Yaroslavl Roadmap 10-15-20

10 Years to Implement
15 Steps to Take
20 Pitfalls to Avoid

International Experience and the Path Forward for Russian Innovation Policy
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The New York Academy of Sciences presents the Yaroslavl Roadmap 10-15-20 as a contribution to the historic transformation that Russia is undertaking under the leadership of President Medvedev.

The Yaroslavl Roadmap 10-15-20 takes as its timeframe the ten-year period up to 2020 in accord with Russia’s own planning horizon. Ten years for accomplishing the transition to an innovative economy is actually quite short. A recent study prepared by RUSNANO put the time frame for achieving sustainable innovative development at twenty-five years for the United States of America and Taiwan Province, China, twenty years for Israel and ten years for Singapore and Finland. By these standards, if Russia achieves this status by 2020, it would be a relatively rapid transition and one that will require both perseverance and patience.

The Yaroslavl Roadmap 10-15-20 is an overview and summary of the historical experience of innovation policy in five locales – Israel, Finland, Taiwan Province, China, India, and the United States of America. It then summarizes the current state of the innovation economy in Russia and makes fifteen specific recommendations for Russia based on comparing international experience with the current state of the Russian innovation economy and President Medvedev’s priorities. It also highlights twenty pitfalls for Russia to avoid.

The New York Academy of Sciences sincerely believes that by implementing the recommendations contained in the Yaroslavl Roadmap and avoiding the pitfalls, the road to an innovation economy will be shortened. At the same time, it accepts that these recommendations are not an exclusive list and there may be other possible steps to take. Therefore, these recommendations are meant to be indicative and subject to further refinement.

In preparing the report, work which began on May 24th and finished on August 18th, 2010, the New York Academy of Sciences carefully limited its scope to focus on innovation. The New York Academy of Sciences recognizes that there is a parallel process of modernization of Russian society that is also a focus of Russian government policy. The New York Academy of Sciences understands the importance of creating modern and transparent institutions, establishing an effective legal system and developing democratic procedures; however, this was not the topic of the Yaroslavl Roadmap 10-15-20. Those issues can and should be addressed separately.

It is important to state that the pursuit of innovation does not imply that every aspect of the existing Russian economy is obsolete. Significant portions of Russia’s productive base should be preserved and strengthened as partners with new technology companies in a diversified and modernized economy. Russia does not need another period of destruction of the existing economic mechanism in pursuit of a new ideal future. The adoption of what might be technologically disruptive innovations should be a means of increasing the productivity of Russia and increasing the well-being of its people.

The achievement of an innovative, knowledge-based economy in Russia should be understood as an ongoing process, not an end in itself. It is a process that will assist in resolving Russia’s fundamental issues, while raising Russia into the leading ranks of countries contributing to overall human welfare and solution of global problems.
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While the current global economic crisis has left few corners of the world untouched, it has also highlighted the long-term resiliency and growth of a relatively small group of nations who have been able to differentiate themselves through leveraging a robust innovation system.

Economists have long sought answers to the question: Why do some places grow prosperous while others do not? Robert Solow won the Nobel Prize in 1987 for his work in addressing this question. He argued that while capital and labor supply were certainly important to economic growth, technological innovation was a significant factor that had to be included in the growth model. His work found that productivity—vis-à-vis technological innovation—was responsible for over half of the gains in U.S. economic growth.1,2

Building on Solow’s work, a new generation of economists are helping us understand the roles of education, research and development, technology, entrepreneurship, and—most recently—public policy and programs in helping nations achieve national and regional prosperity. Supplemented by studies of leadership, product development, and success within and among companies, these elements comprise what many experts call the National Innovation System.3 There is a commonly understood definition of a national innovation system, but nowhere is there an official formalized legislative definition.

An innovation-centric view of economic growth does not suggest that the roles of fiscal policy, rules of law, compulsory education, human rights, and regulatory burden are any less important. Quite the opposite, these elements are critical foundational elements for economic growth that are also intimately linked to innovative capacity. For example, international entrepreneurship rates have been linked to tax burden, bankruptcy laws, and regulatory burden, as well as other cultural factors.

Given this foundation and an increasingly global, interconnected world, nations and regions face both substantial hurdles and increasing opportunities for success. Looking ahead, as the world plans for its

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next phase of growth after this downturn, innovation will continue to play an important role as nations seek competitive advantages globally. Certainly the international development literature is full of stories that explore why certain states or regions fail and the role of public policy therein. This report attempts to explore the role of public policy in a few, exceedingly successful nations and regions, especially in relation to innovation. We will also suggest policy measures that can or, perhaps more importantly, cannot be applied to Russia.

**Innovation System**

For those nations that strive to foster innovation, unfortunately, there is not a “one size fits all” solution, but each nation needs to adapt an innovations system that is unique and that specifically leverages its indigenous strengths.

In the simplest context, innovation systems can be described as starting with inputs that, if effectively utilized, can lead to economic outputs in the form of innovation, productivity, and prosperity (Figure 1). The challenge for policymakers is to institute a structure that facilitates that utilization.

These inputs can be grouped into three broad categories: assets, networks, and culture. Assets include many of the most widely recognized economic strengths, such as human and financial capital, research and development institutions, and an industrial base. Also grouped with assets are electronic and physical infrastructures (online resources, transportation, etc.) that meet modern business needs, a legal and regulatory environment that promotes enterprise and flexibility, and a quality of life desirable to employees, helping to attract and retain the necessary human capital.

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4 See, for example, Bill Easterly, *The Elusive Quest for Growth* (Cambridge, MA: MIT Press, 2002).

Introduction

Networks link the assets. Linking technologies to each other and to other components in the innovation system is as important as developing the individual technologies. This ensures that researchers are fully networked within the science and technology (S&T) community and also with other stakeholders, including venture capitalists. An effective structure should facilitate multidisciplinary initiatives through which industry can partner with academia and the hard sciences partner with the social sciences. Collaboration is also key within individual industries. Jointly conducted research, especially at the precompetitive stage, can fund projects that would be too expensive and high-risk for any institution to fund independently. The third subcategory, global networks, is growing in importance, with off-shore suppliers, markets, and fellow researchers increasingly central to innovation.

Creating a culture that fosters entrepreneurship and creativity is critical. Openness to diversity allows for contributions from all fields, and democratization facilitates new ideas from all levels, so that innovation will not get stifled in a hierarchy. Tolerance of failure is also a necessary element of the culture of entrepreneurship. Essentially, a healthy innovation culture minimizes the social, geographic, and bureaucratic barriers between researchers, entrepreneurs, and investors and creates a fertile atmosphere for the creation of new ideas.

In the end, fostering a productive innovation system that allows researchers in all fields to commercialize their technologies is just as important to achieving significant economic impact as developing strength in specific technology areas. The varieties of inputs from one global region to another preclude a universal innovation prescription, but much can be learned by how governments and other institutions have tried to maximize outputs with the inputs available.

Project Description

The Russian Federation is currently focused on developing a robust national innovation system. President Medvedev has declared that Russia will transform itself from being driven primarily by natural resource production into a knowledge-based economy. Modernization of the society as a whole will be accompanied by a thorough integration of cutting edge science and innovation into productive activity, fulfilling the human and intellectual potentials of the country and creating entirely new areas of world-class technology.

Governments not only provide critical funding but also can play a crucial convening role in creating networks that draw upon the science, technology, financial, entrepreneurial, and business leaders necessary to drive innovation.

The New York Academy of Sciences was requested by the Russian Federation to prepare a report outlining a set of recommendations aimed at fostering such innovation. This 12-week project was focused not on a detailed analysis but on thematic trends in how a subset of locales have successfully fostered innovation. The Academy was invited to complete this request because of its neutrality—it is not a national entity and serves neither sectoral nor disciplinary interests—and also its strength to access an international network of leaders and experts who can address science, technology, and innovation related issues and its proven history of synthesizing key information in a thoughtful way to communicate effectively with the target audience.

The report is meant to be a set of practical recommendations to be used by President Medvedev and his staff as they continue to develop innovation policy for Russia.
Report Methodology

In addition to Russia, Finland, the United States (U.S.), Israel, India, and Taiwan Province, China (Taiwan) were selected as the focus of the research conducted to generate the recommendations proposed in this report. These locales were chosen because they all embodied technologically driven innovation and economic growth from which lessons could be drawn. Additionally, they covered the spectrum of small to large countries/provinces in size and from emerging (BRIC) to more developed economies. This project commenced on May 24, and the report was completed on August 18. Given a longer project timeline, additional countries would have been considered, including China, Korea, Sweden, Singapore, Malaysia, and Brazil.

Background research was conducted using books, scholarly journals, periodicals, and white papers that were related to these five locales only. References are included throughout the report. It should be noted that a comprehensive literature review was not completed on each of these entities, given the timeline of this project.

In addition to the background research, a series of interviews were conducted with world-recognized business, academic, government, and innovation leaders. A list of those interviewed can be found in the Authors and Contributors section. We have not attributed specific examples to specific individuals unless the information is publicly available.

Based on the background research and the information gleaned from the interviews, the New York Academy of Sciences has compiled the set of recommendations presented here. These recommendations were compiled from a collective of lessons and cautions learned, drawn from the research on Israel, Finland, U.S., India, and Taiwan, which subsequently were applied to Russia, generating the final set of recommendations.

Report Layout

The report is organized in six primary chapters. Following this introduction, Chapters One through Six provide a historical overview and analysis of the innovation policies for Israel, Finland, U.S., India, Taiwan, and Russia, respectively. Each chapter begins with a macroeconomic view of the country or province as represented through its gross domestic product (GDP) and foreign direct investment (FDI) data, followed by a summary of key lessons, which are restated with more details specific to the country or province at the conclusion of the chapter. The paper concludes with an analysis of the key learnings from Israel, Finland, U.S., India, and Taiwan and closes with the specific application of these learnings to Russia in the form of a road map of recommendations to foster innovation.

Within each chapter, specific attention was given to three key areas that were identified as issues of interest for Russia. These areas were identified through early conversations with the Russian Government.

The first area is attracting and retaining S&T talent to build the human capital necessary to drive innovation. The second area is fostering entrepreneurship, establishing and growing new enterprises. This is a broad category that encompasses aspects such as creating entrepreneurial training, leveraging serial entrepreneurs as mentors, and linking S&T to market opportunities. The third and much-related area is gaining an understanding of developing markets. Critical for innovation is understanding the potential for opportunity recognition and market penetration. Policies to help identify and understand markets that leverage a region’s or country’s strengths and needs are a focus of this area of interest.

Although these were the three areas to which special attention was given as the research and interviews were being conducted, the recommendations are not limited to these areas. The research was driven by the existing innovation policies and systems in the specified countries/province.
Executive Summary

Israel was chosen for this analysis due to its rapid economic development since its establishment in 1948, its rapidly increasing rates of educational attainment and entrepreneurship, and its relative resilience during the recent global economic crisis. Israel has evolved to become one of the world’s most R&D-intensive countries and, despite its proximity to hostile neighbors, has developed a unique entrepreneurial and technology-driven culture. This chapter derives the following lessons (and cautionary lessons) learned from the project’s analysis of Israel.
## Israel’s National Innovation System at a Glance

### Key Institutional Elements

<table>
<thead>
<tr>
<th>Institution</th>
<th>Year established</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAFAEL</td>
<td>1948, by the national government under the Ministry of Defense</td>
<td>Develops weapons and military technology. RAFAEL is a former subdivision of the Israeli Defense Ministry and is considered a governmental firm.</td>
</tr>
<tr>
<td>Discount Investment Corporation (DIC)</td>
<td>1961, by the Recanati family, owner of the Israel Discount Bank</td>
<td>One of the most prominent holding and direct investment companies in Israel</td>
</tr>
<tr>
<td>Office of the Chief Scientist (OCS)</td>
<td>1968 by the national government, under the Ministry of Industry and Trade</td>
<td>Implements government policy for support of industrial research and development; provides competitive R&amp;D grants valued at approximately NIS 1.3 billion per year</td>
</tr>
<tr>
<td>Bi-national Industrial Research and Development Foundation (BIRD)</td>
<td>1976, by the U.S. and Israeli Governments</td>
<td>Funds joint U.S.-Israeli teams in the development and commercialization of nondefense products. BIRD derives its primary income from interest on a $110 million fund created by the U.S. and Israel governments. Additional funds come from repayment income from companies participating in successful BIRD-funded projects.</td>
</tr>
<tr>
<td>Technology Incubators Program</td>
<td>1990, by the OCS</td>
<td>Supports entrepreneurs in developing innovative technologies and setting up companies to commercialize them</td>
</tr>
<tr>
<td>Yozma</td>
<td>1993, by the OCS</td>
<td>Spurs and supports the Israeli VC market; since inception the group has managed more than $170 million in its two funds</td>
</tr>
<tr>
<td>MAGNET</td>
<td>1992, by the national government, under the OCS</td>
<td>A precompetitive R&amp;D program designed to solve common technology problems among small companies, to better utilize academic R&amp;D, and to disseminate the results; when it was established, MAGNET initially covered a significant portion of the cost for the academic partner, up to 66%, with the industrial partner(s) covering the balance; funds are provided as grants, and no repayment is needed</td>
</tr>
<tr>
<td>Yozma II</td>
<td>1998, by Yozma</td>
<td>Continues Yozma’s strategy of making direct investments in technology companies and adds value by recruiting senior managers, formulating business strategies, raising additional capital rounds, and attracting investors</td>
</tr>
</tbody>
</table>

### R&D Tax Incentives

Currently, expenses related to an R&D project approved by the Israeli government can be deducted in whole for that tax year, up to a specified ceiling (which is usually 40% expenses). Qualifying projects must have a goal of making advancements in industry, agriculture, transportation, or energy.
Israel Gross Domestic Product (Current US Dollars, Not Adjusted for Inflation)
Source: World Bank, World Development Indicators - Last updated June 15, 2010

Israel Foreign Direct Investment (Balance of Payments in US Dollars)
Source: World Bank, World Development Indicators - Last updated June 15, 2010
Lessons learned:

- Ever-present security threats and grand challenges can provide a powerful motivation for the development of world-class S&T capabilities.

- S&T education and accessible human and financial support systems provide important seeds for entrepreneurship and future technology development. In particular, BIRD played a crucial role in brokering the technology of large (mostly U.S.) multinational information and communications technology (ICT) companies with small Israeli high-tech companies. Well-run public-private partnerships can help domestic companies connect with international markets, companies, and funders.

- An understanding of global markets, especially the technology needs of large, technology-oriented corporations, can help small, domestic companies tailor their own technology development efforts. Furthermore, the presence of a well-educated, interconnected Israeli Diaspora abroad, especially within the U.S., has played a critical role in global markets. When the Diaspora began to return to Israel, it was for reasons of economic opportunity and national pride; no formal public incentives were offered.

- Israel did not attempt to reform existing R&D institutions but instead created new policies and programs during several progressive iterations.

- OCS played a critical role in the coordination and mission orientation of Israel’s S&T-oriented economic development policy. During its initial creation, it faced inept leadership and the inefficiencies of small grants. However, strong leadership from a strong, experienced MIT graduate with an international network helped imbue OCS with a flexible, responsive culture dedicated to the interests of industry. Although strong leadership was initially important, this later led to conflict of interest problems and personality dependence.

- While venture capitalists are an important source for high-tech entrepreneurship funding, at least as valuable is their guidance in management, operations, and services for entrepreneurs.

Cautionary lessons learned:

- Nurturing one sector can result in a large disparity in the economy, which then can translate to socio-economic issues.

- Focusing too much on R&D and technology capabilities for new VC (VC) creation while “neglecting” the management and marketing of small start-ups can over time inhibit the long-term growth potential and sustainability of new firms.

- Providing capital only for early-stage and not for long-term growth and expansion of businesses is problematic. It is important to foster the development of mature businesses as well.
Early Beginnings

Much of the economic development history of Israel can be traced back to the formulation and realization of the modern Jewish state. In the late 19th and early 20th centuries, British-controlled Palestine attracted Jewish settlers and immigrants fleeing persecution in Europe and elsewhere in the world to settle the barren, arid lands. While these settlers were from different places, many of them were doctors, scientists, engineers, and academics, and they brought with them an appreciation for education that was evident in the establishment of rigorous postsecondary schools, such as the Weizmann Institute, founded in 1934. When Israel was established in 1948 by the United Nations, the surrounding Arab nations refused to recognize the legitimacy of the decision and declared war shortly thereafter. Education, immigration, and responses to this existential threat—infused with resilience and ambition—provided the context and foundation for Israel’s innovation economy.

Early in its history, the Israeli government pursued an interventionist and protectionist economic policy that emphasized military security, economic stability, and the continuing assimilation of immigrants. Israel initially committed to a policy of full employment for stability purposes and was largely perceived as a “socialist” nation. As we will see, the Israeli government indeed played an important role in the evolution of the economy, for example, by creating policies to promote development of the textile industry. However, less well known is the strong commitment of political leaders to develop a private firm-based economy, an important contextual consideration underpinning the defense-related development of technology in the 1960s.

Israelis credit Charles de Gaulle, President of France from 1959 to 1969, with the establishment of the Israeli armament industry and de facto emergence of the Israeli high-tech sector. Early in its history, Israel’s closest ally was France. Israel not only bought large weapons platforms (i.e., tanks, ships, aircraft) from France, but also teams of French and Israeli engineers conducted joint R&D to modify, customize, and at times advance French weapons systems for Israel’s use and security. However, in 1967, on the eve of the Seven Day War in June, France allied itself with the Arab world and declared an immediate military embargo of Israel. The decision resulted in Israel’s inability to procure critical off-the-shelf weapons systems internationally.6

While Israelis felt “betrayed,” the actions of France became one of Israel’s pivotal motivations for development. Faced with an inherent lack of technological capability and impending military insecurity, Israel immediately invested enormous amounts of R&D in order to build its own high-technology defense industry and to “never again” have to rely upon a foreign power for its weapons platforms. The focus of R&D was shifted from specific applications to the overall development of larger platforms and systems. These investments also created significant demand for well-trained scientists and engineers, boosting wages in the process.

