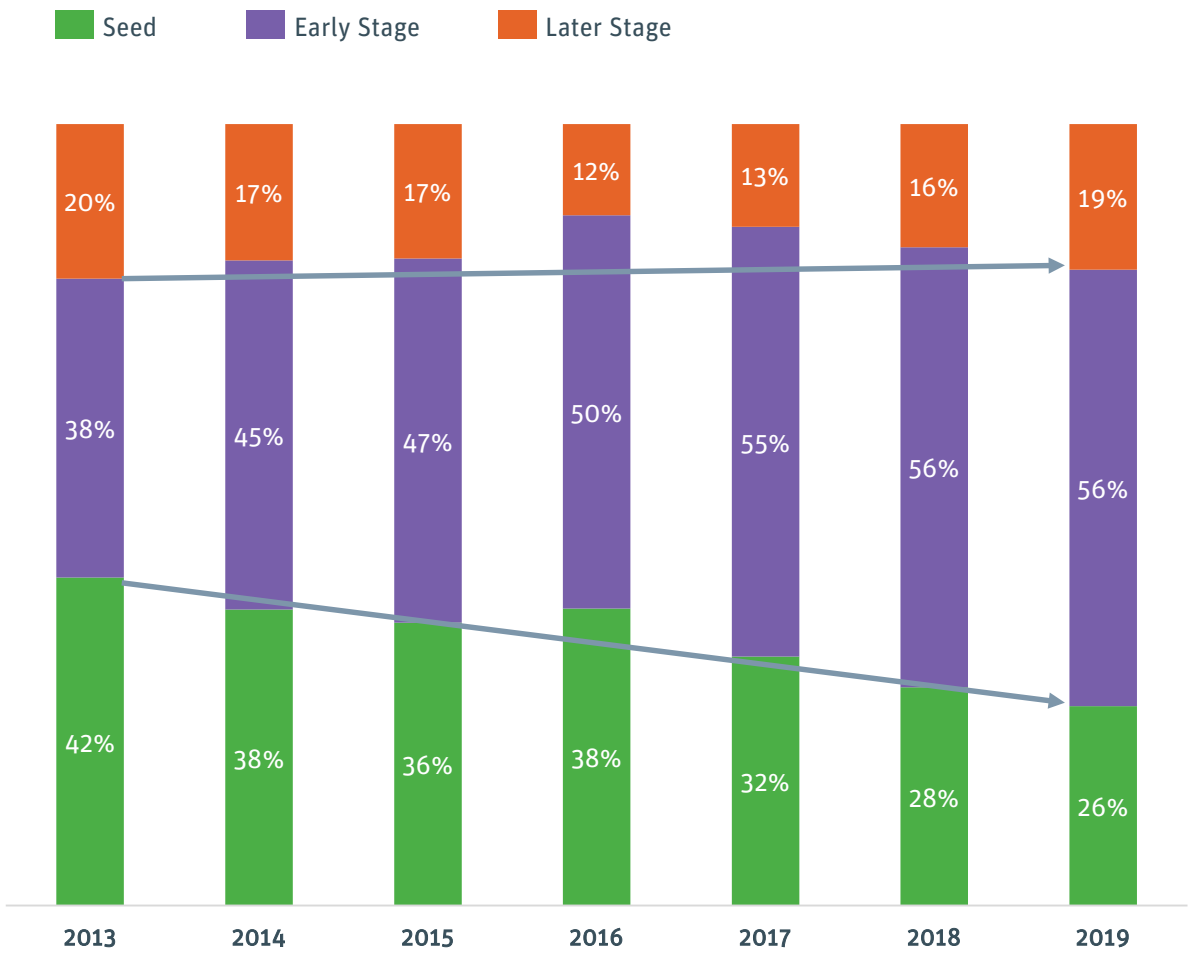
VC Investment in Robotics[2] (2013–2018)

Notes: 1) Encompasses robotics-related segments of public companies, where reported, for 2018. 2) VC investment calculated for 2013–2018 VC investment in robotics and related hardware startups.
Source: S&P Capital IQ and PitchBook.

Robotics Startups Cross the Early Stage

An increasing share of robotics venture deals is comprised of Series A and B rounds, with seed representing a declining share and later stage holding steady. This suggests that in the coming years we will likely see more later stage activity as the market matures. The next phase of segment maturity will be a surge of later stage activity.

