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Regional Technology-Based Economic Development: Policies and Impacts in the U.S. and Other Economies

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Regional Technology-Based Economic Development: Policies and Impacts in the U.S. and Other Economies

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ABSTRACT

The complexity of new technologies is forcing economies to (1) address an increasing scale and especially scope of the research and development (R&D) required to develop them, (2) capture the co-location synergies inherent in multidisciplinary and capital-intensive research processes, and (3) provide greater support for production scale-up and other commercialization investments needed to penetrate global markets. These policy imperatives are driving a regional focus for technology-based economic development (TBED) strategies in order to focus investments in technology, facilities, hardware and software, labor skills, and supporting technical infrastructures and thereby achieve both the economies of scale and scope needed to compete with increasingly aggressive national programs across the industrialized world.

A critical characteristic of these regional TBED strategies is an elaborate technical and economic infrastructure, including research consortia based around major universities, technology incubators and accelerators to support startups and

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entrepreneurs, community college curricula focused on training laboratory and manufacturing technicians, and ample supplies of risk capital at each phase of a technology's development. Investment in such regional ecosystems is shown to produce significant economic benefits in the form of higher profits and substantially higher worker incomes.

To design and manage these strategies, a "technology element" framework is presented to illustrate the range of policy instruments used by governments to promote growth over a technology's development cycle. This approach shows policy makers where in the TBED life cycle different policy instruments should be applied and how to assess the results. A comprehensive index of these high-tech inputs is applied to indicate the economic impacts.

The major policy tools are described in terms of (1) their economic rationales (i.e., the market failures that require their use); and, (2) the specific elements of each policy mechanism and how they are intended to remediate targeted underinvestment gaps at various phases of a technology's development.

Examples of state government implementations of TBED policy mechanisms are presented to indicate the various ways they can be constructed and integrated into a regional TBED ecosystem. In the last part of the monograph, the evolution and impacts of regional TBED policies in other industrialized nations are described and compared with U.S. experiences.

The analysis finds a wide variation in overall levels and scope of investment in TBED across states and significant differences in the structure and integration of individual policy instruments, emphasizing the need for a systematic, consensus policy framework.

The major policy messages are (1) regional TBED is becoming the main driver of economic growth in industrialized nations, (2) most nations are expanding their TBED investments, and, (3) the U.S. economy lacks a comprehensive national strategy implemented through an institutionalized TBED policy infrastructure, which is placing too great a burden on individual state programs. Learning, achieving scale and scope effects, and simply increased investment need national government support.

1

The Need for a Regional Technology-Based Growth Policy

Economic growth policies focused on the development and commercialization of technology have expanded rapidly across the global economy in recent decades in response to the ability of technology to deliver globally competitive products and services and thereby higher rates of economic growth, including higher incomes for domestic workers.

This monograph describes the economic rationales, policy elements, implementation mechanisms, and expected economic impacts of strategies that are being pursued in almost all 50 states within the U.S. economy. The specific policy tools and integration strategies are still evolving, so a definitive single model is not available. Thus, the following discussion will focus on alternative forms and implementations of major mechanisms and general strategies for integrating them into a viable technology-based economic development (TBED) ecosystem.

Once the dominant leader in the development and commercialization of technology, the United States has failed to respond to this globalization trend with comprehensive TBED strategies. At the national level, a substantive "innovation policy" infrastructure does not exist. This situation has left state governments with the daunting task of constructing and implementing their own TBED strategies. Such efforts are rapidly expanding, but with uneven results due to the difficulty in developing and managing the set of instruments comprising the required policy ecosystem.

The remainder of Chapter 1 assesses the economic trends that provide the rationales for the range of policy initiatives occurring at the state level. In Chapter 2, individual policy mechanisms and options for their integration into a holistic TBED ecosystem are described and critiqued. Examples of individual state policies are used to illustrate the relative efficacy of variants of generic policy instruments and how they are integrated into the target ecosystem. The analysis is based on a technology element model (TEM), which rationalizes and characterizes specific policy mechanisms, their interactions and sequencing, and their target impacts.