While Israel did have several civilian research centers (discussed below), these did not meet the emerging defense technology needs of the country. In response, the Israeli government created RAFAEL (the Hebrew abbreviation for Armament Development Authority), an applied academic institution dedicated to the development high-technology systems and their underlying technologies. RAFAEL was established within the Ministry of Defense and, given the Ministry’s unique relationships with the Ministry of Industry and Trade and the Ministry of Finance, RAFAEL became a unique hybrid organization. RAFAEL was not only a place where scientists and engineers conducted advanced, technological research, but also it was accredited as an educational institution conducting training, granting degrees in engineering and applied sciences, and sponsoring graduate education in Israel and abroad. Furthermore,

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Early Beginnings

graduates had a unique scientific perspective, not only learning the fundamentals of their discipline but also learning how to translate this knowledge into systems, such as an analog computer, RAFAEL’s first large project in 1956. This cadre of technically trained researchers working with a clear, applied mission led RAFAEL to later become an incubator of small, high-technology companies. Furthermore, it created and spun off several related units, such as MAMRAM, Israel’s military computer unit, that were also infused with a culture conducive to spinning off high-tech start-ups.

The establishment and evolution of RAFAEL illustrate a recurring theme visible in Israel today: the relationship between government training, education, and applied R&D projects with the development of talented, entrepreneurial citizens. Several authors have attributed this trend to Israel’s compulsory military service, by which draftees are selectively placed in the Israel Defense Force (IDF) based on their capabilities, followed by intensive technological training, followed by reserve service until the age of 34. Furthermore, many Israelis return for short periods of government service to advise the government on technology development, entrepreneurship support, and economic development, often after establishing a company or working abroad.

In 1966, given the technology development successes it had enjoyed with RAFAEL and the relative lack of progress made with its civilian S&T infrastructure, the Israeli government created the Katchalski Committee. The Katchalski Committee, headed by prominent academics, was appointed to critically review the structure and management of the Israeli R&D authority, the principle funder of R&D, and 14 civilian public research institutions. The Committee’s work attracted a great deal of attention and urgency, given that its work coincided with war.

Facing imminent military attacks from Egypt, Jordan, and Syria, Israel launched a preemptive attack on three fronts. Dubbed the Seven Days War, the campaign was an overwhelming military success and attracted much public attention as to the reasons why Israel was successful—and ways to continue its success. Given this political environment, there was great interest in the Katchalski Committee’s report and its recommendations when it was released in 1968.

Aside from recommendations for the specific institutes, the Katchalski report also had a lasting impact in two areas. The first was the recommendation for the creation of a chief scientist position. The position would be staffed by a high-level outside “consultant,” allowing the government to hire a top scientist and pay them well, but also give them authority as a personal advisor to the Prime Minister. The other lasting impact was that the government would from then on play a proactive active role in the development of the country’s S&T policy. S&T development and application became a major priority for Israel for defense reasons, but government leaders quickly understood its implications for the economy.

As a result of the Katchalski Commission report and a groundswell of political support, Israel increased R&D spending and created the Office of Chief Scientist in 1968. While these were important steps, many felt that the intent of the report was not followed. For example, for at least the next 5 years, the OCS position was staffed by a university professor who did not, in fact, enjoy much influence or stature. Added R&D funds were channeled through the existing public research institutions for research projects similar to those funded before the report was released. Furthermore, inefficiency and bureaucracy plagued a small grants program, originally established in 1965 to support entrepreneurship among government scientists.

At the same time, development in the defense sector continued to gain traction and enjoy numerous technological breakthroughs. Clear of the existing bureaucracy that plagued the public research institutions, the defense sector enjoyed stunning technological successes by attracting the most talented researchers and then later helping them establish companies. While this disparity was first tolerated because academic culture was simply accepted as “different,” this began to change in the 1970s.
The 1973 War

In 1973, Israel was attacked by both Egypt and Syria during the Jewish holiday, Yom Kippur. Though Israel eventually stopped and turned back the attacking nations, the Yom Kippur was an embarrassment for Israel. Unlike the Seven Days War in 1967, Israel was completely surprised and suffered relatively large casualties. A high-profile government investigation was announced after the war that eventually led to the resignation of the Prime Minister and the head of the IDF.

Relating to innovation, the conflict demonstrated that Israel’s adversaries were acquiring increasingly sophisticated weapons from the (then) Soviet Union and other nations. Part of the official inquiry into the war included an in-depth introspection relating to Israel’s civilian S&T infrastructure. Government leaders decided that despite increasing levels of R&D funding since 1968 and strong civilian scientific capabilities, too little research was being translated into useful application. Specific focus was placed on a marginalized OCS and the relatively ineffective civilian research institutes. Furthermore, successful initial public offerings (IPOs) on the NASDAQ in the 1970s of companies like Elscient, a medical imaging company, captured the imagination of policymakers and potential entrepreneurs alike for what was possible within the Israeli economy.

The confluence of these events in the early 1970s helped Israeli leaders come to several critical realizations that laid the cultural foundation for many of the attitudes toward civilian S&T that are pervasive today. The first was that, as a small country surrounded by hostile neighbors, Israel did not have the luxury of having S&T assets “disconnected” from the rest of Israeli society, like many of the research institutions in Europe and the U.S. The second was that a robust civilian S&T infrastructure was not only important for defense, but also it was important for future economic growth, an important consideration for a country continually inundated with waves of immigrants from all over the world. Most importantly, it was understood that the government had to take an active role in innovation, but a role that emphasized agility, rapid commercialization, and the primacy of the industry-led initiatives.

Political support crystallized around these points, leading to a fundamentally restructured Israeli innovation system. To lead these restructuring efforts, government leaders recruited Itzhak Yaakov, a well-respected and strong-willed military general, to serve as Chief Scientist. Yaakov had not only held several high-level R&D leadership positions within the IDF, he had also overseen key transformational projects in the military, such as the ramp-up of development R&D and the establishment of RAFAEL. Furthermore, Yaakov was a graduate of the Massachusetts Institute of Technology (MIT) and had an expansive international network that included MIT alumni, technical peers, and high-ranking officials in the U.S. government and World Bank.

Charged with the transformation of the Israeli civilian innovation system, Yaakov came to OCS with a clear vision. At least through the early 1970s, the government had a heavy hand in the economy, prioritizing employment, security, and the assimilation of the continuing waves of Jewish immigrants. Yaakov thought that Israel could deal with these issues even better through the development of a more robust private sector economy. Furthermore, Yaakov felt that Israel’s long-term military and economic security was tied to technological leadership in the private sector. However, unlike previous government attempts to foster a domestic textile industry, he believed that government policies and programs should be “neutral and horizontal” in nature, broadly encouraging innovation through applied private sector R&D without targeting a specific industry, technology, or firm.

Given his well-known accomplishments in the IDF and the urgency surrounding the reform of Israel’s innovation system, Yaakov’s political support was high and he was given a high degree of autonomy and resources. Yaakov set off to first restructure OCS, and he did this through four principle goals:
1. **Pursue the necessary authority and funding for OCS.** Yaakov first sought the necessary and “official” authority and funding for OCS from the government in two significant ways. First, OCS received the funding and authority to create an R&D fund whereby the state loaned up to 50% of the cost of a development project to companies that was repayable only if the project was successful and earned revenue. Part of the authority package was to streamline government funding processes and regulations in order to improve flexibility and responsiveness; OCS project managers could sign final funding agreements within 10 days of proposal approval. Second, Yaakov sought and received the authority for OCS to grant a special status to high-technology firms, giving them tax discounts and benefits in order to encourage innovative behavior.

2. **Transform the OCS organizational structure.** Given OCS’s new focus on supporting industry innovation, Yaakov immediately recruited and hired talented individuals from the private sector, based on their technological knowledge and business experience. His goal was to create a professional, industry-savvy staff with a strong identity and ethos for serving industry, while avoiding typical bureaucratic behavior. OCS personnel, including Yaakov, regularly visited companies, building a thorough, although confidential, understanding of their capabilities. Yaakov also helped create a culture of risk tolerance whereby technological failure was accepted so long as the reasons were documented and shared among staff and often, if permitted, with other companies.

3. **Change the relationship between OCS and public research institutions.** While previous policy attention had been placed on reforming public research institutions, Yaakov thought that these institutions could not meet his aggressive goals as currently structured. However, Yaakov did think they could play an important role, especially in early-stage R&D. He therefore substantially decreased general support to these institutions and created a public-private partnership model to encourage more responsive, industry-oriented behavior. Projects that involve a research institution require industry initiation. Once OCS approves a project, it provides a 1-to-1 match to company contributions. The structure of a project is flexible and determined by the funding company; university researchers may solely perform research, or projects may include company researchers.

4. **Pursue international partnerships to build technological competency.** Yaakov had good contacts at the World Bank and knew that Israel was approaching the upper end of what the Bank considered a “developing” country, and he convinced Israeli policy leaders to use their last loan to fund a substantial increase in R&D. Furthermore, after the visit of U.S. President Nixon, Yaakov was involved in the creation of the Bi-National Industrial Research and Development Foundation (BIRD). As discussed below, BIRD was set up to fund cooperative R&D projects between U.S. and Israeli firms. The endowment fund, which eventually reached $110 million, was put under the management of the U.S.-Israeli Advisory Council on Industrial R&D, which was comprised of senior science, government, and industry officials from the U.S. and Israel and coordinated in Israel by OCS.

Yaakov spent the next 4 years ensuring that this vision was realized, until he stepped down in 1978 to work for the World Bank. While his reforms took time to implement and establish, all were critical to the foundation of Israeli technological leadership as understood today. Perhaps Yaakov’s most lasting leadership contribution was his allegiance to two maxims. First is the belief that ideas for specific technologies and research projects should be both generated and performed by the private sector, typically small Israeli start-up companies. Second was his belief that the primary role of the government is to encourage companies to participate in innovation vis-à-vis applied R&D by lowering but not completely eliminating the cost and risks associated with these activities.
Creation of BIRD

Although BIRD was created in 1976, it was not until 1978 that BIRD took an active role in the Israeli innovation system. BIRD initially suffered from a lack of leadership and had not awarded a single grant in the 2 years since its establishment. Ed Mlavsky, a member of the BIRD Advisory Council and Executive Vice President of Tyco International, was unhappy with the pool of candidates submitted to lead the foundation and allegedly joked that he could do a better job himself. The committee took Mlavsky’s comment seriously, and they soon convinced him to resign his corporate position in the U.S. and move to Israel.

At the time that BIRD was established, U.S. companies had been relatively unchallenged in the global marketplace. However, this was changing with the emergence of postwar economies, primarily in Japan and Germany, and the failure of U.S. companies to remain competitive. Many U.S. companies were searching for new, innovative products and technologies and—by the time BIRD was established—many small, emerging Israeli companies had built world-class R&D and technological capabilities.

Under Mlavsky’s leadership, BIRD became a “matchmaker,” connecting small Israeli companies that focused on R&D and technology with larger U.S. companies that focused on product definition and marketing. To this end, Mlavsky hired a competent, business-oriented staff to better understand U.S. markets, while he built relationships with U.S. companies. These in-person efforts were later supplemented by the creation of a comprehensive database to track the relevant technological interests of U.S. multinational companies. BIRD concurrently recruited Israeli scientists, many of whom worked for U.S. multinationals, to return to Israel. These researchers were often lured back to Israel by the prospect of returning “home” to their families while taking advantage of the emerging economic opportunities. Although the Israeli government provided no formal incentives for their return, many found the prospect of helping Israel prosper enticing. Faced with the prospect of losing many of their top researchers and a host of financial incentives, many large multinationals opened subsidiary R&D operations in Israel.

Important to BIRD’s success was the generous financial incentives it disbursed as part of its matchmaking mission. Backed by its founding endowment, BIRD funds up to 50% of the total cost of joint projects between Israeli and U.S. companies. Current grants range from $500,000 to $1 million for up to 35 projects, lasting 2 to 3 years, as well as 20 annual microprojects of $100,000 each. Similar to OCS grants, BIRD funds these projects with guaranteed loans, repayable only if the project technologies are commercialized. Loan repayment takes the form of royalties: 5% of sales of the final product, up to a maximum of 150% of the original loan. BIRD funding is also closely leveraged with other government programs and goals; multinational Israeli subsidiaries are classified as Israeli firms and therefore not only allowed to take advantage of BIRD grants but also allowed to receive R&D funding from OCS.

BIRD also focused on building and developing the operational capacity of Israeli partner firms. Although Israeli companies typically had technical expertise, they often did not have the management, systems, or personnel capacity to work with large partner companies. BIRD played this “coaching” role by first hosting seminars on how to approach and cooperate with U.S. firms and by sponsoring numerous personnel exchanges and meetings. Furthermore, BIRD built a network of finance, technology, and management experts that could work with Israeli companies to help them understand the product development and marketing processes of large U.S. companies.

OCS and BIRD, headed by capable, ambitious leaders, served as powerful change agents in the Israeli economy. Most immediately noticeable were the increasing attention and presence of large multinational

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7 For example, Dov Frohman, a senior Israeli researcher at Intel’s Santa Clara, California, headquarters, was recruited in 1974 to be a senior research at Hebrew University. Faced with his departure, Intel decided to open its first R&D center outside the U.S., with Dov Frohman as its chief and four other employees.
companies, primarily in the semiconductor industry, an area of evolving technological and manufacturing capability in Israel. Companies such as National Semiconductor, Digital Corporation, Motorola, IBM, Intel, and others had located R&D facilities there, a trend that continued as the global demand for IT products and services grew in the early 1980s. Furthermore, BIRD and OCS played an important role in the acceleration of Israel's entrepreneurial culture; by 1992, 60% of Israeli companies listed on the New York Stock Exchange and 75% of those listed on the NASDAQ had been supported by BIRD.

Changes in the Early 1980s
At the time of Itzhak Yaakov's departure from OCS in 1978, an economic crisis that began after the Yom Kippur War intensified. While the IT industry, led by foreign multinationals, continued its steady growth, the Israeli economy slowed down substantially and the number of start-ups established each year declined substantially. While the OCS was credited with helping to establish the foundations of Israel's civilian high-tech industries, much of that success was attributed to Yaakov himself. However, the same flexible, adaptable OCS structure that served Israel well under Yaakov became a liability without a strong leader.

Government leaders, frustrated with OCS's declining reputation and anxious to continue Israel's development in the high-tech sector, undertook a series of significant reforms. First, the government signaled its desire to focus on civilian technology development by relaxing its “self-reliance” doctrine and canceling the development of the “Lavi,” a costly fighter jet project. Furthermore, it passed the 1984 R&D law that prioritized the development or acquisition of cutting-edge industrial technologies from abroad, recognized software as a specific area of focus, and formalized the operations and role of OCS in the Israeli economy.

With these reforms and favorable market considerations, the Israeli economy began to turn around and entrepreneur rates rebounded. However, one problem presented a persistent obstacle to the growth of Israeli start-ups: the availability of early-stage financing. To be sure, sophisticated tech-savvy investors were present early in Israel's development. For example, the DIC, an investment company established in 1961, was one of the first to identify the potential of the IT industry for growth in the Israeli economy. Early investments by DIC in high-tech companies such as Elscient, Elron, and Elbit and their high-profile IPOs on NASDAQ were not only important to the Israeli economy but also helped DIC wield a great deal of influence regarding the restructuring of OCS and creation of BIRD.

Furthermore, limited partnerships, such as Israeli R&D Associates (IRDA), were formed in the early 1980s to take advantage of U.S. tax shelter laws. U.S. investors could form limited partnerships to invest in foreign (in this case Israeli) companies, with OCS playing the role as broker/matchmaker. Because most of the operating expenses of these start-up companies were used for R&D, investors could take advantage of the U.S. R&D tax credit for their proceeds. Although the discount ended in 1985, it did help bolster the R&D orientation of Israeli companies and strengthen ties to U.S. financial markets.

Despite these efforts and repeated attempts to attract VC investors from the U.S., Israeli start-ups typically lacked both funding to finance advanced R&D (especially without revenues) and—despite the advances made by BIRD—strong management and operations capabilities. The Ministry of Finance first focused on these problems by creating Inbal, a program intended to spur the development of a private VC industry in Israel. Inbal provided insurance for VC funds on the Tel Aviv Stock Exchange, guaranteeing up to 70 percent of their value at time of IPO. While four funds were created under Inbal, they were

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8 Senor and Singer, p. 164.
relatively small, “excessively bureaucratic,” and, most importantly, did not focus on the networking and management assistance aspects prevalent with U.S. VCs. Still faced with the same challenges, OCS created Yozma in 1992 to make up for the relative failure of Inbal and to attempt again to foster an Israeli VC industry. Specifically, Yozma was created to (1) increase the number of investors and overall amount of VC available to Israeli firms, (2) create a professional VC industry that would not only provide companies with early-stage capital but also provide managerial and operational guidance, and (3) like BIRD, help companies better understand the consumer markets and sources of financing in the U.S. Yozma sought to fulfill these goals in two ways. First, it created an $80 million fund that invested $8 million in 10 private limited partnerships on the condition that public money would constitute no more 40% of the overall fund value. Second, it established a second $20 million fund to support partnerships between local Israeli financial institutions and established foreign VCs.

By all accounts Yozma has been very successful. As planned, 10 venture funds were created and capitalized at more than $20 million each. A second fund, Yozma II, was later started in 1998 with the backing of well-known U.S. and European venture capitalists, increasing the total funds under management to currently more than $170 million. Furthermore, the Yozma funds created the capacity to provide meaningful support to its companies by “recruiting senior managers, formulating business strategies, raising additional capital rounds, and attracting strategic and financial investors,” primarily with the help of its U.S. VC partners.

The creation of the first Yozma fund coincided with the creation of the Technology Incubators Program. By the early 1990s, entrepreneurial attitudes had taken hold in several, but not all, segments of Israeli society. The Incubators Program was created to promote and support entrepreneurship within two distinct groups, including research scientists in universities and other research institutions and the substantial wave of immigrants from the newly open Russia and Eastern Europe, who were often educated in engineering and the sciences. While members of these groups often possessed great scientific talent, they also lacked the management operations experience to establish a company, pursue financing, and commercialize their technology.

With a total budget of $30 million USD, the program has overseen the establishment of 24 technology incubators throughout the country. About 10 projects (or companies) are incubated annually, with projects lasting 2 to 3 years at an average cost of $350,000 to $600,000, with $1.8 million USD for biotechnology projects. The Israeli government provides 85% of incubator funding, with the remainder covered by VC firms, the individual incubator, or the entrepreneur, in exchange for equity in the company. By 2001, 13 of the incubators were self-sustaining, with VC firms and local governments providing financial backing. Furthermore, while the program initially mirrored Yaakov’s adherence to “horizontal neutrality,” the program evolved to focus on specific industries, such as biotechnology, chemistry, and materials.