Percentage of VC Deals by Stage
Robotics Hardware Companies

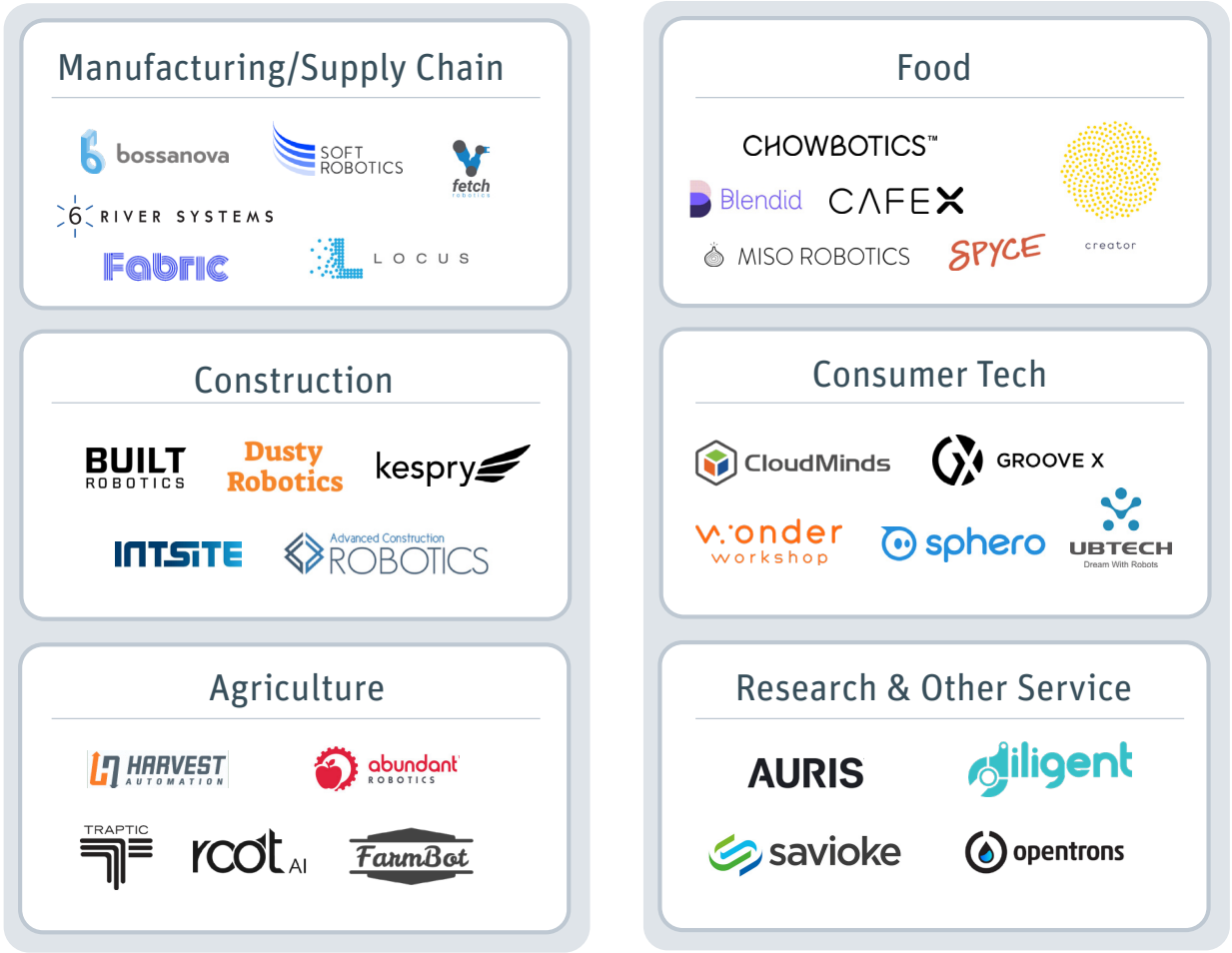


Source: PitchBook.

Robotics Solves Many Different Problems

Like AI or cloud computing, robotics is a general purpose technology capable of adding value to a wide range of industries. Robots are increasingly prevalent in factories, farms, warehouses, hospitals, homes, and elsewhere. This market map is not exhaustive, but it shows some exemplars in identified categories.

SVB Robotics Market Map[1]



Notes: 1) Includes a selection of representative companies; not exhaustive.
Source: SVB Analysis.

VC and Robots

An Emerging Framework

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The RaaS Mindset: SaaS Meets Hardware

The most successful and well-funded robotics startups have adopted business models based on well-known preferences of venture capitalists, such as recurring revenue and a focus on unit economics. Whenever possible, enterprise robotics companies should position their robots as recurring operating expenditures, not one-off capital expenditures.

Robot-as-a-Service Metrics

Customer Acquisition Cost

$$\frac{(S\&M^{1} + \text{Hardware Cost})/(ARR^{2} \times \text{Gross Margin})}{\text{Number of Customers}}$$

Annual Revenue per Robot

$$\frac{\text{Annual Revenue}}{\text{Number of Robots Deployed}}$$

Robot Lifetime Value

$$\frac{\text{Annual Revenue per Robot}}{\text{Annual Robot Decommission Rate}}$$

Software-as-a-Service Metrics

Customer Acquisition Cost

$$\frac{(S\&M/(ARR^{2} \times \text{Gross Margin})}{\text{Number of Customers}}$$

Annual Revenue per User (ARPU)

$$\frac{\text{Annual Revenue}}{\text{Number of Customers}}$$

Customer Lifetime Value

$$\frac{\text{ARPU}}{\text{User Churn Rate}}$$

Key Differences

Revenue Growth: Robotics companies will naturally lag software companies in terms of topline growth. Typical benchmark growth rates for SaaS companies won't translate to otherwise similar RaaS models.

Data Acquisition: An underappreciated feature of robotics companies is their access to unprecedented streams of physical data. Many applications are in environments for which such data does not exist, such as kitchens, farms, and hotels.

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Notes: 1) S&M = Sales and Marketing Expenses. 2) ARR = Annual Run Rate.

RaaS Shifts Robot from CapEx to OpEx

Traditionally, industrial machinery is owned or leased – not "subscribed to." RaaS models shift robotic systems from a one-time capital expenditure to a recurring operating expenditure. SVB proprietary data show that higher multiples are awarded to robotics companies with RaaS models.

An interesting implication of this is that it makes robots more clearly labor-replacing. Like wages, RaaS fees are recurring payments toward an entity that performs tasks.

Business Models

Robot as OpEx

RaaS Fixed:
Charging customers a **standard contracted amount** for services rendered on a monthly, quarterly, or annual basis.