Chapter 3 describes similar TBED investment efforts in European and Asian economies. Distinct differences in the structure of and relative emphasis on individual policy tools are analyzed relative to U.S. trends. Of particular note is the relatively greater reliance on national level support and direction for individual regional efforts.

1.1 The Economic Rationales for a TBED Strategy

Beginning with the Second Industrial Revolution in the late 1800s and early 1900s, the U.S. economy grew to become the world's leader by doing the one thing that drives long-term increases in incomes: investing in productivity growth. This investment had four major components:

(1) *Technology*: The core driver of long-term productivity growth.

(2) *"Fixed" capital*: Hardware and software that embody most new technology and, thereby, enable its productive use.

(3) *Human capital*: Skilled labor capable of designing and using the new hardware and software and associated techniques.

(4) *Technical and institutional infrastructure*: Public-private infrastructure to leverage the development and use of modern complex technology systems.

Sustained investment in these four categories of economic assets has yielded

- *New products, services, and processes*, which (1) raise the standard of living and (2) enable achievement of social objectives (defense, health, environmental quality, etc.).
- An *economic return on R&D four times the return on investment in physical capital* (Jones and Williams, 1998, 2000).
- *Incomes for high-tech workers that are 70 percent above the average for all industrial workers* (Jones, 2014).

Today, however, globalization demands even more investment in order to raise productivity growth at the higher rates required for domestic industries to outperform a growing number of global competitors. This investment must be targeted at the above four categories of economic assets: technology, hardware and software, skilled workers, and modern economic and technical infrastructures. Extremely important is that the nature of this investment requires effective cooperation between government and industry to respond to its combined public and private character.

The failure to face up to globalization, especially once its scope and hence impacts began to accelerate in the 1980s, has caused large numbers of U.S. workers, especially the lower middle class, to suffer minimal growth in their real incomes. More specifically, as the world's economies upgraded the skills of their workers and invested in productivity enhancing technologies, a relentless global labor arbitrage ensued. The resulting "offshoring" of investment (and hence jobs) and the simultaneous increase in the amount and diversity of imports forced remaining domestic workers to accept stagnant or even declining real incomes to keep the remaining jobs.

The poor domestic income performance has been caused by inadequate investment in the four asset categories. The direct result has been weak productivity growth. Since the Great Recession, labor productivity has grown at one-half the average annual rate for the first 25 years after

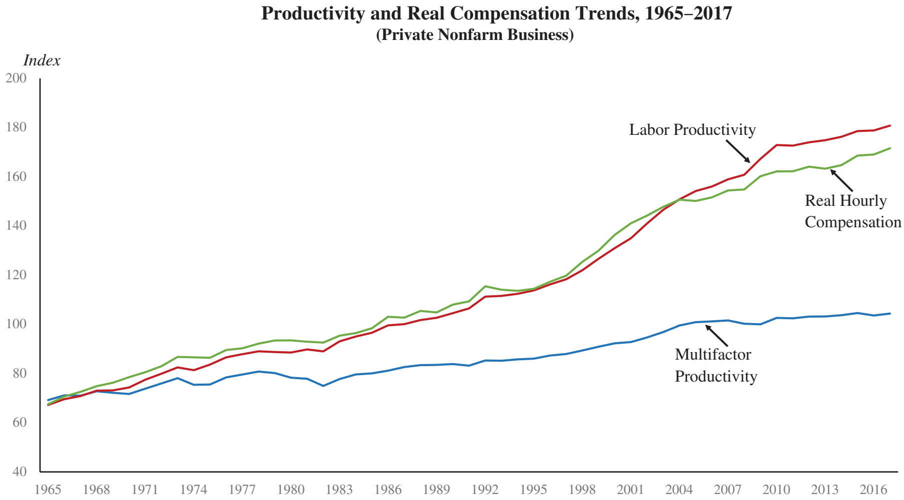

Figure 1.1: Labor productivity, multifactor productivity, and real hourly compensation.
Source: Bureau of Labor Statistics., Office of Productivity and Technology. Data normalized and converted to natural logs.