The last significant reform that occurred in the early 1990s was the creation of MAGNET in 1992. MAGNET, overseen by OCS, is a precompetitive R&D program designed to solve common technology problems among small companies, better utilize academic R&D, and disseminate the results. MAGNET

10 Breznitz, 78.
12 See http://www.incubators.org.il/.
was established following a policy of horizontal neutrality, and it seeks proposals from industry, in consultation with academic researchers, for projects of up to 3 years in length to develop generic industrial technologies. When it was established, MAGNET initially covered a significant portion of the cost for the academic partner, up to 66%, with the industrial partner(s) covering the balance. Funds are provided as grants, and no repayment is needed. Resulting intellectual property is shared equally among members of the consortia and must also be made available to other Israeli companies at a “reasonable cost.”

Subsequent changes to the MAGNET program have resulted in increases in the partnership grant to research institutions; the program grants up to 90% of the cost of the overall project, with 10% covered by industry, depending on one of four chosen tracks. These include:14

- **Consortia.** Based on the original MAGNET partnership, teams of industry and academic researchers conduct precompetitive R&D needed for the future development of advanced products. Projects may last 3 to 6 years.

- **Association.** These consortia help members of the same industrial sector understand and apply existing advanced technologies to advance their industry.

- **Magneton.** Magneton is a joint project between a single company and academic group. The purpose of the project is to test the feasibility of early-stage academic research and aid in its transfer to industry. Projects last up to 2 years with funding up to $800,000.

- **Nofar.** Nofar funds industry-relevant basic and applied research. The goal of the program is to advance or “prove” research to the point where industrial partners might make future investments. Projects last for 1 year and are funded up to $100,000 with a company paying 10% of the project costs.

This new generation of reforms also coincided with the privatization of many state-owned defense companies, including RAFAEL, which became a government corporation in 2002.

Many state-owned defense companies are slowly being privatized, and many of the sector’s “graduates” from military and industry left to start their own companies. RAFAEL established the RAFAEL Development Corporation as an incubation company with investment funds from Elron and others.

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Analysis and Lessons Learned

The results of 62 years of evolving public-private partnerships and policy reforms, along with the determination and entrepreneurial spirit of the Israeli people, have been stunning. Israel has developed cutting-edge technological capabilities in Internet protocol VoIP, LAN systems and chips, urban networks, switches, routers, software, mobile phone technology, and microprocessors. Furthermore, Israel has not only had one of the fastest rates of sustained economic growth since its establishment, but also it has the highest per capita rates of entrepreneurship in the world.

While Israel has (mostly) benefited from a continuous influx of immigrants, often possessing high levels of education, skill, and experience, immigration alone cannot explain the Israel phenomenon. Three major periods demarcate the establishment, maturity, and critical evaluation of government programs that were crucial for Israel’s technological and economic development. These include:

• An early self-reliance procurement policy by the IDF that promoted early investment in S&T and the creation of institutions, such as RAFAEL, to develop advanced technologies and provide advanced education and training opportunities for aspiring scientists and engineers
• The creation and evolution of civilian S&T institutions, such as OCS and BIRD, that helped create awareness among Israeli companies regarding the composition and dynamics of U.S. markets, attract large, multinational companies through technology, and build the foundation for high-technology entrepreneurship
• A contemporary innovation policy designed to encourage and support high-technology entrepreneurship with a specific focus on the establishment and development of a domestic Israeli VC industry, and other programs and policies to provide start-ups with services, technical assistance, and access to research alliances

Positive lessons learned from these policy evolutions include the following:

• Through defense-related, government-funded programs and institutions like RAFAEL, MAMRAM, and subsequent IDF technology units, the government stimulated a domestic market for technologically skilled individuals. Furthermore, Israel’s universities and educational hybrids (RAFAEL) helped train individuals to meet these needs.
• Ever-present external security threats and strong institutional leadership fostered mission-oriented cultures within RAFAEL, OCS, BIRD, and other research institutions.
• OCS and BIRD followed “neutral and horizontal policies” designed to promote general innovation, gain an understanding of U.S. markets, and respond to the needs of entrepreneurs themselves, in contrast to the more common “clusters approach.” Financial support was primarily structured to encourage partnerships between Israeli companies and larger multinationals, primarily from the U.S.
• U.S. high-technology multinational companies were attracted to Israel not only by the generous funding and policies that supported their R&D activities but also by the talent and sophistication of the Israeli workforce.
• An increasing number of job opportunities in Israel, along with increasing entrepreneurship rates, provided powerful stimuli for the return of talented Israelis living abroad.
• Evolving policies and culture supported a growing trend in high-technology entrepreneurship, the most important of which may be the development of an Israeli VC industry in partnership with U.S. venture capitalists. Whereas Israel’s initial attempts at building a domestic VC industry failed (with Inbal), a better understanding of the U.S. VC market, related U.S. tax laws, and a program to attract U.S. VC expertise (with Yozma), the Israelis were very successful.
Concerns and opportunities from the evolution of the Israeli economy include the following:

- The Israeli economy is highly, heavily specialized and dependent on IT, with many other sectors not experiencing the growth and success that IT has experienced. As the IT sector has become increasingly disconnected from the rest of the Israeli economy, it has prompted various income disparity and socio-economic issues.

- Similarly, critics have questioned the long-term sustainability of the U.S.-centric start-up model. They fear an overemphasis on R&D and technology capabilities and not enough emphasis on the management, marketing, and development capabilities of Israeli start-ups. Although OCS, BIRD, and the evolution of the VC industry have helped, these areas remain a weakness within Israel.

- While Israel has successfully developed a VC industry, the stated goal for most VCs is an exit through acquisition or IPO. Many lament the lack of “patient capital” that would encourage the long-term growth and expansion of Israeli firms.

- Together, these factors make Israeli start-ups vulnerable for takeover or purchase by larger, better-organized multinationals. With a few exceptions, market niches once pioneered and controlled by Israeli firms no longer have an Israeli firm presence. While most innovative companies and activities taken over by multinationals remain in Israel, a question reminiscent of the 1967 Arab embargo remains: does Israeli ownership matter for economic and—in the long run—defense security? Furthermore, this reliance on the IT industry and foreign multinationals makes the economy especially vulnerable to market fluctuations and the performance of a few specific companies.

- The Technology Incubators Program, like more recent policy initiatives, has been controversial because of the lack of metrics to understand the program’s marginal contribution to Israeli entrepreneurship. Some critics argue that the program is too costly, especially for the lack of results, while others argue the program provides too little financing and forces the wrong behavior among start-ups.
Executive Summary

Finland was chosen for this analysis due to its rapid economic development in the second half of the 20th century. During that period, its GDP skyrocketed, and it became—and remains—one of the world’s most R&D-intensive countries. It is also particularly relevant to Russia because of its close ties to the Russian economy prior to 1991 and the crisis it faced from the dissolution of the Soviet Union. This chapter derives the following lessons and cautionary lessons learned from the Project’s analysis of Finland.
### Key Institutional Elements

<table>
<thead>
<tr>
<th>Institution</th>
<th>Year established</th>
<th>Description</th>
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<tbody>
<tr>
<td>VTT Technical Research Centre of Finland</td>
<td>1942, by the national government</td>
<td>The biggest multitechnological applied research organization in northern Europe; a technology broker and technology transfer office</td>
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<tr>
<td>Sitra, or the National Fund for Research and Development</td>
<td>1967, by Finland’s Parliament</td>
<td>A quasi-independent national investment fund designed to fund companies and projects focused on technology commercialization and VC funding; Sitra uses the returns from its large endowment as the funding source</td>
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<tr>
<td>Nokia Corporation</td>
<td>1967, through a merger between Nokia Ab, Finnish Rubber Works, and Finnish Cable Works</td>
<td>Government-created telecommunications giant</td>
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<tr>
<td>Academy of Finland</td>
<td>1970, under the authority of the Ministry of Education to advise the government on scientific issues</td>
<td>Governmental funding body for scientific research in Finland; yearly, the Academy administers over €260 million to Finnish research activities; over 5,000 researchers are working on projects supported by the academy</td>
</tr>
<tr>
<td>Science Parks/Incubators</td>
<td>1982, under federally managed projects</td>
<td>Provides business support, infrastructure, and services for companies; the first of these was Technopolis Oulu</td>
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<tr>
<td>Tekes, or the Finnish Funding Agency for Technology and Innovation</td>
<td>1983, under the authority of the Ministry of Commerce and Industry</td>
<td>Main public funding organization for research, development, innovation, and regional development in Finland; Tekes’ funding is usually in the form of low-interest loans or grants; Tekes had an R&amp;D budget of €579 million in 2009</td>
</tr>
<tr>
<td>Research and Innovation Council (RIC)</td>
<td>1987, as the Science and Technology Policy Council (STPC), by the Prime Minister</td>
<td>As an advisory body to the government, RIC tracks developments in R&amp;D and S&amp;T more generally, including the impact of those developments on Finland; 100% of funds come from the national government; the funds go mainly to administration and the preparation of policy reviews; the Science and Technology Policy Council also funds research and evaluation projects related to S&amp;T policy</td>
</tr>
<tr>
<td>Centres of Expertise Programme</td>
<td>1994, by the national government, through the regional development act of 1990</td>
<td>Promotes areas of regional expertise that have the potential for international competitiveness</td>
</tr>
<tr>
<td>Regional Centre Programme</td>
<td>2001, by the national government</td>
<td>Fills gaps left by the Centres of Expertise Programme and other industrial development initiatives; their goal is to promote the competitiveness of every Finnish region</td>
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### R&D Tax Incentives

Finland neither subsidizes nor extends preferential tax treatment to business R&D, although it has a high level of private R&D expenditure. However, it does allow the deduction of expenses (including R&D expenses) related to income-producing products. The country also allows companies a deduction for purchasing or constructing buildings and other tangible property related to R&D.
Finland Gross Domestic Product (Current US Dollars, Not Adjusted for Inflation)
Source: World Bank, World Development Indicators - Last updated June 15, 2010

Finland Foreign Direct Investment (Balance of Payments in US Dollars)
Source: World Bank, World Development Indicators - Last updated June 15, 2010
Lessons learned:

- Improving the national innovation system requires a long-term commitment.
- Local and federal innovation policies should reinforce each other.
- Innovation initiatives should build upon preexisting technological strengths.
- Government regulations can spur innovation.
- Innovation policy and funding decisions should be grounded in an analysis of market trends.
- Natural resources can be leveraged for high-technology, value-added exports.
- The remaking of Nokia demonstrates the role that government can play in creating a ripe environment to foster a high-tech company’s growth.
- The export-driven tech model worked for a small domestic market country.
- Science and high-tech parks can be both self-sustaining and an instrument of innovation.

Cautionary lessons learned:

- Too much dependence on a single national champion, Nokia, leaves the entire innovation economy vulnerable to international market changes.
- Too much focus on regional policies, rather than connecting to the international markets and trends, is proving ineffective.
- Bureaucracy can slow critical funding decisions to the point that the new businesses needing the funding miss key opportunities.
Introduction

Finland has achieved remarkable economic growth in recent decades, catapulting from a low-wage, natural resources-based economy to the top tier of industrialized nations. Progress was driven largely by two industries, forest products and ICT. While the government has invested significant resources in its innovation system, the private sector and fortuitous market conditions also played large roles in Finland’s transformation.

Now in its second decade as a robust knowledge economy, Finland continues to offer reasons for optimism. Its educational system is among the best in the world; both the top performers and lowest performers fare remarkably well against their counterparts in other countries. It also ranks among the top few countries in R&D spending as a percentage of GDP. The government has drafted and begun implementing its next generation innovation strategy focusing on systemic improvements in the national innovation systems’ functionalities and cross-sectoral combinations of talent and socio-economic interests. These key policies are also addressing the potential risks of the increasing reliance on pure ICT sector strengths by aiming to minimize national vulnerability to changing market trends in that industry. However, today there is little evidence that innovation policy or start-ups are diversifying the economy. Moreover, a heavy reliance on exports intensifies the consequences of global economic downturns.

The evolution of the Finnish innovation system can be described in two phases: (1) the creation of key institutional innovation components and (2) the creation of the innovation system.

Creation of Key Institutional Innovation Components

The 1950s and 1960s saw what might be considered the seeds of a modern innovation system in Finland, prompted largely by the actions of both the national and regional governments. The central government had long endorsed a regional economic policy, but its strategies centered on manufacturing rather than high-tech R&D. The policy doubled as a security initiative, because more-prosperous hinterlands would likely become more populous, decreasing their susceptibility to both foreign invasion and Communism. Technological advancement was not a primary objective, and the initiatives were not grounded in an overarching innovation system.

At the same time, regional governments did perceive the connection between innovation and economic opportunity, and they began planning universities and polytechnics. Some of the new institutions were founded from scratch, while others began as branches of larger institutions based in Helsinki and later became independent. While this development did not signify the advent of a national innovation policy and its economic benefits were not immediately significant, it laid the groundwork for subsequent national policies to converge with local initiatives.

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The first national shift toward innovation occurred in the late 1960s. The central government understood that an economy based heavily on exporting raw or minimally processed materials would not raise the standard of living to that of more industrialized neighbors. This recognition arose concurrently with a push by the OECD, which Finland joined in 1969, to use science for societal development. Thus began an ambitious agenda of government-supported innovation initiatives, including the following key institutional elements:

- **Sitra, or the National Fund for Research and Development (established in 1967).** Sitra is a quasi-independent program designed to fund companies and projects that will help address challenges within Finnish society and promote economic growth. Current areas of interest include municipal service development, energy efficiency, and the mechanical and metal industries. Sitra was established in 1967 by Parliament in honor of the 50th anniversary of Finnish independence. Granted an endowment of 100 million markka ($24.8 million in real 1967 USD), its charter stipulated that “the returns of the fund must be used for financing measures which promote the stabilisation of the value of the Finnish markka [which had just been devalued], the acceleration of the economic growth of [Finland] and the improvement of [Finnish] international competitiveness.” Furthermore, it required that Sitra’s efforts be self-financing. While Sitra initially operated under the Bank of Finland, it was given an independent charter in 1991. Sitra today functions primarily as a think tank and as a VC fund. (This is discussed further, below.)

- **The Academy of Finland.** The Academy of Finland was established in 1970 within the Ministry of Education to advise the government on scientific issues. Later, the Academy became the primary funder of basic, peer-reviewed R&D, primarily in universities. This role was expanded in 1997 with the Additional Funding Programme, which was designed to bolster the country’s basic research capacity. In 2008, the Academy funded about $380 million USD, nearly four times the amount funded in 1992.

- **Tekes, or the National Technology Agency (established in 1983 and since renamed the Finnish Funding Agency for Technology and Innovation).** In response to a recession, in 1980 the Finnish Council of State established a committee of finance and business leaders to analyze and improve national industrial policy. As a result of the committee’s recommendations, Tekes was created to help Finnish companies become more innovative by encouraging public-private applied R&D partnerships among government, industry, and universities to develop new technologies. Therefore, this organization is focused on applied research and commercialization, whereas the Academy of Finland is focused on basic research. Tekes funds more research than any other public entity in Finland. In contrast to Sitra, Tekes does not act in the capacity of a VC firm, but instead, Tekes funding can take the form of grants or low-interest loans for which it does not seek financial gain. For each project funded, a Tekes staff member is assigned to provide assistance and monitor

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progress. Foreign companies conducting R&D in Finland are eligible for funding, provided that Tekes deems the work likely to contribute to the Finnish economy.\textsuperscript{26}

**Technical Research Centre of Finland (VTT).** VTT was established in 1942 when the President signed the Technical Research Centre Act, and its mission was “to engage in technical research for the benefit of science and society.” In the 1960s, VTT grew to become Finland’s biggest research institute, with 26 laboratories staffed by a total of more than 400 research scientists. VTT further renewed its structure and focus in the beginning of 2006 to ensure that technology opportunities afforded by its strategic research could be exploited both nationally and internationally in collaboration with private industry and other partners. As part of this technology transfer effort, understanding the market landscape is presently a critical focus as well.

**Incubators (established in 1982).** The first incubator was created in Oulu in 1982. They took off most prominently in the Helsinki area as a response to the depression of the early 1990s. Between 1994 and 1996, that region welcomed 15 new incubators, where only 1 had existed before. They were established under a federally managed “jobs through entrepreneurship” project administered by the newly created Employment and Economic Development Center (TE-Center). Three-fifths of the total funding of EUR 2.15m came from various government ministries, with the remainder provided by the European Community. Instead of seeking unlimited growth, most companies started in incubators aim for a rather small size of 50 to 100 employees. This may be attributed to a culturally low tolerance for risk taking and a limited supply of VC. The Helsinki incubators provide business support services but do not subsidize rent. Specifically, through the partnership with the TE-Center, services including testing of business ideas, search for copartners, market development, management training, and international intelligence are offered to incubator companies. Frequently, companies move directly from incubators to science parks (discussed below), where they continue to receive at least some measure of institutional support. Companies founded in incubators enjoy an extraordinarily high survival rate, which may signify that the selection process is too conservative. That is, incubators have produced few failures as well as few exceptional successes. The Helsinki area incubators are sponsored by various educational institutions, city governments, and local organizations.\textsuperscript{27}

**Science and High-Tech Parks.** The central government began establishing science parks to house and support scientifically minded businesses. Starting with Technopolis Oulu in 1982, 21 science parks had been built by 1999.\textsuperscript{28} Their purpose is to site the innovation infrastructure in the vicinity of academic scientific research.\textsuperscript{29} Today, Technopolis, a publically held company (HEX), manages technology centers not only in Oulu but also in Vantaa, Espoo, Lappeenranta, Jyvaskyla, and Tampere, providing business and development services to the resident companies. By developing and managing multiple parks, Technopolis is able to leverage its experience and bring best practices to benefit its clients. Although in general the parks have not met with universal

\textsuperscript{26} Tekes, *How We Work*, www.tekes.fi/en/community/How%20we%20work/342/How%20we%20work/1287 (July 12, 2010).


acclaim and are criticized for being funded predominantly by investments from private developers whose first priority appears to be collecting rent rather than concentrating truly innovative companies,\(^{30}\) the Technopolis-run parks are touted as self-sustaining businesses that still promote company development.\(^ {31} \)

An example of a Technopolis-run park is Technopolis Helsinki-Vantaa. This is one of the newer high-tech parks and has received a lot of attention, partially because of its location near the Helsinki-Vantaa Airport as part of Aviapolis, a business, retail, entertainment, and housing marketing brand area in central Vantaa. Aviapolis, like many other private-public partnerships between developers, high-tech companies, and government, is focused on creating a vibrant community to attract the people and companies necessary to build an economically prosperous region. Aviapolis combines innovative small and medium enterprises’ technologies to bigger companies and provides platforms for joint development, prototyping, testing, demonstrations and integrated product/service solutions. The business model is geared towards fast commercialization through a combination of in-house and sourced (bought and imported alike) technology development efforts. This improves ventures and their collaborators chances to reach quickly the proof of concept stage and move on to value system level, integrated business development.