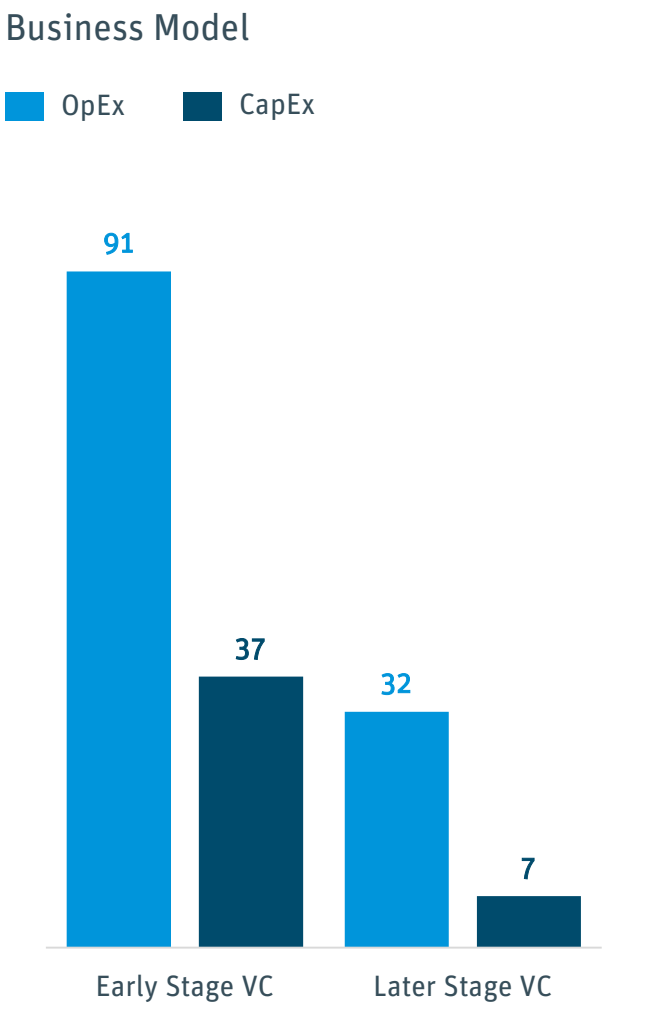
RaaS Variable:
Charging a **variable contracted amount based on either usage or consumption**. Every time the robot executes a task, the company collects payment.

Robot as CapEx

HW + Maintenance:
Customer buys and owns hardware upfront, and the **company then provides recurring maintenance and software services.**

One-Time Sale:
Sell customer a robot upfront with **no contracted recurring revenue streams from the customer.**

Median Revenue Multiple



Source: SVB Proprietary Data, PitchBook.

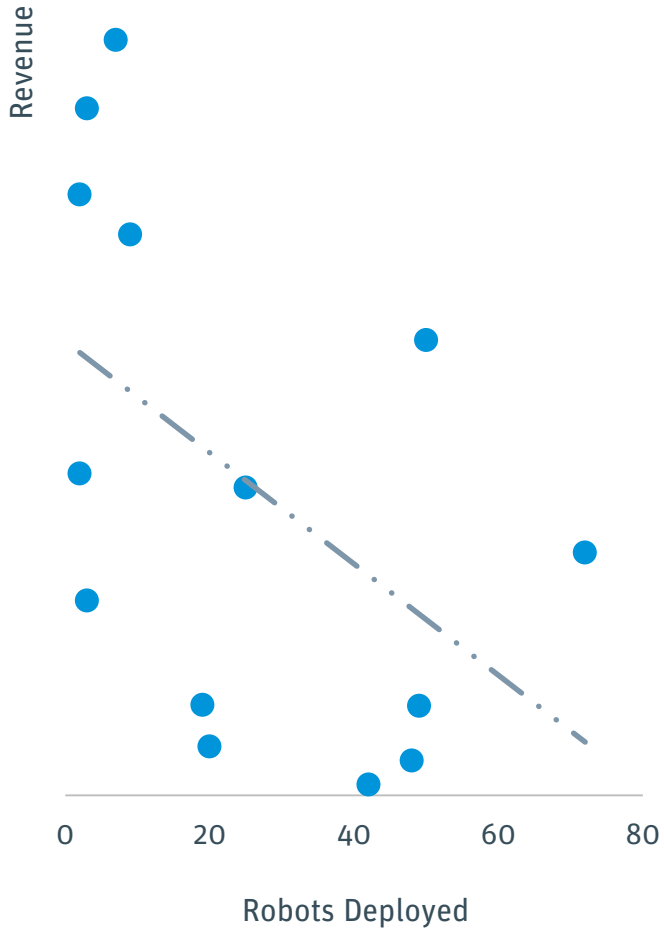
Don't Put All Your Eggs in One Robot

In theory, maximizing revenue per robot is a good thing. However, companies should avoid concentrating revenue in a small number of robots – even if such a scenario would yield higher ARR/robot. As companies mature, we actually observe unit revenue coming down, as sales disperse from a small handful of early, quasi-pilot robots to a more robust fleet.