World War II. The unfortunate consequence has been wage and income stagnation, and hence little growth in the standard of living.

While most economic policy discussions have been focused on the decade of recovery from the 2008 "Great Recession," more telling is the fact that real incomes were declining well before the recession. Bureau of Census data show that real median household income—the major metric for assessing growth in the standard of living—was only marginally higher (2.4 percent) in 2017 than in 2000.[1]

Important for future trends is the fact that labor compensation stopped growing at the pace of labor productivity growth about a decade ago, as globalization reduced domestic labor's bargaining power, as indicated in Figure 1.1. Note also that MFP is a more comprehensive measure of productivity, as it reflects the combined impact on profits of capital and labor. Because multifactor productivity therefore drives

[1]Bureau of Census Historical Income Tables: Households (https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-income-households.html).

corporate profits, companies will only pay labor for its contribution to MFP. The implication is that a more holistic investment strategy is needed to raise domestic corporate productivity.[2]

The U.S. economy once had an investment strategy through which increases in both labor and capital productivity were achieved. Government funding of the early phases of new technology development spawned virtually every major technology driving the U.S. economy in the post-World War II era and U.S. labor out-skilled the rest of the world. U.S. companies, with little foreign competition, were willing to invest over the longer periods of time necessary to bring new technologies to market, which raised productivity and hence workers' incomes.

In recent decades, U.S. national innovation policy has not adapted to growth in global competition (Tassey, 2007, 2018). Whereas a growing number of the world's economies have adopted aggressive and comprehensive TBED strategies, the U.S. Government continues to rely on a mission-oriented national R&D strategy. Approximately 90 percent of the Federal R&D budget still goes to developing technologies for specific social objectives, such as national defense, health, clean energy, space exploration, education, etc.

While such spending stimulates technology-based economic activity in industry, which, in turn, stimulates the employment of highly skilled and hence highly paid workers, many of the technology development portfolios supported by federal spending are suboptimal from an economic growth perspective. When the U.S. economy had little competition from other economies, this strategy "worked" in the sense that the "technology platforms" developed with government funding to serve as the basis for mission-oriented applications were eventually

[2]Specifically, if a company invests in more productive equipment (more embodied technology), measured labor productivity will increase even if labor's skill level is unchanged. Corporations will not pay for this artificial increase in measured labor productivity. On the other hand, if labor's skill level is increased, then its intrinsic productivity increases and it makes a contribution to MFP. Corporations will pay for such an increase. The separation over the last 10 years of the LP and RHC lines in Figure 1.1 may be a reflection of this relationship.

expanded/adapted and then applied to the development of innovations with commercial market objectives.[3]

However, the indirect path to broad and larger commercial markets was slow and uneven. Today, the U.S. economy faces rapidly growing competition from the rest of the world, which is developing TBED policies and infrastructures focused on economic growth. In fact, even with a more economic growth-oriented strategy, U.S. investment indicators are weak. Specifically,

- U.S. R&D intensity is static (unchanged in the past decade and well below competitors such as Germany, Japan and South Korea, while China's R&D intensity has grown 38 percent in this period).
- Domestic corporations persistently cite critical skill shortages.
- Corporate investment in hardware and software has declined relative to GDP.
- Technical infrastructure is inadequate and inflexible.

For societies that wish to create not only jobs but raise the incomes of workers, a technology-oriented economic growth strategy is the only approach, as evidenced by the much higher return on investment in technology and higher worker incomes.

With respect to the TBED policy target, Katz and Muro (2014) summarize the economic impacts from promoting "advanced industries" as follows:

> Advanced industries are manufacturers, energy providers and service firms that are fueled by research and driven by science, technology, engineering and mathematics (STEM). They punch way above their economic weight, making up only 9 percent of our country's workforce but generating nearly 18 percent of our GDP, 58 percent of our exports, 81 percent of our patents and 90 percent of our private research

[3] The U.S. Government not only funded much of new technology development for several decades after WWII, but it also actively promoted its diffusion and commercialization through its procurement practices (Holbrook, 1995).