- **Science and Technology Policy Council (established in 1987, and since renamed the Research and Innovation Council).** This body is composed of representatives from the Ministry of Education and Culture and the Ministry of Employment and the Economy and is chaired by the Prime Minister. It seeks to promote economic development, strengthen business and industry, disseminate new knowledge, and augment the knowledge base.\(^ {32} \) As an advisory body to the government, it tracks developments in R&D and S&T more generally, including the impact of those developments on Finland.\(^ {33} \) The Council is credited with important initiatives (discussed below), but some observers suggest that its influence is overblown, noting that it is limited to a few ministries rather than being government-wide.\(^ {34} \) Its renaming in 2009 was meant to acknowledge the need for horizontal innovation policy.\(^ {35} \)

At the same time that the above-mentioned national initiatives were being developed, many industry- and region-specific initiatives were putting Finland on a course toward greater prosperity. Below, these are discussed.

In 1969, Finland and the other Nordic countries founded Nordiska Mobil Telefongruppen (NMT) to coordinate mobile telephone service across the region.\(^ {36} \) In the early 1980s, NMT adopted the world’s

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\(^ {30} \) Squicciarini, p. 175.

\(^ {31} \) Comment provided by a contributor.


\(^ {36} \) Sabel and Saxenian, p. 63.
first digital telephone standard, resulting in the world’s first pan-national cellular network system.\textsuperscript{37} As a result, mobile phone usage in Finland came earlier and with greater intensity than nearly anywhere else in the world. This creation of a domestic market gave Nordic mobile phone enterprises, particularly Finland’s Nokia Corporation and Sweden’s Ericsson, tremendous first-mover advantage, readying them to enter foreign markets as cellular networks became more widespread. In 1991, Radiolinja, a Finnish mobile network operator, established the world’s first Global System for Mobile communications network, offering improved quality over less bandwidth.\textsuperscript{38}

The Nokia we know today—likely to be Finland’s most recognized brand—was created in 1966 during its final merger to become Nokia Group. It was at this time that it expanded its businesses to include electronics. Prior to the merger, it was a conglomerate of three very distinct companies: Nokia, a wood-pulp/paper mill; Finnish Rubber Works; and Finnish Cable Works.\textsuperscript{39} Shortly after its modern establishment, Nokia was quick to produce its first radiotelephone in 1963, followed by a data modem in 1965 and a digital telephone switch in the early 1970s.\textsuperscript{40} Although Nokia experienced these achievements, the company entered a serious crisis that carried through to the collapse of the Soviet Union in 1991. The company’s difficulties were mostly attributed to the conglomerate model and hierarchical management practices.\textsuperscript{41} Through a new leadership and business strategy, Nokia reinvented itself during the 1990s (discussed below).

Nokia played an important early role in helping NMT ensure interoperability, preparing it to enter a wide variety of networks abroad.\textsuperscript{42} Furthermore, the Global System for Mobile Communications network eventually became the European standard for mobile telecommunications. As a result, Nokia and other Nordic telecom equipment suppliers benefited from first-mover advantages in the international mobile telecom industry. In addition to coordinating mobile standards and regulation with Nokia, the Finnish government has supported Nokia’s innovative activities for years; Tekes supported, on average, around 8\% of Nokia’s R&D budget between 1980 and 1995.

By contrast, the forest industry—another pillar of the Finnish economy—benefited from a policy that at first glance might have seemed to be thwarting it. Shortly after Finnish independence, as a measure to support tenant farmers the government forbade the forest industry companies from owning land. In order to access timber, they were required to contract separately with thousands of individual landowners. Sweden implemented no such policy, and forestry companies owned the majority of the land they used. Thus, Sweden specialized in mass producing homogenous paper products in a manner that Finland’s less consistent patchwork of suppliers rendered infeasible. Instead, Finnish manufacturers specialized in high-value-added niche products, such as glossy paper coated with new varieties or combinations of chemicals.\textsuperscript{43} In the 1980s, the Finnish paper industry’s technological capabilities overtook those of its Swedish counterpart.\textsuperscript{44}

\textsuperscript{37} Palmberg, p. 134.
\textsuperscript{38} Palmberg, p. 134.
\textsuperscript{40} Navin De Silva, Matti P.T. Juvonen, Roopinder Singh, “Innovation at Nokia: a Case Report,” (London: Imperial College of London), p. 4-5.
\textsuperscript{41} Castells and Himanen, p. 30.
\textsuperscript{42} Sabel and Saxenian, p. 63-67.
\textsuperscript{43} Sabel and Saxenian, p. 38-39.
\textsuperscript{44} Sabel and Saxenian, p. 27.
Throughout this period, local and regional governments continued their drive to attract universities. In the 1960s and first half of the 1970s, the city of Tampere built a teaching and research center from scratch. A local development coalition convinced the School of Social Sciences to relocate there from Helsinki in 1960. Then, it negotiated for the Helsinki Institute of Technology to establish a branch in Tampere in 1965; the branch became the independent Tampere University of Technology 7 years later. In addition, in the 1970s, the national government opened a Tampere branch of the Technical Research Centre of Finland (VTT). In 1987, Nokia chose to site its research laboratory in Tampere. By the year 2000, about 15,000 workers in Tampere were employed in ICT.

The federal government also began to take note of the innovation gap between the hinterlands and larger cities. Indeed, the gap, at least as measured in economic terms such as employment and wages, was closing. By most measures, however, Finland had not yet attained its place as one of the world’s most innovative counties. Before that could transpire, it would have to endure its most severe economic crisis in nearly half a century.

Creation of the Innovation System

Many feel the Finnish innovation system was really developed in the 1990s, catalyzed by Finland’s economic depression. By 1993, the GDP had fallen 9.5% from its 1990 level. Unemployment reached 17%. The proximate cause of the turmoil was the disintegration of the Soviet Union, Finland’s largest trading partner. Beyond its direct impact, this upheaval led to a global recession, thereby expanding Finland’s problems beyond the sphere of a single bilateral trade relationship. Despite the scope of its problems, Finland was quick to regain—and then surpass—its former economic footing, reprising the cocktail of sound fiscal policy and industrial growth that rescued it from the perilous aftermath of World War II.

The policies contributing to Finland’s resurgence were not entirely reactive. Many had been considered, or even implemented, prior to the depression and continued to guide decision makers as the crisis unfolded. For instance, Tekes’ support for R&D did not waver despite the economic hardship. The Science and Technology Policy Council’s Review 1990 – Guidelines for Science and Technology Policy in the 1990s set innovation as a national priority and spurred a more conscious organization of the innovation system. It was around this time that Finland can be said to have adopted a national innovation policy. The policy favored knowledge and R&D over capital investments such as manufacturing facilities. Expenditures on R&D remain well over 3% of GDP, placing Finland among the top countries in the world by that measure. As early as 1988, a new regional law emphasized equality of development, indicating a break from simply locating some form of industry in each region. In 1993, the Ministry of Trade published the National Industrial Policy for Finland, establishing its commitment to a cluster-based approach to innovation. This was inspired by the work of Michael Porter, whose 1990 book, The Competitive Advantage of Nations, had a major influence on Finnish policymakers. Moreover, regional innovation policies were being promoted by the European Union, on which Finland had an eye toward joining (it did so in 1995).
Since the early 1990s, Finland has launched a series of initiatives to promote regional development, including:

- **Centres of Expertise Programme (established in 1994).** The Centres of Expertise (CoE) may offer the best example of regional and national policies converging. They are intended to promote those areas of regional expertise that have the potential for international competitiveness, directly leveraging the local development efforts that preceded them. The legal basis for the CoE was provided by the Regional Development Act of 1990. There are currently 21 CoE in Finland. In 2007, the program was redesigned as a cluster-based model, and there are now 21 Finnish Clusters of Expertise. The Clusters aim to align regional resources, including industry, academia, and municipal governments, to promote industries of national importance.

- **Regional Centre Programme (established in 2001).** Regional Centres are intended to fill the gaps left by CoE and other industrial development. Their goal is to promote the competitiveness of every Finnish region. Their premise, as established in regional development acts (of which there have been several), is that every Finnish province has at least one urban area, however small, capable of competitiveness. The program has been implemented in 34 regions.

Tekes merits further discussion here for its continuing support of R&D. In 2009, it provided EUR 579m to 2,177 projects. Total funding for R&D services (e.g., software and data processing; architecture, engineering, and technical services) was slightly greater than that for industrial R&D (e.g., machines and metals; electronics and electrochemical research). Universities collected EUR 236m of Tekes funding, while private enterprises collected the balance of EUR 343m. The trend in recent years has been toward larger grants for fewer projects.

Beginning in the late 1980s and early 1990s, Tekes also began to serve a valuable networking function. It provided a central node where local innovation advocates, even in the absence of a formal innovation policy, could meet each other and share ideas. Members of this group, many of whom were involved in scattered local innovation projects, advocated for an innovation policy at the national level. Tekes’ focus also widened in more official ways: it was granted authority over regional technology development (in 1984) and regional economic development initiatives (in 1997). In a reflection of this gradually broadening mission, the Ministry of Trade and Industry, which oversaw and funded Tekes, merged in 2008 with the Ministry of Labour and the Ministry of the Interior’s regional development unit to become the Ministry of Employment and the Economy.

Sitra’s priorities have also shifted in the decades since its founding. In the 1980s, it directed its efforts toward technology commercialization, introducing the first significant VC funding in Finland. The change was codified in the mid-1990s, when Sitra reformulated its strategy, focusing more on...
providing VC for early-stage companies as well as continuing in its role as a think tank. In 2009, Sitra invested EUR 38m, including VC and research support in key program areas. Sitra’s VC role is quite complementary to the basic and applied funding roles that the Academy of Finland and Tekes fill, respectively.

The factor most responsible for Finland’s speedy economic recovery in the mid-1990s was the growth of the ICT industry. It was during this period that Nokia, leveraging its early experience domestically and transforming its business culture under the leadership of Jorma Ollila, became the world’s top manufacturer of mobile phones. Jorma Ollila was the head of the Nokia Mobile division, and as CEO focused on mobile communication, selling off most of the other businesses. The combination of Nokia being newly listed on the New York Stock Exchange and it relentless focus on increasing the efficiency of its supply chain and manufacturing techniques, through operating in a very open international network, launched Nokia as a leader in the industry.

The 1990s also saw an increase in the (already high) educational achievements of the Finnish population. Attendance at polytechnics in particular increased threefold from 1993 to 1998, reflecting the scientific and engineering drivers of the Finnish economy. Universities experienced a twofold increase in attendance.

By 2010, Finland has become known for its continuous high rankings in its innovation capacity, first-class elementary and high school education system, and openness for global innovation collaboration. It is considered a front-runner in innovation system development and frequently bench-marked for its innovation activities. Since becoming a member of the European Union, it has established strong connections to the pan-European science and technology collaboration circles and extended its participation in all major European innovation institutions. This development has made it possible to leverage smartly the Finnish indigenous R&D strengths and create the necessary critical mass behind nationally important development initiatives.

### Analysis

As Finland is an open market economy producing mostly investment-intensive goods and services for export, it is strongly connected to the world’s economical, investment and market development cycles. Any radical change on its export markets (like the collapse of Soviet Union) results in shock waves throughout the economy and hits hardest the national flagship manufacturers. The consequent impacts can be seen in all related statistics. However, it should be noted that Finland has learned to live with these realities and built a strong, technology-intensive, low-national-dept economy that can prosper even at times of hardship. Since early 1990s the government has reduced the national debt-levels (to 44% of GDP) and secured its access to low-cost capital (national bond yield under 1%) from global markets. As a result, the economy is now bouncing back from the recent lows and beginning to recover thanks to improving investment cycles in Europe and Asia (quarterly GDP growth in 2010 is over 3%). Consequently, it could be argued that Finnish investments in high-tech future and national innovation capacities are supporting its development even at times of difficulties.

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64  Berghäll, 9.
65  Castells and Himanen, 32-34.
66  Sabel and Saxenian, 69.
Even so, Tekes and Sitra have both been criticized recently for an unwieldy administrative bureaucracy and practices that lag considerably behind the pace of business cycles. Several years can elapse between initial funding requests and the receipt of funds, raising the specter that a private enterprise will be obligated to perform research with Tekes funding that is no longer relevant to its business needs.\textsuperscript{67} Although Tekes recently started a project specifically to assist start-ups, it remains to be seen what impact it will have on that time-sensitive sector.\textsuperscript{68} Furthermore, Sitra’s mandate to be an “evergreen” fund, with the pace of its funding dependent on returns on its previous investments, neglects the cyclical and risk-oriented needs of early-stage VC markets. This is especially true in high-technology markets, the kind that Finland wishes to target.

Perhaps a larger question is whether these programs’ target-oriented research approach remains suited to the Finnish economy. Now that Finnish technology is a world leader and thus has nothing to catch up to, it is unclear what direction government-led research should take.\textsuperscript{69} An external review of the National Foresight Network—a working group established by Sitra to keep pace of research needs—concluded in 2009 that the Network struggles to devise new strategies based on societal developments.\textsuperscript{70} One possible new research thrust is efficiency in public services, the burden of which will become increasingly unmanageable in Finland as the population ages.\textsuperscript{71} The government is attempting to utilize the high-tech hubs of Tampere and Oulu for the purpose of designing and expanding e-governance.\textsuperscript{72}

Additionally, forest products and ICT, major industrial drivers of Finland’s economy, have been viewed pessimistically in recent years. Pulp and paper manufacturers are shifting production to developing countries, which offer more than just cheap labor and raw materials. They are also the sites of cheaper raw materials. As emerging economies, they are also becoming major paper markets. The Finnish market, by contrast, already has excess capacity.\textsuperscript{73} The forest products industry’s domestic capital investments in entities such as processing plants or factories are no longer compensating for the depreciation of existing facilities. This reflects a broader, cross-sector shift over several decades during which Finland fell from the top tier of OECD countries in capital investment per unit of GDP to the bottom tier.\textsuperscript{74} Since the 1990s, profit margins have decreased. Finnish firms are losing their technological edge and becoming volume producers of the once-specialized products that they helped to create. For now, though, forest products continue to account for one-quarter of Finnish export earnings,\textsuperscript{75} roughly the same as ICT/electronics.\textsuperscript{76}

ICT, led by Nokia, is undergoing a similar shift. Drawn by low wages and expanding markets, companies are constructing new manufacturing facilities in China and India rather than Finland. Even when locating a factory in Europe, Nokia recently passed over Finland in favor of Romania. As Nokia moves abroad, so too must its Finnish suppliers. Those left behind have, in many cases, so completely

\textsuperscript{67} Sabel and Saxenian, 113.
\textsuperscript{68} Sabel and Saxenian, 98.
\textsuperscript{69} Sabel and Saxenian, 19.
\textsuperscript{70} Sitra, 2009 Annual Report, 11.
\textsuperscript{71} Oxford Economics.
\textsuperscript{73} Berghäll, 24.
\textsuperscript{74} Berghäll, 1.
\textsuperscript{75} Sabel and Saxenian, 27-28.
\textsuperscript{76} Oxford Economics.
molded their business models to meet Nokia’s needs that they now have limited intrinsic innovative capacity. The impact might also be felt at universities. Like the supply chain, Nokia’s R&D may be relocated for proximity to its manufacturing.

As Finnish industry turns its investments outward, the country’s historic pattern of attracting little foreign direct investment persists. A recent rise in inward FDI is largely a consequence of service sector acquisitions, such as bank mergers, not capital or R&D investments. A major issue continues to be its small size—that is, its meager domestic market. Although prosperous and highly educated, its domestic market is smaller than those of competitors India and China by a factor of 200. Finland’s labor pool also suffers from the small population; despite high educational attainment, foreign companies have reason for concern about finding a large qualified workforce. Perversely, highly educated young Finns may find insufficient demand for their skills in their native country and go abroad for greater opportunities.

The preceding paragraphs are not meant to present too bleak a picture. Finland, as stated previously, has quickly rebounded from much more dire circumstances in the past. Rather, this discussion is intended merely to sound a cautionary note against interpreting Finland’s recent prosperity as a complete validation of its national innovation policies. Stated more bluntly, the ICT industry, led by Nokia, benefited enormously from Tekes funding and expanded educational institutions, but its success has not been replicated fast enough by other firms or in other industries.

77  Sabel and Saxenian, 77-79.
78  Berghäll, 20.
79  Berghäll, 23
80  Berghäll, 5.
81  The Science and Technology Policy Council of Finland, 10.
82  Berghäll, 36.
83  Sabel and Saxenian, 74.
Lessons Learned

Bearing in mind the qualifications discussed above, the case of Finland illustrates several principles worthy of consideration by countries seeking to enhance their innovation systems.

- **Long-Term Efforts.** Finland’s recent prosperity resulted from several decades of effort and progress, and most observers consider even that to have been remarkably swift. Innovation policy is not a quick stimulus for an ailing economy. Instead, it can provide a structure on which an economy can sustain itself and expand. Policymakers should not be too quick to deem as failures those policies that do not bring immediate returns. A corollary is that benefits may derive from initiatives indirectly, initially masking their value. The aim should be to create a comprehensive innovation system rather than to expect specific policies to yield specific dividends.

- **Technological Strengths.** Finland did not invent its technological strengths for the sake of its innovation policy. The strengths preceded the policy, but were not recognized. A successful industry is difficult to create from scratch on a national level. Therefore, any policy should begin with an assessment of existing strengths and an analysis of how to leverage them along with the political will to focus on achieving them.

- **Market Creation through Government Regulation.** Finnish industry has repeatedly become more creative and flexible in response to government regulations. Regulations can promote innovation even when that is not their underlying objective, yielding industries that are capable of adapting to regional considerations in markets around the world.

- **Government initiatives contribute to creating innovative environment for business growth.** Nokia’s international success has been based on a combination of innovation and public-private cooperation that has mixed government regulation and R&D funding support with good business decisions and global opportunity.

- **Understanding Market Trends.** Finland has several government organizations that analyze market trends. Tekes, Sitra, and the RIC keep apprised of technological, economic, and societal developments that could impact the nation’s economy. These are the same organizations that provide policy advice and distribute R&D funding, increasing the likelihood that the government’s actions reflect its analyses.

- **Mutually Reinforcing Local and Federal Policies.** In Finland, both the regional and national governments have long instituted economic development policies. These measures were generally not detrimental, and they prepared a valuable infrastructure for future growth. The most productive results, however, have been achieved with synchronicity between local and national efforts.