Median Revenue/Robot

Round	Median ARR/Robot
Series A	$75,000
Series B	$45,333
Series C	$31,316

Revenue vs. Robots Deployed

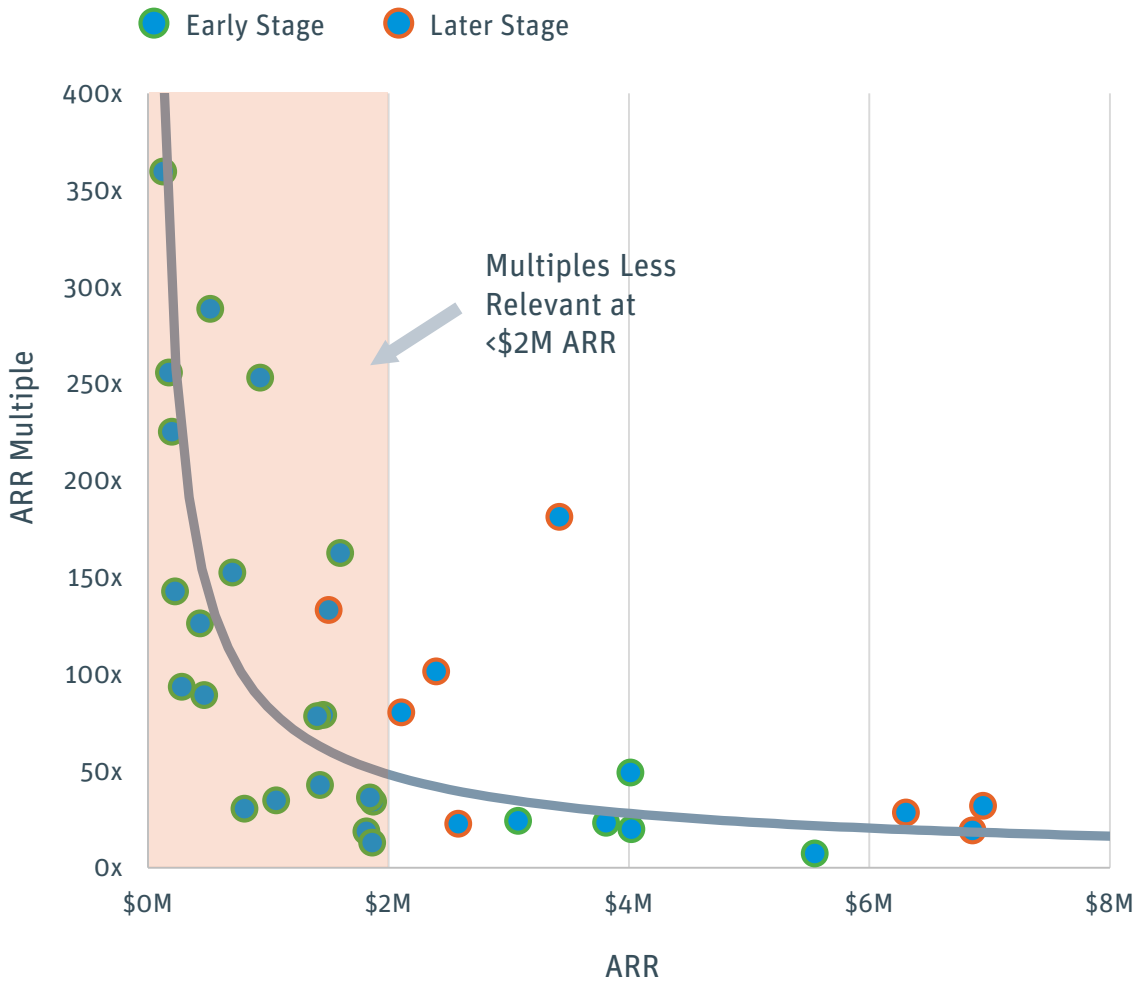


Source: SVB Proprietary Data, PitchBook.

Expectations, Not Sales, Drive Early Post-Seed Valuations

At lower levels of revenue, ARR multiples of post-seed robotics companies vary significantly and can be strikingly high. There appears to be significance in the $2M annual revenue mark, after which valuations come down as a multiple of revenue and companies grow into their earlier expectations.

ARR and ARR Valuation Multiple
Robotics Hardware Companies



Source: SVB Proprietary Data and PitchBook.

Investors Run the Gamut

Venture investment in robotics companies is driven largely by accelerators and incubators, as well as early-stage VCs with a focus on emerging tech. As companies gain traction, investment activity from corporate venture and larger VC firms picks up.

However, activity of some of the most well-known Sand Hill firms has been surprisingly scant. This may soon change as investors build an investment framework and are reassured by successful exits.

Notable Large Funding Rounds

Company	Deal Size	Lead Investor
nuro	$940M	SoftBank
UBTECH	$241M	Tencent 腾讯
AURIS	$280M	COATUE
BERKSHIRE GREY	$263M	SoftBank
CloudMinds	$186M	SoftBank

Most Active Investors

Corporate Venture Capital

Qualcomm Ventures
intel Capital
GV
Baidu.ventures 百度风投

Traditional Venture Capital

IDG Capital
Eclipse
khosla ventures
Lux
Lemnos Labs
a16z
innovation works

Accelerators and Incubators

SOSV The Accelerator VC
PlugAndPlay
techstars
Y

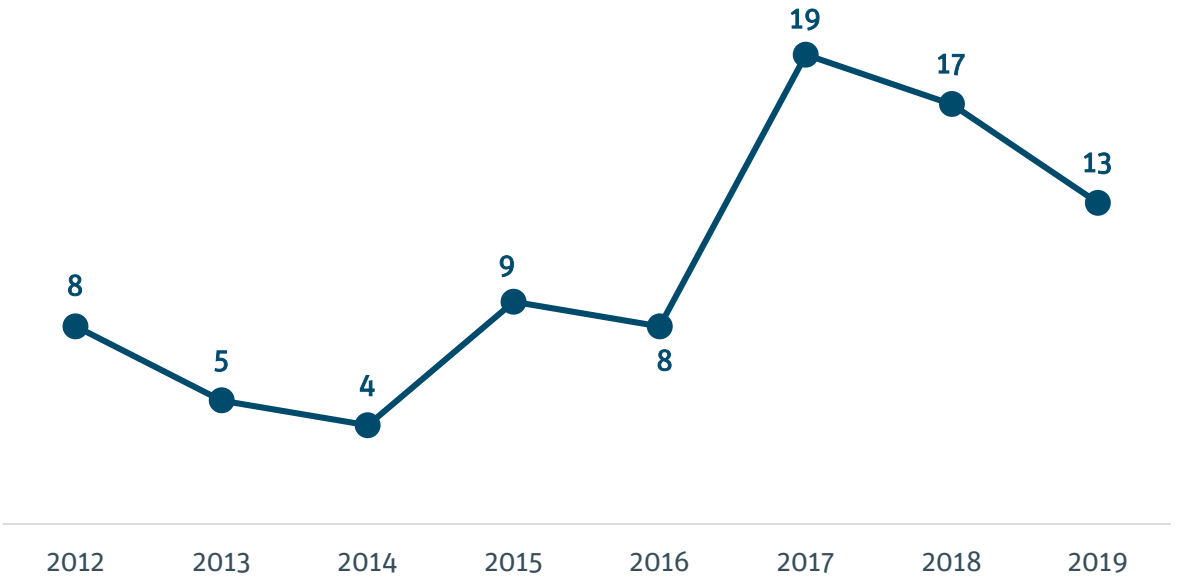
Source: PitchBook.

Industrials and Ag Lead Exits

Increased exit activity, highlighted by several large M&A transactions in the industrials and agriculture segment, has generated returns for investors in the space, which will encourage continued participation. Notable transactions include major strategic acquisitions by companies relying on robotics solutions, such as Shopify, or by established industrial robotics conglomerates like FANUC.