> and development. What's more, according to Moody's data, advanced-industry workers earn an average of $90,000 per year compared to $47,000 for our economy as a whole.

This significant difference in economic impact should clearly focus economic growth strategies on technology as the core investment policy. However, only 13 percent of the U.S. workforce is classified as being in the "science, technology, engineering, or math (STEM)" category, which clearly indicates that the current U.S. economic growth strategy is inadequately focused on the technology-productivity-growth nexus (Tassey, 2018).

The most common metric for assessing a nation's commitment to competing on the basis of productivity-enhancing technology is its spending on R&D. In this regard, although experiencing a steadily declining share of global R&D, the U.S. economy still spends about 25 percent of the world's total. While substantial, it means that for every dollar spent on R&D within the U.S. economy, three dollars are being spent elsewhere in the world. Moreover, NSF data show that federal R&D spending—critical because a major portion is spent on breakthrough research that drives the development of new technology platforms and potentially new industries and future high-paying jobs—has declined as a share of GDP by 41 percent over the past 40 years.[4]

Moreover, as this monograph discusses in detail, R&D spending is only a summary indicator of an economy's commitment to compete on the basis of technology. A large number of more specific investment strategies and a variety of institutional support mechanisms are needed as part of a TBED strategy that emphasizes efficiency in all TBED areas:

(1) Public-private R&D funding and coordinated spending and conduct strategies.

(2) R&D infrastructure support (advanced materials data bases, research methods, process control techniques, etc.).

(3) Provision of skilled labor in all STEM categories.

[4] https://www.aaas.org/page/historical-rd-data.

(4) Public assistance for starting high-tech firms and using technology transfer mechanisms to acquire available technology.

(5) Scale-up support for new production configurations.

(6) Market entry and penetration assistance.

In constructing a national TBED strategy to respond to rapidly growing global competition, the scale and scope dimensions of such a strategy are particularly important. Minimum scale is critical because the range of R&D, capital investment, and technical and financial infrastructures all have their own minimum threshold and conduct requirements for achieving economic efficiency.

For example, early-phase technology development (so-called “proof-of-concept” or “technology platform” research) is broad in scope and requires diverse research skills and facilities. This fact plus the long projected times to commercialization combine to impose high technical and market risk, which causes substantial underinvestment in the early phases of R&D. This leads to the need for research consortia embedded in broader innovation clusters, which can combine research assets from multiple private and public sources and thereby achieve research efficiency while pooling risk.

As another example, venture capital (VC) is only relatively plentiful in large state TBED ecosystems, where venture capitalists can achieve larger investment portfolios and hence diversify risk. Further, the average expected rate of return is higher due to the economies of scale and scope inherent in larger TBED ecosystems. Also, when such investments mature, it is easier for VC firms to “exit” the investment in a large, diversified ecosystem where the population of potential corporate acquirers is large.

Furthermore, R&D is increasingly being pushed backward from system integrators (OEMs) at the ends of high-tech supply chains to component and even advanced materials suppliers due to the relentlessly growing complexity and science dependency of modern technologies. This means that co-location synergies are becoming increasingly important among the tiers of high-tech supply chains, and therefore larger, more diverse "innovation clusters" are desirable (Silicon Valley and the Route 128 corridor around Boston are the original examples).

To maximize TBED and the resulting economic benefits, the categories of policy targets listed above must be designed and managed in response not only to specific areas of underinvestment but also by taking into account the fact that technologies are created, commercialized, and eventually obsoleted as new ones replace them. This dynamic "technology life cycle" dimension of TBED policies is a critical factor in maintaining long-term domestic competitiveness and thereby income growth (Tassey, 2013).

However, proper management of the time dimension is frequently poorly handled by policymakers. For example, a recent trend retarding the needed transition to a comprehensive economic growth policy is the fact that national policy discussions over the past decade (the post-recession period) have fixated on the slowness of the recovery—with little attention to the longer-term structural weaknesses that have progressively constrained the growth rate of the domestic economy. That is, slow growth has been treated almost entirely as a business-cycle stabilization problem (Tassey, 2018).