- **Leveraging Value-Added Natural Resources.** While “knowledge economies” are sometimes posed in opposition to “natural resources economies,” Finland’s forest products industry has borrowed successfully from both models. Utilizing the nation’s abundant lumber resources, the industry became a world leader in high-end paper products, specializing in niche goods over cheap, high-volume production. This technological edge allowed it to thrive even as more basic products emanated from lower-wage countries.

- **Financially Sustainable Science Parks Are Achievable.** Whether the Finnish science parks meet the goal of bridging research and industry is still to be determined, but the Technopolis model of providing common management and high-tech services to several of the parks has resulted in self-sufficient parks independent of government funding for the long term.
Executive Summary

The U.S. was chosen for this analysis due to its long history of technological innovation and economic growth. From its early days as an agriculture-based economy to the present as an integrated industrialized economy, science and innovation have been at the core of its prosperity. This chapter derives the following lessons and cautionary lessons learned from the analysis of the U.S.
### Key Institutional Elements

<table>
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<tr>
<th>Institution</th>
<th>Year established</th>
<th>Description</th>
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<tr>
<td>National Academy of Sciences (NAS)</td>
<td>1863, by President Abraham Lincoln and the Act of Incorporation</td>
<td>An organization which advises the national on science strategy</td>
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<tr>
<td>National Institutes of Health (NIH)</td>
<td>1887, as the Laboratory of Hygiene, by the federal government, and reorganized in NIH in 1930</td>
<td>An agency of the U.S. Department of Health and Human Services; the primary agency of the U.S. Government responsible for biomedical and health-related research</td>
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<tr>
<td>National Institute of Standards &amp; Technology (NIST)</td>
<td>1901, as the National Bureau of Standards, by the federal government</td>
<td>Promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology; NIST's 2009 budget was $992 million, but it also received $610 million as part of the American Recovery and Reinvestment Act</td>
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<tr>
<td>National Science Foundation (NSF)</td>
<td>1950, by the federal government</td>
<td>Promotes science and engineering through research programs, R&amp;D grants, and education projects; NSF's budget expanded from $1 billion in 1983 ($2.19 billion in 2010 dollars) to just over $6.87 billion by FY 2010</td>
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<td>Small Business Administration (SBA)</td>
<td>1953, by Congress, with the passage of the Small Business Act</td>
<td>Helps and protects the interests of small businesses. The most visible elements of the SBA are the loan programs it administers, guaranteeing against default certain portions of business loans made by banks and other lenders that conform to its guidelines</td>
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<td>Small Business Investment Companies (SBICs)</td>
<td>1958, by the Small Business Investment Act</td>
<td>Facilitates the flow of capital through the economy to small entrepreneurial businesses in order to stimulate the U.S. economy</td>
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<td>Defense Advanced Research Projects Agency (DARPA)</td>
<td>1958, as an agency of the Department of Defense (DOD)</td>
<td>Develops defense technologies and supplies technological options for the entire DOD</td>
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<td>Office of Science and Technology Policy (OSTP)</td>
<td>1976, by Congress, but grew out of the Office of Science and Technology formed by President John F. Kennedy in 1961</td>
<td>Advises the President, and others within the Executive Office of the President, on the effects of S&amp;T on domestic and international affairs</td>
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<td>Small Business Innovation Research (SBIR) program</td>
<td>1982 by Congress, which passed the Small Business Innovation Development Act</td>
<td>An R&amp;D funding program that helps small businesses to commercialize technology</td>
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<tr>
<td>Manufacturing Extension Partnership (MEP) program</td>
<td>1988, by the Omnibus Trade and Competitiveness Act</td>
<td>A network of not-for-profit centers funded by both states and the federal government to diffuse and implement manufacturing and other process technologies to small businesses</td>
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<tr>
<td>Technology and Innovation Program (TIP)</td>
<td>2007, as part of the America COMPETES Act, under NIST</td>
<td>Funds companies at the “Valley of Death” stage</td>
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<tr>
<td>Advanced Research Projects Agency-Energy (ARPA-E)</td>
<td>2007, as part of the America COMPETES Act</td>
<td>Funds basic, goal-oriented research through the challenge-based model long-employed by DARPA; received its initial funding allocation—$400 million—through the American Recovery and Reinvestment Act of 2009; total funding is expected to reach $1 billion in the coming years</td>
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### R&D Tax Incentives

The U.S. has offered both a tax credit and tax deductions for R&D expenditures, although greater amounts of support are provided to business R&D through direct financing than through tax incentives. Before the piece of tax code expired in 2009, the U.S. offered R&D tax credits based on the increment of R&D, and allowed businesses to take a tax deduction of up to 14% for certain expenses. Small businesses may deduct capital R&D expenditures as current business expenses. It may deduct R&D expenditures in the tax year, or can amortize expenditures over a period of more than sixty days. R&D must be performed in the country to be eligible for tax incentives, which are sales-based in that a firm can claim a tax credit whenever its R&D expenditures constitute a higher percentage of sales than in the year the base was fixed. Additionally, most states have their own R&D tax relief. Contributions to endowments would normally be classified as gifts and subject to up to 100% deduction.
United States Gross Domestic Product (Current US Dollars, Not Adjusted for Inflation)
Source: World Bank, World Development Indicators - Last updated June 15, 2010

United States Federal Direct Investment (Balance of Payments in US Dollars)
Source: World Bank, World Development Indicators - Last updated June 15, 2010
Lessons learned:

- A large internal competitive markets play an instrumental role in achieving economic success and in particular in creating cutting-edge high-technology products and services.
- Government procurement creates markets necessary to spur technology development.
- A strong university system is critical for providing a pipeline of technology and the human capital to complement it. Universities importantly should not only house basic research but also should focus on applying technology to private industry needs as well.
- Clear guidelines and regulations create an open and transparent environment necessary for attracting, retaining, and creating technology firms.
- Government catalyzes partnerships necessary for technology commercialization.
- Government financial capital is key to support research and early stages of technology development where investment from private industry is considered too high of a risk.
- In addition to cutting-edge research, a strong entrepreneurial and VC community is necessary to drive innovation regionally. As part of this ecosystem, a mechanism for investors to exit from their investments, e.g., NASDAQ, is also critical.
- Flexible, open, decentralized networks are an important component of a successful regional cluster.
- Government support for young business while maintaining more established companies creates a healthier innovation system (a mix of new and mature companies is important).

Cautionary lessons learned:

- Federal policy not aligned with regional policy loses its optimal impact and likelihood of success.
- Funding basic research without supporting the later stages of research is not advantageous.
Early Foundation

The political development of the U.S. is characterized by a long-standing tension between the founding mission to keep government decentralized and local with the practical need for centralization in a large, rapidly growing nation. While early economic hubs, such as Philadelphia, Boston, New York, and the agrarian South, emerged early in the colonies, the need for a coordinated trade policy, common currency, and infrastructure created the need for a coordinated federal response. One of the earliest known statements for the government’s appropriate role was written by Alexander Hamilton in his 1791 document *Report on Manufactures*, which advocated an active role for the government in the economy of the young nation.\(^84\)

The U.S. military played an early role in the economic development of the nation by funding the development of defense-related technologies. Early defense-related contracts to Eli Whitney in 1798 to develop interchangeable musket parts and to Samuel Morse in 1842 to develop the telegraph are illustrative.\(^85\) Furthermore, the military—vis-à-vis the U.S. Army Corps of Engineers—oversaw the construction of much of the nation’s infrastructure. This mission was so important to the new nation that Thomas Jefferson established the U.S. Military Academy at West Point in 1802 to train future Army officers in engineering and the scientific disciplines and as the headquarters for the Army Corps of Engineers.

The work of Army Corp officers was supplemented by the work of graduates from the first private engineering schools in the U.S., including Rensselaer Polytechnic Institute and the Ohio Mechanics Institute, established in 1824 and 1828, respectively. Rapid westward expansion, immigration, and economic growth, however, created an enormous need for technically trained engineers and scientists, the demand for which these schools could not fully meet. To this end, Congress passed the Morrill Land Grant College Act in 1862, giving states federal lands based on their population (and consequent political representation in the House of Representatives). States were required to use the land or proceeds from the sale of the land to establish educational institutions that would “teach such branches of learning as are related to agriculture and the mechanic arts... in the several pursuits and professions in life.”\(^86\) A second Morrill Act of 1890 was designed to expand the network of land grant colleges in the southern U.S.

Subsequent federal legislation sought to build research capacity in these newly created universities as well as encourage the dissemination of new knowledge. The Hatch Act of 1887, for example, established a system of agricultural experimental stations to conduct relevant research related to agriculture, the largest economic sector in the mid-1800s. The Smith-Lever Act of 1914 created the Cooperative Extension Service to encourage the dissemination and application of new knowledge from newly created state land grant universities and stations.\(^87\) The Morrill Act and subsequent legislation combined with state leadership resulted in a decentralized, nationwide network of technical universities dedicated to training skilled engineers, conducting research, and providing technical assistance to industry—primarily farmers—within their respective states.

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85 Wessner, *The Advanced Technology Program*.


The onset and conduct of the American Civil War introduced a wide range of scientific issues for the young republic in terms of medicine, engineering, weaponry, and food preservation. While a number of early scientific societies existed at this time, Congress and President Lincoln established the National Academy of Sciences in 1863, a nonprofit, nongovernmental organization designed to provide nonpartisan scientific advice to the federal government. Subsequent acts by the federal government to establish the Laboratory of Hygiene in 1879 (which would become the National Institutes of Health in 1930), the National Bureau of Standards in 1901, the National Advisory Committee on Aeronautics, and the creation of the National Cancer Institute in 1937, all demonstrated the increasingly active role of the federal government in scientific research.

Furthermore, the government took an active role in applied technology development and industry formation. For example, during World War I, the U.S. Navy sought to create a government-owned monopoly in order to rapidly advance radio technology to meet the emerging requirements for improving ship-to-ship communication. It did this by suppressing patents held by U.S. radio manufacturers and pooling them to form a radio company with all sales going to the Navy and Army. Although Congress eventually rejected the idea for a government-controlled monopoly, the Navy later partnered with General Electric to help establish the Radio Corporation of America (RCA) in 1919, not only ceding its radio patents but also guaranteeing a market for its products.

**World War II and The Cold War**

In the 1940s, the U.S. government mobilized, and in some cases directed, production within the U.S. economy in order to provide materiel support for the U.S. military and its allies during World War II. In addition to military procurement, the government created new programs and invested in the development of new technologies through the Office of Naval Research and other Pentagon agencies. Government investments in radar, aerospace, computing, health, and atomic energy were not only crucial to the outcome of the war, they also led to the formation of many of the leading industries in the U.S. today. For example, the University of Pennsylvania was commissioned by the Army’s Ballistic Research Laboratory in 1943 to build the ENIAC, the first digital reprogrammable computer.

In addition to existing Pentagon research agencies, the government created the Office of Scientific Research and Development (OSRD) in 1941 to coordinate U.S. S&T assets to support the war. Led by Vannevar Bush, a well-known engineer and computer scientist, OSRD was credited with organizing no fewer than 6,000 scientists and had access to vast funding and resources. It was created to improve the accuracy and reliability of weapons, create more versatile vehicles, improve the efficacy of medical treatments and—most secretive—develop nuclear weapons, among other missions.

Vannevar Bush reported directly to President Franklin Roosevelt and in effect became the first presidential science advisor. Bush developed an understanding of the role of the government in S&T development not only for military success but also for medicine, the physical sciences, and the overall condition of U.S. society. In 1945, Bush wrote a report to the President entitled *Science, the Endless Frontier*, which articulated the importance of basic science as a foundation for technological progress.

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90 Wessner, *Government-Industry Partnerships*.
and argued for the creation of a civilian agency that would be responsible for funding it. Bush’s idea was mostly realized in 1950 with the creation of the National Science Foundation, which competitively awards basic research grants to university researchers.

After World War II, tensions increased between the (then) Soviet Union and the U.S. and their respective allies over the political makeup of Europe and peripheral regions. This Cold War resulted in political, economic, and technological competition, including several proxy wars. The Soviet launch of Sputnik in 1957 is considered by many to be the beginning of the so-called Space Race: competing demonstrations of scientific and technological superiority as signs of national strength. In any case, Sputnik, along with the preceding Russian development of the world’s first intercontinental ballistic missile, mobilized political support in the U.S. for a series of S&T investments and programs important to the future of the U.S. economy.

In response to Sputnik, the government created the Advanced Research Projects Agency (ARPA—later renamed DARPA, adding “Defense” to the title) in 1958. Unlike more conventional military R&D entities, DARPA was created to ensure advanced technological sophistication for the entire Department of Defense, not just one branch or mission. DARPA accomplishes this through a small, flexible, interdisciplinary staff of highly educated, rotating individuals who seek out and support advanced technologies within universities, companies, individuals, and labs. DARPA is credited for helping develop, among other things, the Internet, high-performance computing capabilities, advanced aerospace composites, robotics, and the global positioning system.

The National Aeronautics and Space Administration (NASA) was also created in 1958, to advance rocket propulsion, jet propulsion, and other technologies necessary for effective space and air travel. Through a series of rapid development projects, including Mercury, Gemini, Apollo, STS, and others, NASA developed the specific technologies and capabilities needed for manned space flight—while Mariner, Voyager, Mars Pathfinder, and other projects focused on unmanned exploration. Over time, NASA has been crucial in the development of industry-relevant technologies in energy, medicine, weather, satellites, and of course aircraft and rocketry.

The U.S. government also focused on education as an important element to build and advance U.S. technological strength. For example, the National Defense Education Act of 1958 provided more than $1 billion for school construction, the creation of vocational programs, and a wide range of fellowships to help educate the brightest U.S. minds in critical scientific, math, and technology-oriented fields. Furthermore, the 1966 version of the G.I Bill—with previous versions initially passed in 1944 and 1952—provided stipends to offset college tuition to any individual who had served in the military in times of war or peace. These programs, combined with the expansion of college campuses and the evolution of 2-year community and technical colleges, were critical to increasing postsecondary education attainment rates within the U.S. and helped contribute to a generation of technically trained individuals important for an innovation economy.

Finally, in 1958 Congress passed the Small Business Investment Act, which allowed the Small Business Administration—an agency created in 1953 to advance and protect small business concerns—to license small business investment companies (SBICs). SBICs are limited liability, private investment companies designed to encourage entrepreneurship and spur innovation by filling a major capital funding gap specifically for small businesses. The Act stipulated that SBICs would be established with a minimum of $5 million in capital, be staffed by “professional personnel,” and serve the funding needs of small companies. In return, SBICs received relatively easy access to leverage capital, with

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the SBA providing guaranteed 10-year leverage loans of up to 300% of capitalization, not to (currently) exceed $108.8 million.\(^{93}\) SBICs not only helped shift attention to the importance of small businesses in innovation and the economy but also created the foundations for the growth of VC, primarily in California.

### Contemporary Policy

Similar to how military conflict influenced early U.S. S&T policy, lagging productivity and the decline in the global competitiveness of U.S. firms has had a similar effect in the development of contemporary U.S. S&T policy. The internal competitive U.S. market combined with its diverse immigration-based population had played an instrumental role in achieving economic success and in particular in turning technology into saleable products and services. Now that the market was being integrated globally, the U.S. needed to figure out how to achieve international leadership with international competition. Declining market shares of U.S. firms and substantial job loss in the U.S. during the 1970s and early 1980s were attributed not only to the rapid growth of large, foreign multinational companies, especially from Japan and Germany, but also to aggressive trade and industrial policies within these nations.\(^{94}\) In response, the U.S. government passed a series of policy reforms and programs intended to improve the competitiveness of U.S. firms through intellectual property reform and promotion of technology transfer, deregulation, and the establishment of public-private partnerships to develop new technologies.

#### Intellectual Property Reform and Technology Transfer

Part of the response to the perceived competitiveness challenge was an attempt to use federal funding more effectively by stimulating the dissemination of new knowledge. While the federal government provided billions of dollars in R&D funding to universities and federal laboratories, critics complained that new technologies either “sat on the shelf” or were subjected during their transfer to a patchwork of complex bureaucratic laws and rules. Beginning in the early 1980s, Congress passed a series of measures to address these problems. These measures included:\(^{95}\)

- The Stevenson-Wydler Innovation Act (1980). This act required a certain percentage of federal laboratory R&D budgets be directed towards technology transfer to the private industry. This effort was an attempt to aid industry in achieving global competitiveness.
- The University and Small Business Patent Procedures Act, or Bayh-Dole Act (1980). This act gave universities, small businesses, and nonprofit organizations title to intellectual property (IP) derived from federal research funding. While universities were allowed to own this IP, technology transfer rules and regulations differed among federal mission agencies. The Bayh-Dole Act harmonized these disparate guidelines and sought to foster relationships between the academic and the business communities.
- The Federal Technology Transfer Act (1986). This bill amended the Stevenson-Wydler Act to authorize cooperative research and development agreements (CRADAs) between businesses and national labs, to accelerate the commercialization of government research.
- The National Competitiveness Technology Transfer Act (1989). This bill amended the Stevenson-Wydler Act to allow contractor-operated national labs to enter into cooperative R&D agreements.

While technology transfer activity at the national laboratories grew substantially in the 1990s, the number of CRADAs has since leveled off and fluctuated from year to year. However, since the passage of

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the Bayh-Dole Act, knowledge dissemination vis-à-vis the patenting and licensing of university IP has continued to grow. Furthermore, the number of entrepreneurial ventures established using university intellectual property—otherwise known as university spinoffs—has also grown.96

Most critics would likely agree that the Bayh-Dole Act has had an overall positive role in the disclosure and dissemination of new technology vis-à-vis technology licensing and university spinoffs. However, the current policy is not without detractors; much has been written about the limitations of the current U.S. technology transfer model. These challenges include the propensity for universities to favor licensing revenue growth over more traditional university goals, such as knowledge dissemination, or more modern goals related to entrepreneurship. For example, a report by the Ewing Marion Kauffman Foundation called for the separation of academic entrepreneurship from the licensing of university technology due to conflicting goals within university technology transfer offices.97

**Antitrust Deregulation**

The government also sought to deregulate partnerships between and among companies within the same industry. For nearly 100 years, large U.S. firms have faced strict antitrust policies based on the theory of monopoly power, with the lack of market competition often resulting in higher prices, lower product quality, and slower rates of product innovation. However, U.S. economic theory evolved in the 1970s and 1980s to accept that R&D markets were different. Because knowledge “spills over” relatively easily, then firms without monopoly power have little incentive to conduct R&D, because they may not be able to enjoy the benefits of their investments. However, firms could overcome these challenges if they were allowed to cooperate in upstream technology research and—that development and production ventures.