Mergers and Acquisitions
Robotics and Drone Companies

2012	2017	2018	2019
Amazon acquired **Kiva Systems** for $678M.	**Deere & Co.** acquired **Blue River Technology** for $350M.	**Fanuc** acquired **Life Robotics** for an undisclosed amount.	**Shopify** acquired **6 River Systems** for $450M.



Source: PitchBook and SVB Analysis.

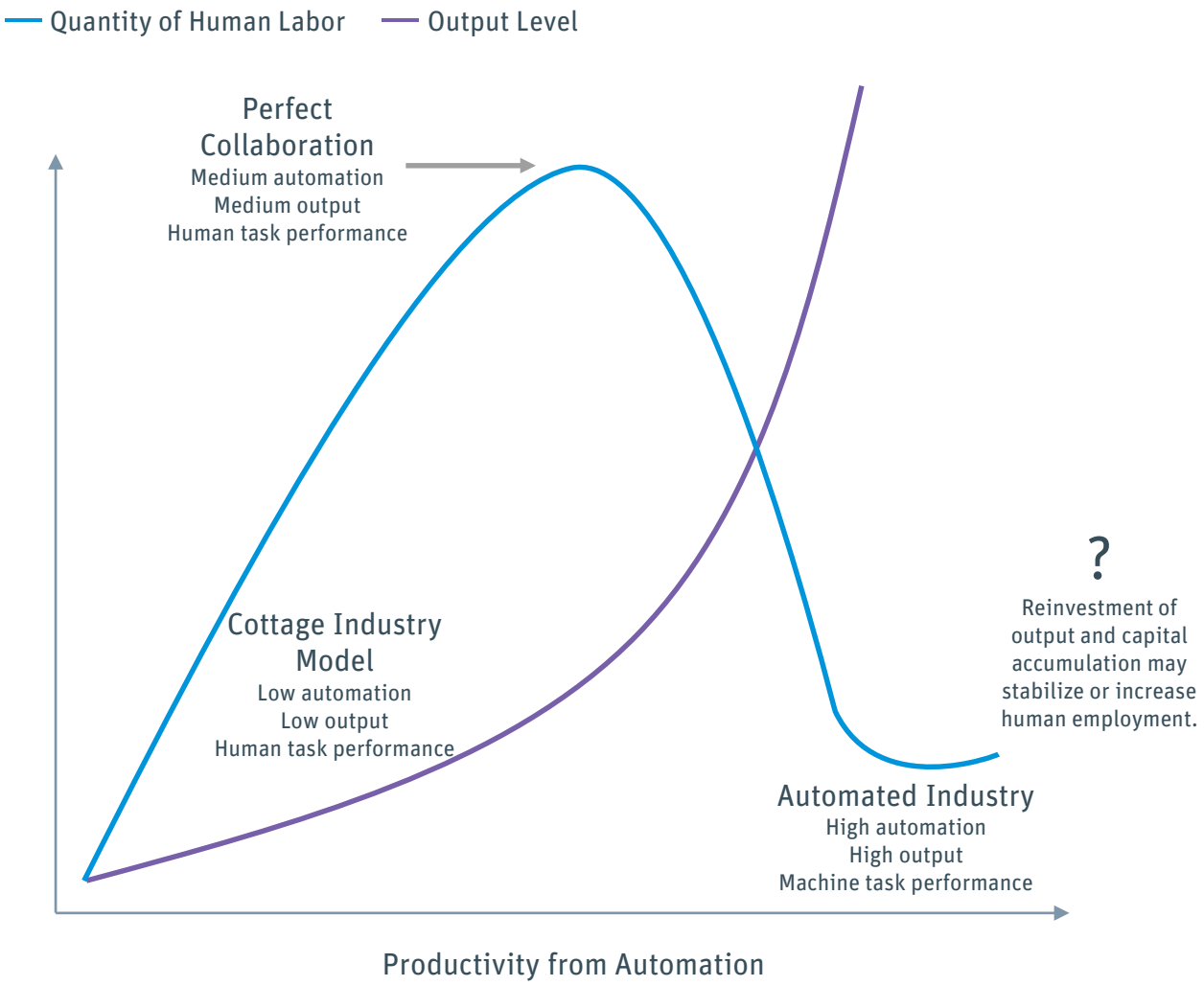
Robots, Humans and Work

The Interplay of Automation and Labor

The Industry Automation Lifecycle

A nascent industry starts with a small number of skilled producers in a "cottage industry" format, with little to no automation and, therefore, human involvement in every task (e.g., British textiles circa Industry 1.0). As the industry incorporates more machines, productivity enables growth, increasing the demand for human labor. As automation deepens to become labor-displacing, employment begins to fall. Over time, the returns from automation can be reinvested in the industry, potentially restoring and increasing employment in the long run.

Conceptual Framework



The Economic Results of Automation

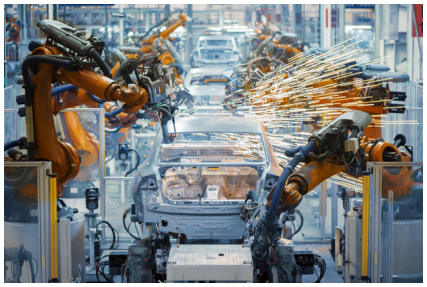
What will robotics do to the labor market and society at large? The risk that robots will displace human workers is real, but countervailing forces, such as productivity growth and capital accumulation, may alleviate its effects in certain industries. We considered three possible mechanisms by which automation affects employment.

Three Mechanisms at Work

Automation Increases Productivity

Productivity, in turn, has ambiguous effects on employment.

Automation Takes Tasks from Human Agents



Some proportion of those agents will lose their jobs.