In summary, the above indicators show that the rate of U.S. economic growth has been slowing for decades, including growth in real incomes. The culprit is globalization, which has created a growing number of technology-based competitors around the world who are increasingly capable of taking shares of high valued-added markets at the expense of U.S. domestic industries.

1.2 TBED in the Context of Current Economic Growth Strategy

To place the expanding role of TBED strategies in its proper economic growth context, it is important to note that, instead of increasing productivity-enhancing investments in technology and innovation, national policy makers have relied almost exclusively on a monetary policy-driven strategy of low interest rates and the demand-stimulation dimension of fiscal policy. In the 2000s, cheap credit led to more excessive borrowing in a desperate attempt to compensate for the lack of investment in the economic assets that drive real income growth. The

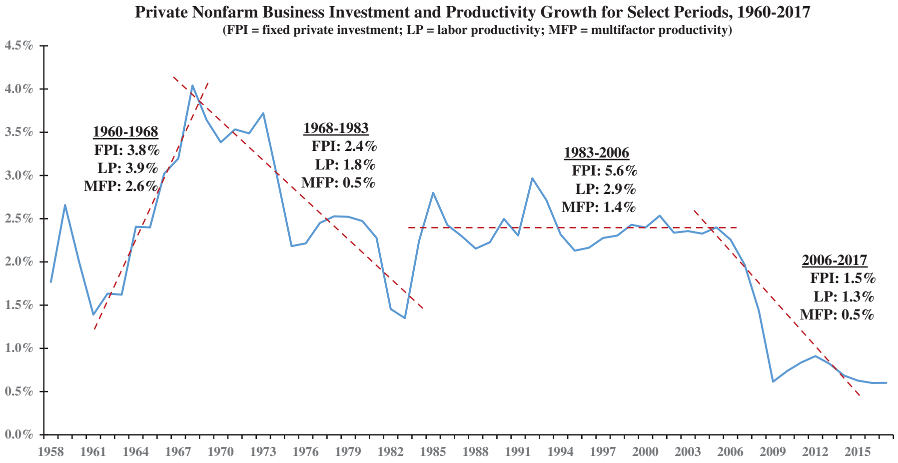

Figure 1.2: Average annual real GDP growth for 10-year periods, 1960–2015. *Source*: Bureau of Economic Analysis for GDP data; Bureau for Labor Statistics for Productivity data.

result was real estate and stock market speculation, and eventually the worst recession since the Great Depression.

The long-term growth problem resulting from inadequate investment is shown dramatically in Figure 1.2. Fixed private investment (FPI), largely hardware and software, is the means by which new technologies are introduced into an economy and thereby have their productivity impacts. In the 1960s, FPI was quite high and, as a result, both labor productivity and multifactor productivity grew at a healthy annual rates.

But, in the following 15-year period (1968–1983), global economic upheavals discouraged domestic investment and the rates of productivity growth declined dramatically. A modest policy response occurred in the subsequent two decades (1983–2006), as years of R&D targeting information technology (IT) paid off in the form of increased productivity growth. IT investment was particularly strong in the late 1990s. Unfortunately, there was no significant follow-on in terms of investment in additional technologies and, with globalization increasing, U.S. investment and productivity growth collapsed (2006–2017).

Indicative of restrained U.S. growth is the fact that domestic FPI in physical assets is too low, and survey after survey of industry managers show that our supply of skilled labor is inadequate. U.S. Government research institutions and R&D budgets are still oriented largely toward a set of social objectives such as defense and public health that only indirectly leverage economic growth. At the same time, other economies are focusing to a greater degree on optimizing their R&D investments to maximize the growth of their domestic economies.

For the first 30 years after World War II (1948–1978), when the United States was the dominant technology-driven and thus the high-productivity economy, the average annual real growth rate of GDP was 3.9 percent.[5] During the next 30 years, the growth rate dropped to 3.0 percent, as the effects of globalization began to be felt. Since the 2008 recession, real economic growth has averaged 2.1 percent, and the Federal Reserve forecasts the average growth rate to remain at around 2 percent for the foreseeable future.[6] Thus, the U.S. economy is expanding at half its post-WWII pace.