In 1984, Congress passed the National Cooperative Research Act (NCRA) to address corporate antitrust concerns and spur joint ventures focused on generic, precompetitive research.98 NCRA did this by first stipulating that research joint ventures (RJVs) must not be automatically subject to antitrust laws but should instead be evaluated on a case-by-case basis depending on their impacts on markets. Second, NCRA established a registration procedure for companies participating in RJVs that limits their liability if prosecuted for antitrust violations and traditionally severe antitrust penalties.99 After the NCRA was enacted, RJVs were slow to proliferate and many experts, including well-known economists, criticized NCRA for not doing enough to deregulate R&D cooperation. They contended that antitrust regulation inhibits feedback from all steps of the innovation process, including research, development, production, and distribution. Therefore, in 1993, Congress approved the National Cooperative Research and Production Act (NCRPA). The NCRPA updated the NCRA by extending antitrust privileges vertically into development and production joint ventures. NCRPA not only relaxed antitrust regulations even further, it also helped precipitate a steadily growing number of formal and informal R&D ventures both domestically and internationally.100

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Public-Private Partnerships

In addition to IP and antitrust deregulation, the U.S. Government also focused on direct ways to encourage public-private partnerships to develop new technologies. While many experts focused on ways to stem the decline of large U.S. firms, new research highlighted the role and importance of small firms in employment growth.\(^\text{101}\) Furthermore, there was emerging recognition that innovation depends on the microeconomic process of firm creation and failure—prevalent among high-tech start-ups—that aids the overall evolutionary development of new technologies.\(^\text{102}\)

In 1982, Congress passed the Small Business Innovation Development Act to support small, high-tech businesses and meet a number of other public goals. The Act created the Small Business Innovation Research (SBIR) program specifically to (1) stimulate technological innovation, (2) use small business to meet federal research and development needs, (3) foster and encourage participation by minority and disadvantaged persons in technological innovation, and (4) increase private sector commercialization of innovations derived from federal R&D.\(^\text{103}\) The SBIR program sought to meet these goals by mandating that agencies with R&D budgets over $100 million set aside 0.2% of their funds for the program. Subsequent reauthorizations of the program have increased this percentage incrementally to 2.5% of agency extramural research budgets.

Eleven mission agencies currently participate in the SBIR program, including:
- Department of Defense
- National Institutes of Health
- Department of Energy
- National Aeronautics and Space Administration,
- Department of Homeland Security
- National Science Foundation
- National Institute of Standards and Technology
- Environmental Protection Agency
- Department of Transportation
- Department of Education
- Department of Agriculture

SBIR grants are awarded in two competitive phases. Depending on the specific mission agency, phase I grants are for as much as $100,000 for 6 months, while phase II grants are for as much as $750,000 for 2 years. Agencies can seek waivers from the Small Business Administration—which coordinates and oversees policy among the agencies—to increase award size. While recent congressionally mandated reviews of the program suggested a number of improvements to the program, including an increase in award size and continued agency flexibility, findings indicate that the program is a critical component in the U.S. innovation system and important for meeting mission agency needs.\(^\text{104}\)

\(^{101}\) For a review of this research, see Zoltan Acs, David Audretsch, *Innovation and Small Business* (Cambridge, MA: MIT Press, 1991).

\(^{102}\) See David Audretsch, *Innovation and Industry Evolution* (Cambridge, MA: MIT Press, 1995). Audretsch’s concept of market turbulence draws from Joseph Schumpeter’s notion of “creative destruction” by which radical innovation transforms economies. In his vision of capitalism, Schumpeter saw that the entry of innovative entrepreneurs in the market sustained long-term economic growth, even as it destroyed the monopoly positions of established companies. This remains true today; see Clayton Christensen, *The Innovator’s Dilemma* (New York: Harper Business, 2000) for contemporary examples.

\(^{103}\) Charles Wesser, *Small Business Innovation Research Program*.

\(^{104}\) Charles Wessner, *An Assessment of the Small Business Innovation Research Program*. 
The government also sought to encourage and create public-private partnerships through the Omnibus Trade and Competitiveness Act in 1988. The Act created both the Manufacturing Extension Partnership (MEP) program and Advanced Technology Program (ATP) within NIST (formerly the National Bureau of Standards). MEP is a network of not-for-profit centers funded by both states and the federal government to diffuse and implement manufacturing and other process technologies to small businesses. MEP centers are located in every state and have traditionally provided process improvement services—Lean, Six Sigma, Kaizen, and others—at a reduced cost, helping to reduce the operating expenses of small manufacturers. Recent MEP efforts have focused on improving product and service development among small firms.\(^{105}\)

The now-defunct ATP was created to “fund high-risk R&D with broad commercial and social benefits that would not be undertaken by a single company or group of companies, either because the risk was too high or the benefits of success would not accrue to the investors.”\(^{106}\) ATP did this by providing matching grants to technology development partnerships between or among large companies, small businesses, and universities and, in some cases, risky research projects within individual companies. Furthermore, the program was created with the (unique) capability to assess the performance of individual partnership projects and the economic impact of the awards, or lack thereof. Peer-reviewed evaluations of the program were generally very positive; ATP was praised for its program evaluation capability, rigorous competitive award review process, and numerous technological breakthroughs in multiple industries.

With that said, both MEP and ATP have been a source of political controversy since the mid-1990s. Critics claim that both programs exemplify corporate welfare and wasteful government spending. Consequently, this controversy has made both programs a target for cancelation and—at a minimum—budget cuts since the mid-1990s. While MEP survived, ATP was canceled in 2007 with the passage of the America Competes Act, and it has now been replaced by the Technology and Innovation Program (TIP), discussed below.

Similar to the global competition the U.S. faced in the 1970s and 1980s, today it faces a threat to economic security from countries such as China, a country with low wages that is capable of high-tech manufacturing. China is attracting key technology firms to set up manufacturing and R&D entities while, in parallel, Chinese students educated in the U.S. are returning home and beginning to drive high-end research and business growth.

Additionally, the general nature of innovation is changing. Innovation cycle times are much shorter—the automobile took over 50 years to invent, whereas the internet took 7 years—and innovation is now much more multidisciplinary and global in scope. In response to the increased competition from abroad and the changing nature of the innovation cycle, the U.S. recently renewed its focus on developing policies to foster innovation.

The U.S. academic and business communities are active participants in the development of these new policies. Specifically, they played a major role in the passage of the America Creating Opportunities To Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act in 2007.\(^{107}\) This law was primarily a product of two influential reports: Innovate America,\(^{108}\) issued in 2004, and

106 Charles Wessner, The Advanced Technology Program.
107 America COMPETES Act, Public Law No. 110-069 (introduced into the House of Representatives on May 21st, 2007, became law on August 9th, 2007).
Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, issued in 2007. Representatives of academia and industry were heavily involved in building consensus for the America COMPETES Act—the Advisory Council for the Innovate America report was cochaired by Samuel Palmisano, Chairman and CEO of IBM Corporation, and Wayne Clough, President of the Georgia Institute of Technology; the Advisory Council for the Rising Above the Gathering Storm report was chaired by Norm Augustine, former CEO of Lockheed Martin.

The America COMPETES Act includes a comprehensive set of policies regarding investment in education (e.g., new math tools for teachers in elementary and middle schools), investment in R&D (e.g., doubling of basic research investment for physical sciences), development of economic policy directed towards innovation (e.g., R&D tax credit), and investment in infrastructure necessary to spur innovation (e.g., ubiquitous broadband internet access).

In addition to highlighting the importance of involving both academia and industry, it is important to highlight two programs created as part of this law that build off the policies established in the 1980s and play an important role in promoting technology commercialization.

**Advanced Research Projects Agency-Energy**

As specified in the America COMPETES Act, the Advanced Research Projects Agency-Energy (ARPA-E) was established under the U.S. Department of Energy (DOE) in 2007 and received its initial funding allocation—$400 million—through the American Recovery and Reinvestment Act of 2009. The purpose of the program is to fund high-risk, high-reward, transformational energy research that might not be otherwise funded by the private sector.

ARPA-E utilizes a challenge-based model similar to that of DARPA; critical areas of interest are identified by ARPA-E staff, in cooperation with other agencies, and through a series of regional workshops, and then requests for proposals are publicly released. For example, the most recent requests for proposals, released on March 2, 2010, will fund projects in the technology areas of grid-scale rampable intermittent dispatchable storage, agile delivery of electrical power technology, and building energy efficiency through innovative thermodevices.

Applicants submit eight-page technical “concept papers” outlining their concept. Those that make the first cut are invited to submit full applications. ARPA-E funds winning projects through three distinct mechanisms: grants to individual companies or researchers, cooperative agreements between DOE labs and companies or universities, and Technology Investment Agreements, a cost-share collaborative research agreement involving one or more companies. Like DARPA, ARPA-E staff are given significant freedom and resources to choose and manage these projects so long as they meet the goals of the program based on measurable outcomes.

**Technology Innovation Program**

America COMPETES Act also created the Technology Innovation Program (TIP) to fund high-risk, high-reward areas of national technology need not necessarily covered by other mission agencies. TIP requests for proposals correspond to critical national needs identified by the TIP Advisory Board, other

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United States Regional Foundations for Innovation and Entrepreneurship

The program received an approximately $70 million appropriation for the 2010 budget year. TIP awards range from $3 million USD for up to 3 years for individual companies and up to $9 million for up to 5 years for joint ventures. Company participants must collectively provide at least 50% of the total project cost and cover all indirect costs. While companies lead most projects, universities may also lead so long as a small business is also a member of the project, or they may participate as a member of a joint venture involving multiple companies. In-kind contributions are counted toward the program’s cost share requirement.

TIP staff is also given a great deal of flexibility to manage projects, while the Impact Analysis Group monitors, quantifies, and analyzes outcomes and impacts of the program.

Regional Foundations for Innovation and Entrepreneurship

Not only has innovation policy at the federal level played an important role in U.S. economic growth, but also fostering innovation has done so at a regional level. Drawing upon the work of Harvard Business School Professor Michael Porter, policymakers have focused on creating regional technology “clusters” to promote innovation. Silicon Valley and Route 128 are perhaps the most widely discussed examples of regional clusters in the U.S. The regions developed very differently despite the presence of many of the same elements, such as (1) direct and indirect involvement by the federal government, (2) the presence of world-class research institutions, (3) the presence of a community of venture capitalists and entrepreneurs, and later (4) institutions with a focus on applied sciences.

While Boston has been a hub for higher education for centuries, MIT and, to a lesser extent, Harvard University, have been credited with the economic growth and dynamism of the region. MIT in particular has played a critical role in the development of new technologies and creation of well-known spinoff companies.

Since its establishment as a land grant college in 1861, MIT has encouraged research and consulting for private industry. This early focus combined with its long tradition of military funding is thought to have had a significant influence on the economic gains the region recognizes today. For example, during World War II, OSRD funded the establishment of a Radiation Laboratory in 1940 to help British scientists develop the first microwave radar system. By the end of the war, MIT employed more than 4,000 scientists and was the largest government R&D contractor.

The aforementioned tensions between the U.S. and Soviet Union led to increasing amounts of defense-related funding for MIT, which came from a variety of government sources. Funding ranged from large-scale outlays directly from DoD, such as the establishment of Lincoln Labs in 1951, to numerous R&D grants to individual faculty members from DARPA, ONR, and NASA. During this time, not only did MIT receive significant funding, but also the government funded the development of new technologies within private companies, most of which had been established by or had ties to MIT alumni. As a result,

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the defense contracts for research, development, and procurement aimed at ensuring U.S. national security contributed to the economic growth around MIT.\textsuperscript{116}

With the emergence of these MIT-affiliated companies also came the seeds of a strong VC community that preceded the aforementioned creation of SBICs. In 1946, a group of New England financiers and academics, including MIT president Karl T. Compton, organized the American Research and Development (ARD) Corporation, the first publicly held VC company in the nation, to supply financial capital to research-based enterprises.\textsuperscript{117} The early successes of ARD-funded companies inspired other financial institutions to invest in technology. As start-ups and spin-offs (mostly in the ICT industry) began to emerge, a pool of experienced entrepreneurs was created. As a result, the Boston region emerged as an important ICT cluster, with the establishment and growth of companies such as Raytheon, Digital Equipment Corporation, and Analog Devices.

While the majority of companies in the Boston region had (and indeed still have) ties to MIT, the development of Silicon Valley was arguably more complex and diffuse. Certainly, Stanford University, with its long-standing traditions of entrepreneurship, service, and relationships with industry, has played a critically supportive role in the emergence of the region. However, the development of the region cannot be traced to a single institution but is attributed instead to the concerted R&D and procurement efforts of the federal government, along with the unique social networks and culture that emerged from the numerous opportunity-seeking pioneers that settled in the region.\textsuperscript{118,119}

In 1939, Stanford graduates Bill Hewlett and Dave Packard established Hewlett-Packard, since considered Silicon Valley’s founding firm, in their garage on the eve of U.S. involvement in World War II. At that time, a general fear existed regarding the relative lack of population and economic growth in the western U.S. compared with the East Coast, especially given Japanese aggression in Asia.\textsuperscript{120}

For military procurement, the U.S. Department of Defense historically favored large, vertically integrated defense contractors that could deliver large volumes, most of which were located on the East Coast or in the Midwest. However, beginning in the early-1940s, military R&D and procurement officers were told to give special consideration to the small aerospace, radio, and later computer component producers on the West Coast. Companies like Varian Brothers, whose company produced vacuum tubes, Hewlett-Packard’s continued growth and production of scientific instruments, and later the establishment of Fairchild Semiconductor and (later) Intel, were beneficiaries of government contracts or of component subcontracts for products sold directly to the government.\textsuperscript{121}

By the 1950s and 1960s, California was by far the largest recipient of defense-related R&D funding, primarily around aerospace, avionics, computers, communications, and solid-state materials. Although several small firms in the San Francisco Bay Area had sold out to East Coast firms, successful public offerings in the mid-1950s by Varian and Hewlett-Packard were important financial breakthroughs.

\begin{itemize}
\item[117] Saxenian, \textit{Regional}, 15.
\item[118] Saxenian.
\item[120] Graham 412–417.
\item[121] \textit{Ibid.}
\end{itemize}
Furthermore, large firms like Fairchild and DuPont began to invest in new corporate ventures based on new technologies as a way to diversify and avoid antitrust prosecution.\textsuperscript{122}

The aforementioned establishment of SBICs in 1958 had a significant impact on the evolution of the Silicon Valley VC industry that we know today. By the early 1960s, many of the individuals involved in the formation of ARD moved to California to establish family SBICs, providing a much-needed financing alternative to more conservative East Coast banks. The SBIC organization became an important stepping stone for participants to learn the nuances of investing in early-stage start-ups with backing from the government.

After several years of experience, many SBICs were reestablished or closed so investors could establish VC firms, taking advantage of limited liability partnerships status—by far the most common organizational form currently—while avoiding many of the regulations associated with SBICs.\textsuperscript{123}

Between 1968 and 1975, as many as 30 VC firms were established, coinciding with the rapid emergence of the computing and semiconductor industries. Furthermore, major acquisitions, such as that of Scientific Data Systems by Xerox for 1 billion dollars, and the success of particular technology platforms, such as the Apple II computer, did much to attract additional VC investment.

Although returns in the 1970s for VC firms were high, averaging 20 to 30%, VC investments were tied to relatively small groups of individuals or families, making investment sizes modest. In the late 1970s, this changed substantially. First, in 1978 the government significantly reduced the tax on capital gains from a maximum of nearly 50% to 28% of earnings. Second, Congress passed the Employment Retirement Income Security Act (ERISA) in 1979. ERISA not only allowed pension funds to invest in VC funds, it also said that such a move was “prudent” so long as the percentage of a pension’s portfolio was relatively small. This attracted significantly higher levels of investments, shifting the focus of VC funds from a small niche market catering to wealthy families to one that serviced large institutional investment pools.

Finally, the establishment and growth of the NASDAQ also played an enormous role in the emergence of the entrepreneurial culture of Silicon Valley. The NASDAQ was established in 1971 as the world’s first electronic trading market. While the New York Stock Exchange is comprised of many iconic U.S. companies, the NASDAQ attracts the IPOs of high-tech companies due to the higher trading levels and ease of transactions. Furthermore, NASDAQ IPOs have provided VC firms with the opportunities they need to exit from their investments, realize their return, and invest in a new generation of start-ups.

Interestingly, while the ICT industry evolved during a similar time period in both Route 128 and Silicon Valley, the regions evolved differently, ultimately with Silicon Valley becoming the leader in the ICT industry. Fundamentally, it is viewed that Route 128 was unable to respond to the international competition, whereas Silicon Valley did. One thesis explaining the origin of this is discussed in Saxenian’s book \textit{The Regional Advantage}.\textsuperscript{124} As mentioned previously, the U.S. DoD historically favored large, vertically integrated defense contractors for military procurement. Although Route 128 benefited tremendously from the U.S. Government’s procurement needs, it ultimately resulted in a region dominated by a small number of firms with strong corporate hierarchies and that internalized a wide range of production and business activities. This resulted in very little need to interact with other firms – a phenomenon Saxenian refers to as the “independent firm-based system.” Silicon Valley, in contrast, is described by Saxenian as having a “regional network-based industrial system.” This network is rooted

\textsuperscript{122} Ibid.
\textsuperscript{123} Ibid.
\textsuperscript{124} Saxenian.
on the region’s dense social networks and open labor market, both of which encourage risk taking and entrepreneurship. Although companies compete with one another, they also learn from one another through informal communication and collaborations catalyzed by the horizontal structure between the suppliers, customers, and larger companies. Additionally, it was culturally accepted for employees, especially engineers, to move from one company to another, whereas loyalty to a company was part of the fabric of the Route 128 region. Although both regions encompass many of the traditional factors that are attributed to regional cluster success—strong research university, a VC community, technical skill, and specialized suppliers—the rise of Silicon Valley as the ICT leader is ultimately attributed to its unique decentralized network and open culture.

Emergence of the Boston Life Sciences Cluster

Despite the decline of the ICT industry in Boston, the area is now a global leader in life sciences. It has the world’s largest concentration of life sciences firms, researchers, and academic medical centers, attracting $2.2 billion annually from the NIH, the primary U.S. government funding agency for life sciences. When this funding amount is adjusted per capita, Boston’s home state of Massachusetts leads the U.S. in NIH funding received. Private investment in life sciences companies is currently $1.3 billion, and the state’s life sciences workforce grew 8% between 2001 and 2006, even as the overall Massachusetts workforce shrunk 2.5%. The success of Boston’s life sciences cluster is built on many of the same elements that marked the initial ascension of the region into the ICT industry.