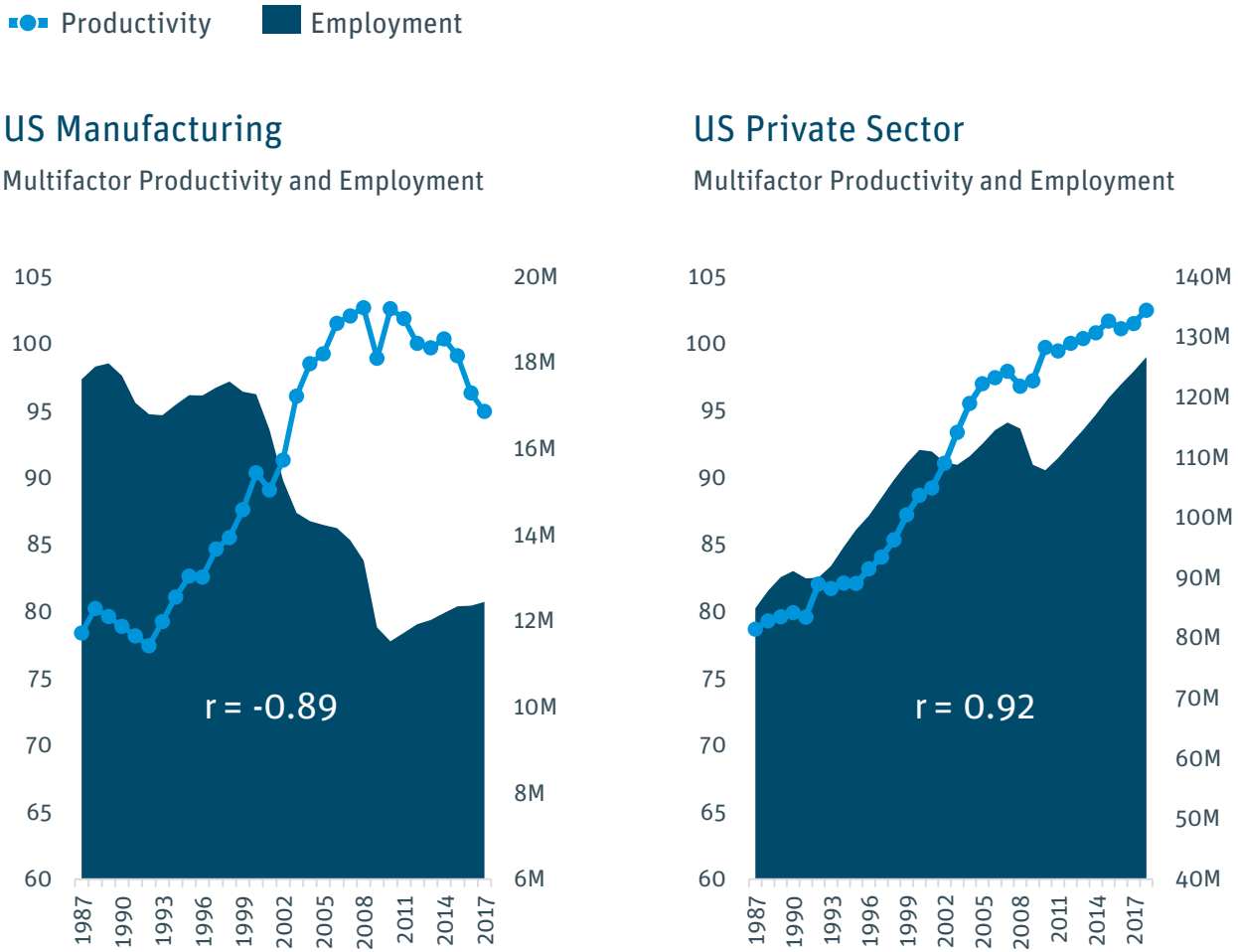
Automation Generates Wealth

That wealth can be used to accumulate capital, growing the economy and employment.

Automation Increases Productivity

In turn, productivity may or may not be associated with increased employment. In the US manufacturing sector, periods of productivity growth coincided with declines in manufacturing employment (though these declines have also been attributed to foreign competition). In the greater private sector, however, productivity growth has coincided with employment gains.

Productivity and Employment



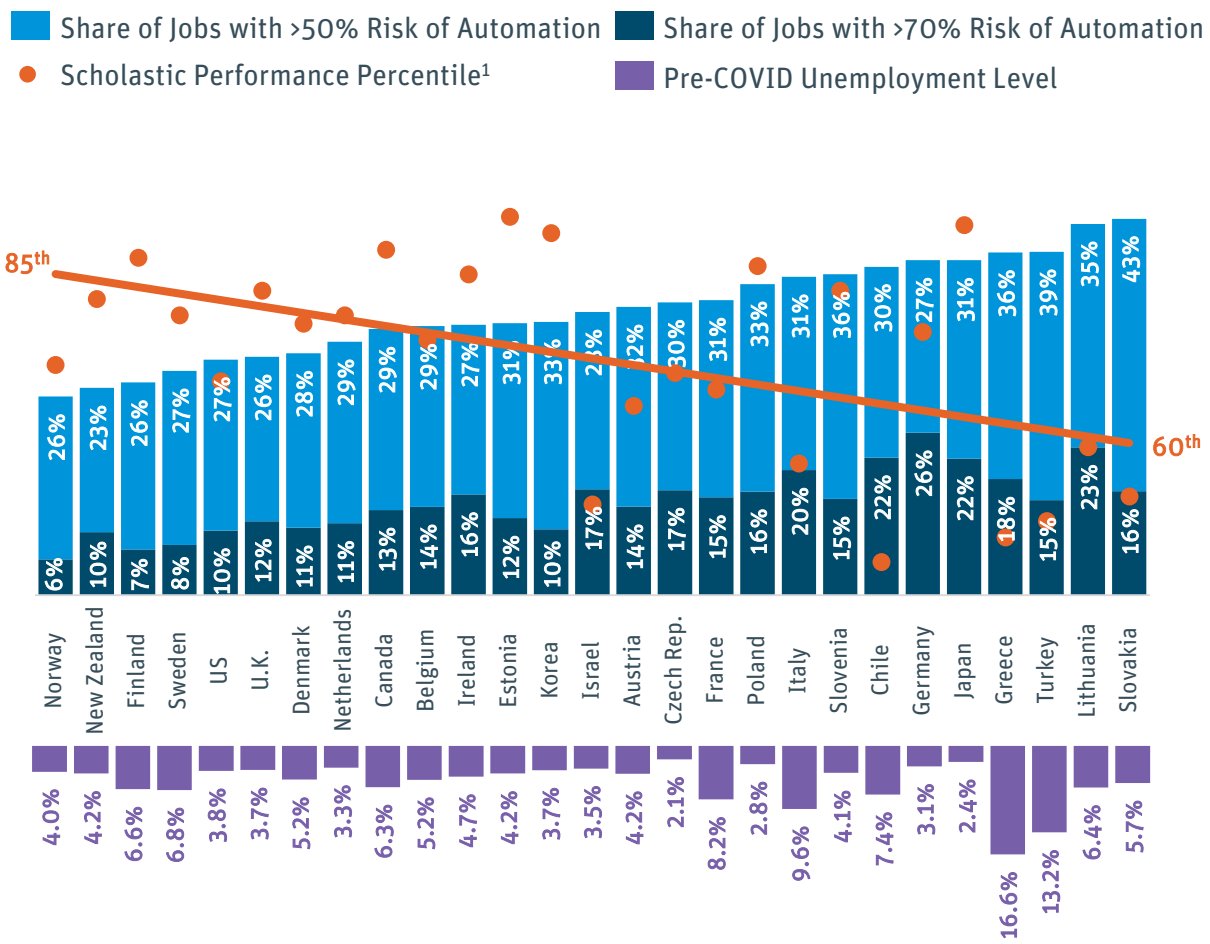
Source: Bureau of Labor Statistics.