The lack of a substantive and comprehensive U.S. innovation policy derives from two factors:

(1) The U.S. tradition of a laissez-faire approach to developing commercial applications of technologies, which asserts that market opportunity is sufficient to entice risk taking and thus lead to the commercialization of innovative products and services.

(2) Change is simply difficult. Older industries, without the tradition or capability to change, can only survive globalization through protection from government through trade barriers, corporate income tax cuts, and deregulation.

This first of these—a simplistic market sufficiency philosophy–was not as serious a problem in the absence of significant foreign competition. The U.S. economy has had a strong tradition of entrepreneurial activity, which encouraged risk taking. Coupled with plentiful VC, the U.S.

[5]Bureau of Economic Analysis (https://apps.bea.gov/itable/db_message.cfm?ReqID=9&step=1#reqid=9&step=1&isuri=1&904=2014&903=1&906=a&905=2016&910=x&911=0).

[6]Federal Open Market Committee (https://www.federalreserve.gov/monetarypolicy/fomcprojtabl20161214.htm).

economy experienced substantial innovation and subsequent technology-based growth.

The resulting new industries slowly took up the economic growth slack. Maintaining an acceptable rate of growth was further supported by a U.S. educational system that produced a consistently strong pool of skilled workers, including large numbers of immigrants from around the world who contributed significantly to the U.S. advantage in both skilled workers and entrepreneurs. Adaptation time was not a serious concern.

Today, not only is adaptation a more pressing problem, but investment behavior has turned more risk adverse. Instead of emphasizing investment to accelerate productivity growth, the Federal Government responded to the 2008 recession with aggressive monetary policies that resulted in the Federal Reserve balance sheet growing from $800 billion in 2008 to $4.5 trillion by 2014.

The critical point is that monetary policies are business cycle stabilization tools, which are useful only in addressing short-term disruptions along a long-term economic growth track. The prolonged cheap credit found its way into financial markets, which mostly benefited wealthy individuals, while providing no incentives to companies to make long-term investments in research and innovation.

So, the message is clear: invest in the right technologies, hardware and software, labor skills, and advanced infrastructure to raise productivity or fail to compete. Competing through productivity growth is the only way to increase market shares and both the number of jobs and workers' incomes over time. Unfortunately, U.S. policy makers at the national level have not gotten the message. Neither political party has a productivity-oriented growth strategy, so the default growth policy has been to hide from global competition (Tassey, 2018).

Most worrisome is the fact that increasing exports relative to imports is not a trivial challenge, as evidenced by the fact that the U.S. hasn't had a trade surplus in manufacturing since 1975, and even the high-tech portion is now running a deficit. The bottom line is that in a modern, technology-driven global economy, governments compete against each other as much as do domestic industries. And, they compete by providing a range of incentives to invest in economic assets that drive productivity growth and thereby increase competitiveness. Currently inadequate attention is being given at the national level to the imperative to invest in the four categories of competitive economic assets identified in this section.[7]

This situation, coupled with the nature of technology-based growth is causing a major shift in the design and management of technology-based growth strategies from a national to a regional/state level. This trend, which is worldwide, is driven by two factors: (1) regional specialization allows the efficient establishment of unique competitive positions; and (2) both the scale and scope of the set of required investments in modern technologies is such that a regional focus is feasible.

This does not mean that no role exists for national governments due to the fact that: (1) the underlying science for modern technologies is typically broader than the average specific regional focus; and (2) substantial cross fertilization exists with respect to the development of TBED strategies and management approaches. A national government therefore can be instrumental in the early stages of TBED ecosystem evolution by funding scientific research and by subsidizing start-up TBED costs. As discussed in Chapter 3, most nations understand this imperative for a government management hierarchy with respect to TBED policy.

1.3 The Emergence of Regional TBED

Within any regional economy, establishing, improving, and effectively using TBED policies is a challenging task. Different policies affect different phases of a technology's development and its commercial applications. The public-good content of TBED economic activity varies significantly both in nature and amount over a technology's life cycle.