At the heart of the Boston bioscience cluster’s success are strong academic institutions with world-class, cutting-edge research. Boston-based researchers, mostly at MIT and Harvard, won 23 Nobel prizes in fields related to the life sciences between 1914 and 2006. One such example is the work of Philip Sharp, who helped launch the life sciences industry in Cambridge, Massachusetts. His Nobel Prize work pioneered a method for rapidly reading the nucleotide sequences of DNA and RNA.

While MIT receives much credit for its role in the ICT industry and the growth of Boston in general, Harvard has also played an important role, especially in the life sciences, given its focus on basic research. For example, as far back as 1906, Harvard purchased the 26-acre Longwood Medical Area, which now plays an integral role in the growth of the life sciences industry as a medical research center. The combination of the two universities—one focused more on basic research and the other more on applied research—in close proximity to several top teaching hospitals provided a strong basic and applied S&T foundation as the region developed into a life sciences hub.

The key inputs for innovation described above do not by themselves guarantee a region’s economic success. Another catalyst for growth, perhaps counterintuitively, was the establishment of early government regulations. In 1977, the City Council of Cambridge, the city adjacent to Boston where Harvard and MIT are located, issued the nation’s first municipal biosafety ordinance. The local law mandated that the NIH Biosafety Guidelines be followed for research using biological agents regardless of the funding source and permitted local regulatory oversight to ensure compliance. The impetus for this law was national

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126 New England Healthcare Institute, p. 11.
concerns about the potential health hazards associated with genetic and viral biological research agents that were being planned for a new laboratory at Harvard. When the announcement for the new laboratory was made public in 1976, it spurred a response from the Cambridge community that resulted in a series of hearings and science fairs to educate the public. These discussions and debates culminated in the passage of this landmark ordinance.130

This law applied only to university research and not to research being conducted by private industry. But because this was a nascent industry, and much uncertainty with regard to future regulations existed, the fact that Cambridge addressed the issue candidly was attractive to industry as well. In 1980, Biogen was looking to expand in Cambridge, near its founding scientists at Harvard and MIT. Seeking an environment of predictable regulation, the company initiated public hearings on regulations for research outside of academia. In 1981, the Cambridge Biosafety Ordinance was issued, encompassing bioscience research, development, and scale-up in private industry. Shortly thereafter, Biogen held its ribbon-cutting ceremony in Cambridge. Soon after that, the city’s mayor gave a tour of Cambridge to Genetics Institute executives looking to expand their companies operations, who, in the end, did.131

As has been noted, it may seem counterintuitive that greater regulation could be attractive to business. But in the late 1970s, when the life sciences was a nascent technology area rife with uncertainty, it had a positive effect indeed. Not only did the regulations increase the certainty of the business landscape, but the process of crafting ordinances spurred public discourse through which the community became educated about the industry’s needs and opportunities.

Over time, biotechnology companies began setting up shop in Cambridge, particularly the area around Kendall Square near MIT. Specifically, in the 1960s, following major molecular biology breakthroughs of the two previous decades, MIT converted a factory in Kendall Square into Technology Square. This rooted biotech companies such as Biogen Idec and Genzyme, both of which benefited from the nearby Longwood Medical Area.132 Young biotechnology companies evolved alongside established biotechnology and pharmaceutical companies, such as Wyeth and Novartis. Close proximity of small and big firms often proves advantageous for both groups. Small firms can receive market information and even access to entirely new markets from big firms, while big firms can access the wide range of new technologies being developed by small firms.133 The central nodes of the Boston biotechnology cluster—Harvard, MIT, Kendall Square, and Longwood Medical Area—were all within a 3-mile walk of one another.134

Sustainment and Growth of Life Sciences Cluster

Today, there are approximately 95 biotechnology companies located in the Kendall Square area.135 Regional policy and initiatives as well as MIT’s focus on entrepreneurship have supported the industry’s continued growth.

130 Summarized from Feldman and Lowe.
131 Summarized from Feldman and Lowe.
132 New England Healthcare Institute, p. 5-6.
134 New England Healthcare Institute, p. 5-6.
Contemporary Policy

In 2006, the State legislature created the Massachusetts Life Sciences Center. This center makes strategic investments in the life sciences workforce and in translational research at critical stages of development. It quickly became a hub connecting key life sciences stakeholders, giving specific attention to the formation of public-private partnerships.\(^\text{136}\)

In 2007, the State government announced a comprehensive $1 billion life sciences initiative for Massachusetts. This 10-year investment package contains two main thrusts: (1) further enhancing the state’s preeminent medical and scientific assets and (2) bridging gaps in federal funding to ensure the progress of life sciences innovation in Massachusetts, from conceptualization through commercialization. The strategy aligns industry, academic research hospitals, and public and private colleges and universities to coordinate these efforts, spur new research, strengthen investments, create new jobs, and produce new therapies that improve quality of life. As part of this initiative, in 2008, the Research Matching Grant program was created to provide $12 million for translational research\(^\text{137}\) and the Massachusetts Life Science Center created the Life Sciences Tax Incentive Program. This program authorizes up to $25 million in tax incentives each year for companies engaged in life sciences R&D, commercialization, and manufacturing. The primary goal of the program is to incentivize life sciences companies to create new long-term jobs in Massachusetts. The Act provides for nine different incentives, which address the significant capital expenditures associated with the life sciences R&D cycle and the high costs of translating research into commercially viable products.\(^\text{138}\)

These nine incentives are:

1. **Life Sciences Investment Tax Credit.** This credit is equal to 10% of the cost of qualifying property acquired, constructed, reconstructed, or erected during the taxable year.

2. **FDA User Fees Credit.** This credit is for 100% of user fees paid to the U.S. Food and Drug Administration and may be claimed in the taxable year in which the application for licensure of an establishment to manufacture the drug is approved by the Food and Drug Administration.

3. **Extension of net operating losses from 5 to 15 years.** This allows a certified life sciences company to carry forward losses for up to 15 years.

4. **Elimination of the throwback provision in the sales factor used in apportioning corporate income.** This allows a certified life sciences company to be deemed to be taxable in the state of its purchaser if the property purchased is delivered or shipped to another state.

5. **$38M research credit refundable.** This act makes the research credit refundable for a certified life sciences company or person.

6. **Life Sciences Research Credit.** This act provides qualifying companies with a means to obtain a research credit for certain expenditures not qualifying for the existing research credit.

7. **Deduction for qualified clinical testing expenses for orphan drugs.** This act allows a Massachusetts deduction for qualified clinical expenses for certain drugs for rare diseases or conditions.

8. **Life sciences companies deemed to be R&D corporations for sales tax purposes.** This act allows a certified life sciences company to be deemed an R&D corporation for purposes of the sales and use tax exemptions.

\(^\text{136}\) New England Healthcare Institute.  
\(^\text{137}\) New England Healthcare Institute.  
9. Sales tax exemptions for property for use in the development of certain facilities and utility systems. This act grants a sales tax exemption for certain tangible personal property purchased for a certified life sciences company.

**MIT Entrepreneurship Initiatives**

Built on MIT's early focus on commercialization of research is its more recent commitment to creating an entrepreneurial environment. Both contribute enormously to the Boston area’s innovative culture. Major MIT programs focused on entrepreneurship are highlighted below.

- Established in 1945, the MIT Technology Licensing Office (TLO) pioneered a strategy of leveraging MIT IP to form companies by taking equity in lieu of royalties. It assists MIT inventors in protecting technologies and in licensing those technologies to existing companies and start-ups. The TLO is a department of the University, reporting to the Vice President of Research, who in turn reports to the Provost. It has a research budget of $1.2 million. Inventors share one-third of royalties after deduction of a 15% administration fee and any unreimbursed patent expenses. MIT takes royalties or, as discussed above, takes a small percentage of equity in lieu of royalties. The MIT TLO is one of the most active and successful programs in the U.S, licensing 224 new companies in just the past 10 years.

- The MIT Enterprise Forum, created by alumni in the 1970s, builds connections between technology entrepreneurs and the communities in which they reside and produces extensive educational programming about entrepreneurship. The Forum currently has 24 chapters worldwide, including one in Russia as of June 2010.

- In the 1990s, the MIT Entrepreneurship Center launched nearly 30 new courses across MIT on entrepreneurship and helped to create student entrepreneurship clubs. This effort has been credited with strengthening the network between students and nearby entrepreneurs and venture capitalists, ultimately leading to new company formation.

- In 2000, the Venture Mentoring Service was created to support any member of the MIT community who was considering launching a new venture. As of 2009, 88 companies had been formed through this service.

- In 2002, the Deshpande Center for Technological Innovation was founded as part of MIT's School of Engineering to provide research grants to faculty with commercially promising ideas. This initiative offers financial support to a university professor, rather than seed money to a business that has already produced a prototype of a product. This is being termed a “proof-of-concept center,” as opposed to an incubator. Jaishree and Gururaj Deshpande donated $17.5 million to create the Center. It has an annual budget of about $1.7 million, with $1.3 million for grants, $320,000 for administration and staff, and $80,000 for operational expenses. The Center provides up to $250,000 per project through biannual rounds of grant proposals and two types of grants: Ignition Grants (up to $50,000) for exploratory experiments and proof of concept and Innovation Grants (up

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139 Roberts, Eesley.
140 O'Shea.
141 Roberts, Eesley, 8.
142 Roberts, Eesley, 7.
143 Roberts, Eesley, 7.
144 Roberts, Eesley, 8
145 Roberts, Eesley, 9
Sustainment and Growth of Life Sciences Cluster United States

to $250,000) to fully develop the innovation. It has funded over 64 projects and awarded over $7 million in grants. There is an 18% approval rate of proposals. Spinoffs have acquired $88.7 million in private capital.147

- MIT Media Lab. The MIT Media Lab is a department within MIT's School of Architecture and Planning that was opened in 1985 by MIT Professor Nicholas Negroponte and the late Jerome Wiesner (former science advisor to President John F. Kennedy and former President of MIT). Based on the recognition of the increasing role of computing, publishing, and broadcasting in a quickly transforming communications industry, the Lab is devoted to multimedia projects on the cutting edge of technology research. It became well-known in the 1990s through a series of inventions in the fields of networks and the internet, and it currently has a bioscience-related focus on “human adaptability,” such as the treatment of dementia or mental illness, the development of technologies for monitoring health, and the development of smart limbs for amputees.148 The Lab has significant industry funding and involvement. A diverse group of more than 60 corporate sponsors, not limited to any specific sectors, is responsible for the majority of the Lab’s annual budget. Most sponsors act as members of various thematic consortia, including Digital Life, Things That Think, and Consumer Electronics Lab. The Lab generates about 20 new patents every year.

In addition to the formal programs outlined above, entrepreneurial MIT alumni are concentrated in the Boston area, creating a crucial pool of entrepreneurs. Many of these entrepreneurs have also become venture capitalists, thereby satisfying another requirement for new company formation. In this case, the venture capitalists provide not just money but also knowledge, experience, and a network. Many of them also teach classes at MIT, exposing students to both the theory and the practice of start-up formation.

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Lessons Learned

Drawing from the discussion above, the cases of both the U.S. federal innovation system and the Boston area’s life sciences cluster illustrate several principles worthy of consideration by countries seeking to enhance their innovation system.

- The large internal competitive U.S. market played an instrumental role in achieving economic success and in particular in creating cutting-edge high-technology products and services.
- U.S federal innovation policy is decentralized. The impact and success of federal programs depend on the action, composition, and culture of local regions and institutions. Specifically, universities operate in a decentralized manner and compete for resources with no core funding. Generally, U.S. federal policies are not well-aligned regionally. Boston is an exception to this statement, where local and state policies are well-aligned with the federal policies.
- U.S. national security needs and global economic competitiveness are both strong drivers for technology development. Government S&T investments and procurement seeded the development of many of the leading U.S. industries today.
- U.S. universities play a key role in the innovation system.
- Investments across the spectrum of basic to applied research at U.S. universities is important. Specifically in the life sciences industry, teaching hospitals and clinical centers play an integral role in transferring basic research to the marketplace. Research universities and teaching hospitals supply the technically savvy and educated workforce necessary to support technological innovation in the U.S. University proximity to private industry and in the case of the life sciences example, hospitals, has proven to be beneficial for technology commercialization and U.S. regional cluster formation.
- U.S. universities, such as MIT, that have a commitment to entrepreneurship have served as a seed to creating new ventures and ultimately an entrepreneurial region.
- U.S universities have traditionally attracted top international S&T talent, much of which went on to work in leading U.S. companies or to start their own enterprises.
- Clear and transparent guidelines have provided a fertile ground for technology creation and development in the U.S.
- As was shown in the case of the Boston’s life sciences cluster, for nascent technology areas where there is a perceived societal risk, establishment of clear regulations is important.
- MIT’s clear policies to support and encourage startup formation by academics has spurred the creation of numerous new ventures.
- Laws defining the use of IP generated from U.S. Government-funded research encourage commercialization.
- Partnership creation in the U.S. is critical for technology development and commercialization.
- Involvement of key stakeholders, industry, government, and academia, of the innovation system in government policy making is important.
- Precompetitive research agreements between businesses are necessary to facilitate high-risk game-changing technology development.
- Partnerships between government labs and industry are crucial for moving government research to the marketplace.
- Public and private financial support for both research and development is necessary to drive U.S. technological innovations.
The U.S. Government funds basic research at universities and also conducts research at national labs, research that private industry will not undertake.

Early-stage seed funding plays a key role in further developing technologies. Programs such as TIP (formerly ATP) and DARPA (ARPA-E) have proven effective for helping technologies cross the risky “Valley of Death” phase.

VC funding is critical. Not only is the financial capital itself important, but those who have been entrepreneurs play an even more important role in that they bring their knowledge, experience, and network to new venture creation and contribute to creating a necessary pool of serial entrepreneurs. Colocation of venture capitalists and entrepreneurs facilitates interaction and creates opportunities. Furthermore, an exit mechanism for investors is also critical. NASDAQ IPOs have provided VC firms with the opportunities they need to exit from their investments, realize their return, and invest in a new generation of start-ups.

U.S small businesses benefit from government support. Programs such MEP and SBIR are two key examples.

Flexible, open, decentralized networks are an important component of a successful regional cluster. Many attribute Silicon Valley’s success in leading the ICT industry to this network. Although perhaps Silicon Valley is unlikely to be replicated, its foundations lie in several government efforts, including R&D funding and procurement programs.

A mix of new and established companies creates a healthier regional innovation system. Although small businesses are the drivers of job creation, large firms fill an important role as well. Small firms can access market information and entirely new markets, while big companies can access new technologies that aid the growth of a regional industry.
Executive Summary

India has evolved significantly in the past 2 decades, from a nearly closed planned economy to one of the most recognized examples of the power of knowledge-driven growth. The country may eventually become an equal player—and eventually leader—in the global innovation system, but it still has several barriers to overcome. The following lists include lessons learned and cautionary lessons.
### Key Institutional Elements

<table>
<thead>
<tr>
<th>Institution</th>
<th>Year established</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>City of Bangalore</td>
<td></td>
<td>Developed as a center for industry and manufacturing in the 1980s. Known as the information technology capital of India; plays important role for encouraging innovation and attracting investment in India</td>
</tr>
<tr>
<td>Council of Scientific and Industrial Research (CSIR)</td>
<td>1942, by the central government</td>
<td>Autonomous body and India’s largest R&amp;D organization</td>
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<tr>
<td>Small Industries Research and Development Organization (SIRDO)</td>
<td>1970, by the Birla Institute of Technology, Mesra, and the Birla Institute of Scientific Research (BISR)</td>
<td>Launches small manufacturing enterprises run by graduates of the Birla Institute of Technology</td>
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<tr>
<td>Department of Science and Technology</td>
<td>1971, by the Ministry of Science &amp; Technology</td>
<td>Promotes new areas of S&amp;T and role in nodal department for organizing, coordinating, and promoting S&amp;T activities in the country</td>
</tr>
<tr>
<td>Science and Technology Plan (1974–1979)</td>
<td>1974, by the National Committee on Science and Technology</td>
<td>Intended to assist technology absorption, assimilation, and development of indigenous capabilities; since then, a chapter on S&amp;T has been included in every 5-year plan</td>
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<tr>
<td>Small Industry Research, Training and Development Organization (SIRTDO)</td>
<td>1978, by the Birla Institute of Technology</td>
<td>Extends entrepreneurs’ technical know-how, financing through bank, sheds, marketing, etc.</td>
</tr>
<tr>
<td>National Science and Technology Entrepreneurship Development Board (NSTEBD)</td>
<td>1982, by the Government of India under the Department of Science &amp; Technology</td>
<td>Promotes knowledge-driven and technology-intensive enterprises</td>
</tr>
<tr>
<td>Science and Technology Entrepreneurs’ Park (STEP) Program</td>
<td>1984, by NSTEBD</td>
<td>Orients the government’s approach to innovation and entrepreneurship through SEZs</td>
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<tr>
<td>Indian Institutes of Technology</td>
<td>Various, mostly through special acts of the Indian Parliament</td>
<td>Group of 15 autonomous engineering and technology-oriented institutes of higher education established and declared as Institutes of National Importance by the Parliament of India</td>
</tr>
<tr>
<td>Ministry of Science and Technology (MOST)</td>
<td>1985, by central government</td>
<td>Formulates and administers rules, regulations, and laws related to S&amp;T in India</td>
</tr>
<tr>
<td>Technology Information, Forecasting and Assessment Council (TIFAC)</td>
<td>1988, under the authority of the Department of Science &amp; Technology</td>
<td>Forecasts technologies, assesses technology trajectories, and supports technology innovation by network actions in select technology areas of national importance</td>
</tr>
<tr>
<td>SIDBI Center for Innovation and Incubation (SCII)</td>
<td>1990, by an arrangement with Small Industries Development Bank of India</td>
<td>Provides infrastructure and R&amp;D for new entrepreneurs, start-up companies, and technology-based organizations</td>
</tr>
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### R&D Tax Incentives

India currently offers a deduction for R&D expenditures of between 100 and 150% (depending on the specific category the expenses fall under). Additionally, SEZs offer large incentives for companies that operate within them. The SEZs are geographically demarcated tax-free enclaves for investors from India and abroad. Through the introduction of SEZs, India wants to enhance infrastructure and invite more foreign direct investment.
India Gross Domestic Product (Current US Dollars, Not Adjusted for Inflation)
Source: World Bank, World Development Indicators - Last updated June 15, 2010

India Foreign Direct Investment (Balance of Payments in US Dollars)
Source: Bank, World Development Indicators - Last updated June 15, 2010
Lessons Learned:

- India’s combined planned economy and innovation system were outpaced by more open systems in the rest of the world.
- Provision of modern infrastructure, offices and residences, is a prerequisite for an adequate business operating environment in an underdeveloped country.
- Foreign investment drives a large portion of innovation in India and then leads to local investment as experience is accumulated.
- The outsourcing industry is an example of creating significant economic growth from a high-tech sector not integrated into the domestic economy of the host country.
- High-quality education in the scientific and engineering disciplines is essential to access economic growth through innovation.
- Participation in the global innovation economy demands trusted and complete IP law.
- Demographic factors of economic disparity, educational attainment, and a large population could limit future growth.
- Scientific publications, citations, and other traditional measures of scientific performance do not necessarily indicate the level of innovation.
- To achieve its goal of 2% of GDP spent on R&D, India will have to find a way to grow industry investment to levels similar to the U.S. and China.