Automation Can Displace Labor

The risk of massive displacement is lower in many of the richest nations. Regrettably, those countries with the highest risk of displacement include some of the lowest-scoring in math, science, and reading. These countries may have a more difficult time adjusting to the changing needs of the labor market, as many experts anticipate that automation will shift demand toward more highly skilled workers.

Displacement Risk and Scholastic Performance

Reporting OECD Countries



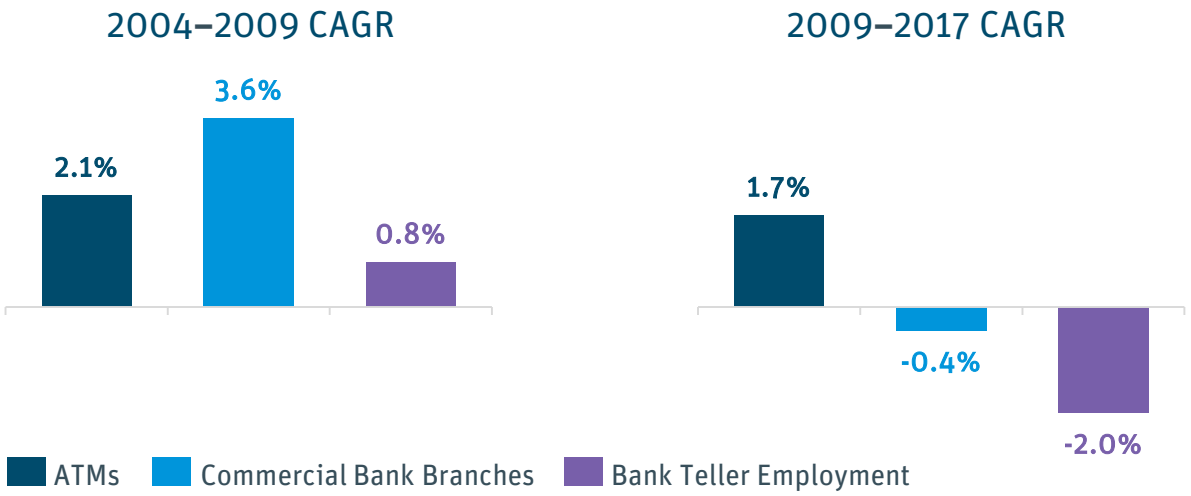
Notes: 1) Measured by mean cumulative Programme for International Student Assessment (PISA) score. Percentiles based on all countries participating in the PISA assessment program, not just those shown.
Source: Organisation for Economic Co-operation and Development.

Automation May Spur Capital Accumulation

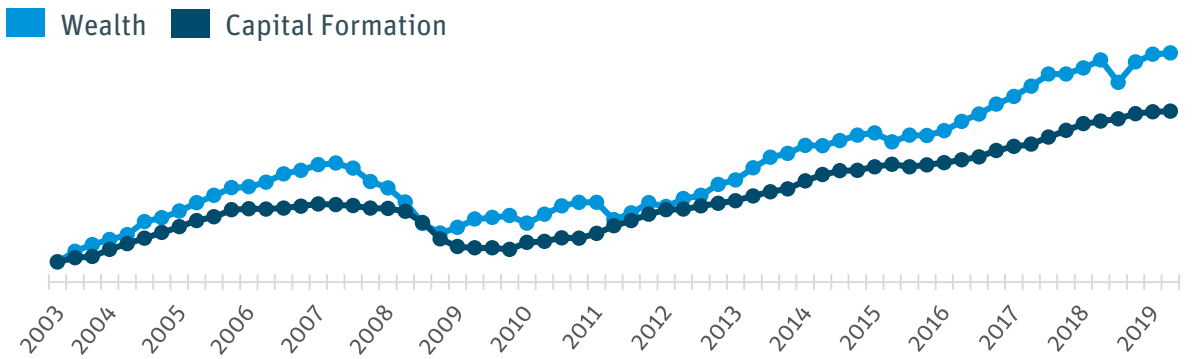
The ATM has been cited as a counterexample to the notion that automation reduces the demand for labor. The initial growth of ATMs coincided with increased bank teller employment. Since 2009, this paradigm appears to have shifted; while ATMs continue to expand (albeit more slowly), branches and teller employment are in decline.

Generally, automation generates additional wealth, which is highly correlated with capital formation. If new capital creates enough new jobs, then the "ATM effect" can occur.