The dynamic and public-private character of modern technologies means that TBED policies must be constructed for a range of private-sector underinvestment behaviors that change in level and character at

[7] On exception is the U.S. Government Accountability Office, which issued a 2018 report stating that "the extent to which the United States is able to focus R&D investment in key technology areas will be a key factor in U.S. competitiveness in the global economy." See https://www.gao.gov/products/GAO-18-396SP.

each phase of the technology's life cycle. Thus, the application of each policy instrument must be adjusted over time in response to industry's needs as the evolution of the targeted technology proceeds.

Modern technologies are increasingly complex systems. This complexity has eliminated or at least reduced the existence of the single dominant high-tech firm. Thus, companies such as IBM, Xerox, Kodak, and AT&T that once dominated their respective industries, in that they developed both system components and the final product or service system themselves, have been replaced by supply chains of R&D-intensive firms, where each tier in a supply chain specializes in the creation, production, and marketing of advanced materials, specific classes of innovative high-tech components, and finally their integration into the final product or service systems.

While this evolutionary change and complexity complicates regional government targeting of companies whose location within their economies would be desirable, it also offers the opportunity to expand the set of resident industries, which increases potential value added within the regional economy and also diversifies the risk of individual firms leaving the local cluster.

The critical economic message for regional governments is that local TBED infrastructure affects the productivity of the entire technology-based economic process from technology development through production scale-up and initial commercialization to full-scale production and market development. The last stage is where the majority of economic benefits are delivered, but the efficiency of the preceding two stages determines the amount, quality, and speed of delivery of these benefits. This fact underscores the importance of timely provision of technical and financial infrastructure support over a technology's entire life cycle.

With respect to the scope of economic activity targeted, the technology-based economic asset categories cited above are the building blocks for four areas of capabilities that constitute the substance of state/regional TBED programs:[8]

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[8]See "What is a TBED?" by the State Science and Technology Institute (SSTI), for an alternative taxonomy (https://ssti.org/TBED).

(1) *Emerging Technology Research Capacity*. The facilities, skilled labor, funding, and integrative research infrastructure required to conduct early-phase proof-of-concept technology research by universities, federal labs, and the private sector in a cooperative setting, implemented through institutional mechanisms alternatively referred to as university-industry partnerships, innovation "hubs", and "manufacturing innovation institutes."

(2) *Innovation and Commercialization Capability*. The set of physical, human, and institutional assets that

   a) support the application of new technology platforms to create applied technologies and products with high commercial potential,
   b) leverage small-firm formation and growth,
   c) assist implementation of commercialization strategies by supporting pilot-scale production and scalability testing, and
   d) enable high efficiency of full-scale production market penetration.

(3) *Government/Industry Infrastructures*. Public support for

   a) increased capacity of entrepreneurs to successfully start and grow companies by improving the effectiveness of entrepreneurial training and opportunities to participate in emerging industries through orientation of business school curricula, accelerators/incubators, and provision of technical infrastructure (standards) to facilitate entry into high-tech supply chains,
   b) provision of access to scientific and engineering databases, high-speed Internet, and other local communication and computing infrastructures,
   c) increased investment in education through focused training facilities and curricula facilitated by co-location of universities, community colleges, and online learning centers that encourage more students to enter STEM fields by providing internship

programs and technical training for workers in existing companies and train entrepreneurs in the skills needed to manage young, high-tech companies.

(4) *Access to Risk Capital.* Increased availability of capital to support startup and emerging companies through angel investor tax credits, direct funding of technology-based companies through programs such as Small Business Innovation Research (SBIR), and assistance to companies trying to access private VC.

In Chapter 2, the policy mechanisms for creating and effectively implementing these TBED capabilities will be described in terms of (1) their economic rationales (i.e., the market failures that rationalize various policy responses); (2) the specific elements of each policy mechanism and how they are intended to remediate targeted underinvestment gaps; and (3) projected economic impacts predicted by existing studies and policy assessments.

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