The Case of the ATM in the US



Wealth and Capital Formation in the US[1]



Notes: 1) Figures indexed to Q2 2003 levels.
Source: International Monetary Fund, ATM Industry Association, BLS, OECD and Federal Reserve.

Bold Policy Proposals Have Gained Traction and Advocacy

The impending shifts in how work is done have catalyzed lively debate over future policy approaches. Thought leaders in industry, academia and politics have made ambitious proposals from a tax on the installation of robotic systems to universal basic income.

Robot Tax

Policy
Tax the cost of installing robots.

Argument For
Wages paid to human labor are already taxed; machine labor should receive the same treatment. Absent this tax, companies can reduce their tax base by replacing humans. The proceeds could be used to finance a stronger social safety net for the technologically displaced.

Argument Against
Implementation would be made difficult by the ambiguity of what exactly constitutes a robot. In slowing automation, this tax would merely postpone the problem of displacement and increase reliance on a bureaucratic social safety net.

Proponents
Bill Gates
Mark Cuban

Universal Basic Income

Policy
Pay a fixed monthly sum to all citizens.

Argument For
Automation will generate massive wealth for a relatively small proportion of the workforce. Industry 4.0 will displace human labor on a very large scale. An automatic income to all citizens would provide an escape from scarcity so that they can adjust their skill set for new, more complex jobs.

Argument Against
Paying for such a policy would require an increase in taxes or the national debt, which would counteract any benefit from the transfer itself. Further, higher incomes will be offset by inflation.

Proponents
Andrew Yang
Milton Friedman

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Source: Politico and Forbes.

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Austin has held a number of roles at SVB and brings over a decade of investing experience to his clients. A Colorado kid at heart, Austin graduated from the University of Colorado and holds a bachelor's degree in finance. Married and the father of two fantastic young children, Austin can be found tinkering with clients' technology to help optimize every life experience.

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Evan takes an interest in macroeconomics and international trends. Prior to this role, he worked for a leading economic consulting firm. He earned Bachelor of Science degrees from the University of Southern California, Bocconi University, and the Hong Kong University of Science and Technology.

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SVB provides targeted financial services and expertise through its offices in innovation centers around the world.

With commercial, international and private banking services, SVB helps address the unique needs of innovators.

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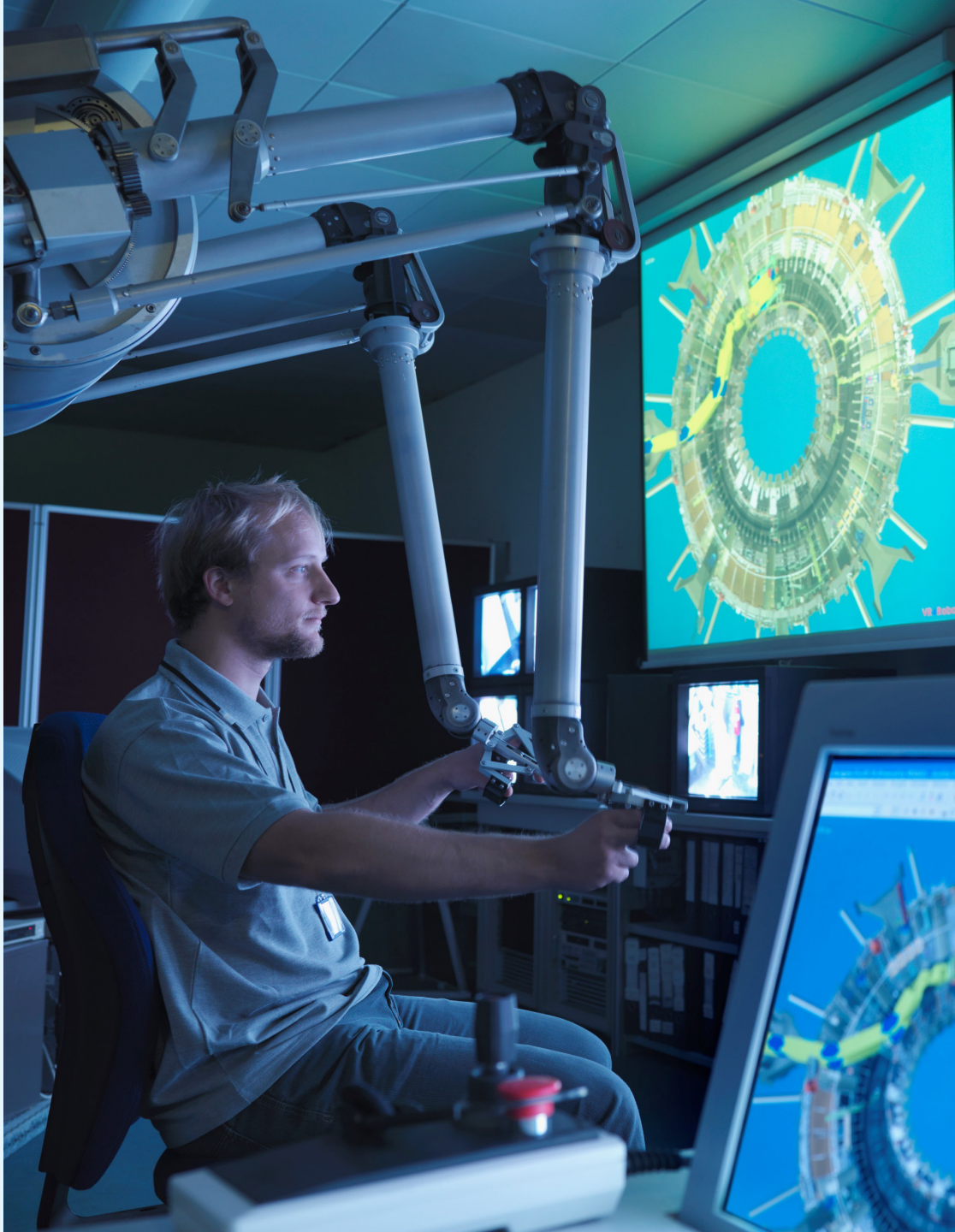

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