Cautionary Lessons Learned:

- The expansion of knowledge-based industries does not necessarily correspond to substantial innovation.
- A policy of technological self-reliance and protectionism as a goal in itself can seriously inhibit innovation, especially when relying on imitation of foreign technology.
- Low labor costs, from unskilled to technical, have been a major draw of foreign investment but may not be sustainable as development progresses.
- Support functions by themselves do not lead to increased indigenous innovation. The prime Indian example is business process outsourcing.
- Weak intellectual property law limits the necessary participation in the global innovation economy.
Evolution of the Indian Innovation System

The foundations of India’s legal system were laid during the period of British rule starting in the 1700s, but it wasn’t until independence was achieved in 1947 that the nation began pursuing what could be called an innovation system. For the purpose of this report, the development of the national innovation system in India is divided into three phases, starting with the period between independence and the first steps of modernization and concluding with the last 2 decades of economic reforms and rapid growth.

While the term “innovation system” is appropriate at essentially all stages, it is necessary to make the distinction between innovation policy and its predecessor, S&T policy. During the first two phases described here, S&T policy was dominant, as science and the economy were separated on the political landscape. More recently, the government has crafted policies that recognize the deeply integrated nature of development.

The country inherited a well-developed bureaucracy and a Western-educated upper class, but early in the Republic, India struggled to escape the legacy of exploitative colonial policies. Since the beginning of the 1980s, India has shown strong economic performance, perhaps explained by its institutional capacity for coordinating entities and policies and limiting the extent to which a bureaucracy interferes in the system.

This report draws on numerous sources, including a good deal of scholarship originating in India.

**Phase One: Postindependence Autarky**

Perhaps in reaction to its colonial past, the early economic policies of the Republic of India were intensely focused on autarky, or domestic self-sufficiency. This approach, which was shared with many other developing countries, held that the core driver of growth would be the development of a large-scale capital goods industry.\(^149\) This was intended to mimic both the productivity and economic independence of developed nations. However, in India autarky was by itself highly valued by the government, even more so than achieving growth.\(^150\) This led to a set of protectionist policies, known as the License Raj, that would affect the innovation capacity of the country for decades.

One of the most effective of these protectionist policies was import substitution, the practice of domestically producing goods rather than relying on foreign production. Any import of a new technology—not just as goods for sale, but also for business processes—from abroad required government approval, which was not granted easily. India also implemented an industrial license regime—a mechanism through which a new company or plant, or an increase in productive capacity, required a government permit.\(^151\)

Internal competition was significantly limited by these policies, but that did not completely hinder innovation or growth. The government stressed the “indigenization” of technology, and Indian companies responded by reverse-engineering and mimicking existing technologies from abroad.\(^152\) This behavior was encouraged by the system of patent law in India, which made it easy for Indian firms to copy foreign inventions and then produce them locally, which importantly included pharmaceuticals.\(^153\) However,
it also had the same effect on Indian creations, which could just as easily be reproduced all over the country, removing a major incentive for innovation.

Nevertheless, recreating manufacturing processes and designs for foreign technology did require significant skill and ingenuity on the part of Indian firms. To help meet this demand, the first parts of the national network of engineering schools, the Indian Institutes of Technology, were founded during the 1950s. While these schools provided excellent faculties and education, even in the early years, graduates were finding more engaging and promising work abroad, a trend which would play a significant role in later stages of the national innovation system. Still, during this time, India established a base of technical skill that was hard to match among other developing countries. Assisting in this was the unique move by IBM to establish an accounting machine manufacturing subsidiary in 1951 which drew on Indian engineering talent.\(^\text{154}\)

In parallel with the development of its industrial base, India began building its national system of scientific R&D as an intentional complement to these efforts. The political will was clearly established with the Scientific Policy Resolution of 1958, which stated “technology can only grow out of the study of science and its applications.”\(^\text{155}\)

With the vast 1974 Science and Technology Plan, the government gave a nod to import substitution reform, but only as a means to increase technology indigenization, while codifying the prevailing policy of a centrally planned R&D program.\(^\text{156}\) The Plan brought together over 2,000 scientists to plan technology development in 24 broad sectors and numerous subsectors.\(^\text{157}\) The written document itself was comprehensive, but implementation was hobbled by budget changes, administrative reorganizations, and a lack of political support from various government agencies, even from some of those contributing.\(^\text{158}\) Although arguably effective in achieving their stated goals in the long run, these measures represented a more thoroughly considered S&T policy than was found in most developing countries.

The main instrument of government-funded R&D—which continues to be the source of most funding—was the Council of Scientific and Industrial Research (CSIR). The CSIR and its system of National Research Laboratories were founded prior to independence, in 1942 and 1947, respectively. As the name implies, the goal was from the outset to assist the development of industry, and the program even received financial support from prominent industrialists.\(^\text{159}\) Between 1958 and 1974, CSIR's budget increased nearly sevenfold, but it still largely failed to transfer any of its technology to industry; the private sector continued to pay the premium for foreign technology because of its perceived superiority.\(^\text{160}\)

Perversely, though, the CSIR had the ability to review requests for technology imports, significantly delaying the process and in some cases deciding that their internal capability was sufficient to fulfill the filer’s request.\(^\text{161}\)

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\text{155} & \quad \text{Ministry of Science and Technology (1958). Scientific Policy Resolution. New Delhi, India.}
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\text{156} & \quad \text{Bhaneja, B. (1976). India’s Science and Technology Plan, 1974–79. Social Studies of Science: 99-104.}
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\text{158} & \quad \text{Ibid.}
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\text{160} & \quad \text{Desai, A. V. (1980). The origin and direction of industrial R&D in India. Research Policy 9(1): 74-96.}
\\
\text{161} & \quad \text{Desai, p. 74-96.}
\end{align*}\]
By 1977, the body responsible for the 1974 S&T Plan had been dissolved and then reconstituted with its authority to plan removed. In that same year, IBM and other foreign companies left India in response to the restrictive License Raj, leaving thousands of skilled laborers and professionals unemployed. Soon after these events, the Sixth Five Year plan in 1980 helped to bring new focus to S&T policy and ushered in the next major phase of the development of India’s innovation system.

**Phase Two: Signs of Change**

Technological self-reliance remained a top priority in Indira Gandhi’s Sixth Five Year Plan, but so did developing S&T capacity, as evidenced in the founding of the Scientific Advisory Committee to the Cabinet. This body coordinated the many existing institutions by allocating specific goals, and it also began implementing some of the stalled measures of the 1974 plan.

A major change in policy came with the 1983 Technology Policy Statement, which for the first time explicitly encouraged the creation of private sector R&D entities. It went even further, as it provided incentives for setting up independent labs and also collaborations with national research organizations. The Statement was remarkably more forward-looking in terms of technological change than earlier policies and resulted in the formation of the Technology Information and Forecasting Assessment Council (TIFAC). In 1985, a milestone of this refined vision was reached with the establishment of India’s first foreign multinational R&D center, set up by Texas Instruments in Bangalore.

The same year, Rajiv Gandhi assumed the office of Prime Minister and began the first economic reforms in a prelude to the coming sea change. However, even though the trade liberalization applied under Rajiv Gandhi’s mandate reduced the number of goods subjected to import licenses, 70% of imports were still restricted by the commercial regimen. Industrial and import controls continued to influence the majority of industrial output, even as growth began to accelerate.

Again, technological autarky held primacy throughout this period and was reaffirmed with the Research and Development Cess Act of 1986, which placed a 5% tax on the import of technology by industry. However, this wasn’t meant to discourage imports as much as it was to create a revenue stream for a VC fund for indigenous technology managed by the Industrial Development Bank of India. This may not seem to represent a clear trend during this second phase, given the government’s continuing use of the policies and rhetoric of the License Raj. However, the nominally still existent industrial license policy was clearly eroding; the government was for the first time encouraging Indian entrepreneurs to decide what new technologies and industries to pursue.

Between 1980 and 1989, FDI in India increased over 300%, but the relative magnitude tells a different story; FDI as a percentage of GDP was only 0.1%. During this same period, under Deng Xiaoping’s

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162 S.K. Subramanian.
163 Taube, Sonderegger, et al.
164 Subramanian, p. 87-101.
167 Krishna and Bhattacharya.
169 Sikka, p. 707-714.
reforms, China’s FDI increased from only 72% of India’s to over 13 times larger while at the same time China experienced several years of double-digit GDP growth rates.\(^{171}\) The connection between FDI, GDP growth, and innovation policy is not direct but does serve to illustrate once again the severe limits that had been placed on international trade in India. The other large economies of the world were rapidly globalizing, modernizing, and prospering because of it; India would soon be forced to reconcile with this new paradigm.

**Phase Three: Economic Liberalization and Internationalization**

India entered into the 1990s with high deficits, high inflation, a broken exchange rate regimen, and an overall spiraling balance of payments.\(^{172}\) The government was able to secure support from the International Monetary Fund to prevent a collapse, under the condition that the country institute liberalizing economic reforms; the License Raj was largely dismantled but not the notion of self-reliance.

The 1991 Statement on Industrial Policy set forth these major reforms.\(^{173}\) Industrial licensing was abolished except for select industries, for which it was only modified, notably, pharmaceuticals, automobiles, defense, and some resource extraction and agricultural products; FDI up to 51% equity was automatically approved; technology imports were more freely—though not completely—approved, including, if necessary, the hiring of foreign professionals; public sector enterprises which were underperforming would be reorganized or possibly privatized. The fact that the government so clearly saw the measures that were necessary to integrate its economy with the rest of the world is perplexing given the consistently opposite policies of the previous 4 decades.

Change was still slow to come to the old S&T policy habits. Throughout the 1990s and early 2000s, the government funded over 70% of R&D in the country, while China was split about equally between government and business and R&D in the U.S. was over 70% business funded.\(^{174}\) Similarly, total R&D spending from 1996 to 2007 remained under 0.8% of the GDP in India, but in the same period in China it went from about 0.5% to almost 1.5%, with the U.S. taking the lead during this period with an average of 2.6%.\(^{175}\) Likewise, FDI increased slowly but steadily, although remaining more than an order of magnitude lower than that of China through 2001.\(^{176}\)

Despite the unfavorable comparison to China, India is still a standout developing country because of its growing involvement in the global economy. Foreign R&D centers in India have gone from only 19 in 1995 to more than 200 today.\(^{177}\) The growth in patents has been explosive, even if concentrated in government activities. The increased competition brought by these reforms put significant pressure on strict S&T planning, as Indian firms had to truly compete with each other as well as foreign companies.

The reigning perspective on national innovation policy was laid out in the 2003 Science and Technology Policy. By this time the notion of self-reliance had evolved into a much more general concept of prosperity on India’s terms. The policy statement itself has little in the way of concrete actions but

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\(^{172}\) Ghosh.


\(^{175}\) http://www.uis.unesco.org/

\(^{176}\) http://data.worldbank.org/data-catalog

\(^{177}\) Krishna and Bhattacharya.
is ripe with contemporary innovation system rhetoric and is widely regarded as a sincere document of national objectives. Key provisions include the following:\footnote{178}{Department of Science and Technology (2003). \textit{Science and Technology Policy}. New Delhi, India.}

- Increased autonomy and decreased bureaucracy of national science organizations
- The ministries and departments most concerned with science will be run by scientists
- Having R&D investments reach 2\% of GDP by 2007
- Recognizing that inexpensive resource and labor have driven foreign investment rather than innovation capacity
- Giving universities and national labs the ability to create technology transfer offices independent of the central government
- Commitment to creating financial incentives for industry R&D, either in-house or through outsourcing
- A focus on a “leap-frogging” process of development
- Committing to IP reform

The intellectual property law reforms were perhaps the most important in terms of promoting innovation because of their effect on the pharmaceutical industry. The Indian Patents Act, which was originally set up in 1970, was first amended in 1999 and then again in 2002 and 2005, bringing it into compliance with the internationally recognized Agreement on Trade Related Aspects of Intellectual Property Rights.

A common measure of innovation is the number of patents granted to a country by the U.S. Patent Office. Before 1991, a total of 375 utility patents were issued by the U.S. Patent Office to applicants from India, including both Indian and foreign companies.\footnote{179}{U.S. Patent and Trademark Office (2010). \textit{Patent Counts by Country/State and Year, Utility Patents Report}. Accessed July 14, 2010.} From 1992 to 2009, that total reached 4,384, but only approximately 40\% were from domestic companies, down from 70\% in 1991.\footnote{180}{Mani, S. (2010). “Are innovations on the rise in India since the onset of reforms of 1991? Analysis of its evidence and some disquieting features.” \textit{International Journal of Technology and Globalisation} 5(1): 5-42.} As recently as 2004 to 2005, India was a net importer of technology (licenses, patents, etc.) but has since become a net exporter of technology, joining the likes of the U.S., Japan, and Switzerland.\footnote{181}{Ibid.}

The growth in patents has been dominated by pharmaceutical and related chemical research. The top patent holder is the CSIR, and of the 23 Indian companies holding five or more U.S. patents in 2007, all but 2 were pharmaceutical companies.\footnote{182}{Ibid.} On the other hand, foreign corporations registering patents in the U.S. for work done in India is concentrated in IT and related technologies. Together, these two industries capture 72\% of patents.

Because of the restrictive technology import polices and government promotion, the IT and business process outsourcing industry (IT-BPO) was fairly well established prior to 1991. Combined with the growing pool of talent generated by the IITs, government computer literacy programs, and low wages, the country was well prepared for the rush of IT-BPO industry expansion that was happening at the same time as the opening of the economy. Software Technology Parks set up in 1991 have been extremely important in allowing businesses to take root by providing access to critical infrastructure, and they now are responsible for more than 60\% of IT-BPO exports from India.\footnote{183}{Nagesh Kumar, N. (2001). \textit{National Innovation Systems and the Indian Software Industry Development}. A Background Paper for World Industrial Development Report.} In general, IT-BPO has quickly...
grown to a $71 billion industry (from less than $150 million in 1991), with 2.23 million employees, 5.8% of GDP, and over 16% of exports.\footnote{184}

The second most used measure of innovation—or more accurately, scientific productivity—is the publication and citation of articles in scientific journals. India’s international ranking in total publications has held relatively stable at 10 to 13 since 1996 and is the third ranking of BRIC and developing countries even as output doubled. However, its total output over that period was only about a quarter of Germany’s (fifth) and 10% of that of the U.S. (first). Additionally, in an important measure of impact, the H-index,\footnote{185} India drops to 25th, implying that there is either a surfeit of lower-quality research or that it is overlooked by the broader scientific community. Indeed, India’s average citations per article are only 5.77, while the top 10 countries average 13.3, excluding China and Russia, which achieve 4.61 and 4.42, respectively.\footnote{186}

Economically, India is performing impressively, with GDP growth of 6 to 8% per year and exports increasing at a cumulative annual growth rate of 30%.\footnote{187} However, the country remains a developing nation, often behind others, with low literacy rates, life expectancy, income disparity, and with most people still working in agriculture.\footnote{188}

Special Focus: The IT Industry in Bangalore

Bangalore, in the state of Karnataka, is widely considered to be the technology capital of India, with about $15 billion in sales in 2009, or about 30% of the nation’s total.\footnote{189} Its rise to dominance as the “Silicon Valley of India” is a microcosm of the country’s ascent up the ladder of innovation. Success has been less the result of planning than of having an underutilized resource available at just the right time—and price—as policy reforms took hold.

The city’s tradition of higher education was established in 1909 with the creation of the Indian Institute of Science (IISc), the first research university in the country and which still leads in research performance.\footnote{190} Today IISc is part of a large network of national, state, and private science and engineering institutions, including the Indian Institute of Information Technology and Indian Institute of Management, both of which are national leaders.

In the late 1970s, the Karnataka government chose to have the State focus on software development, partially with the intent to attract some of the technical professionals left unemployed by the sudden departure of IBM. This change also prompted a Bangalore-based vegetable oil manufacturer, Wipro, to take the bold step of developing a computer hardware business.\footnote{191} Additionally, the young company Infosys relocated to Bangalore in 1983, which was one of the few cities at the time with

\begin{itemize}
  \item \footnote{184} NASSCOM (2009). Strategic Review 2009. The IT-BPO Sector in India. Delhi, India.
  \item \footnote{185} The H-index attempts to quantify the impact of a journal, country or individual. The value is equal to the number of articles that have received the same number of citations. For example, India scores 202, meaning there are 202 articles which have 202 or more citations each; The US scores 1,023.
  \item \footnote{186} All data in this paragraph were obtained from the SCImago Research Group (2009). SCImago Journal & Country Rank. Accessed July 14, 2010.
  \item \footnote{187} Cassiolato and Vitorino.
  \item \footnote{189} The Hindu (2009). Slowdown has no effect on State’s software exports The Hindu. Bangalore.
  \item \footnote{191} Taube, Sonderegger, et al.
the infrastructure to support high technology. The State established Karnataka State Electronics Development Corporation (Keonics) during this period, which began planning the first of what would become the Software Technology Parks of India.

The partial liberalization in the 1980s had an important effect on Bangalore by leading to the establishment of the Texas Instruments (TI) research facility in 1985. TI selected the site mainly because of the availability of low-cost trained workers coming out of local institutions. TI brought an essential communications infrastructure to the region, including satellite connections that it allowed local companies to utilize as well, greatly increasing their access to foreign firms. It also began engaging directly with the local educational institutions to train students and fund research.

The success of TI was a catalyst for other companies to take notice of Bangalore, and by 2005, some of the largest U.S. corporations (IBM, Microsoft, Google, Cisco, and Dell) had set up operations there, many within the STPI “Electronics City,” along with Wipro and Infosys. Like the rest of India, the foreign companies with operations in Bangalore relied on these units for services and support functions, not for independently creating products. However, Bangalore moved a step beyond many other industries and regions, with Indian companies actually dominating exports, in particular Wipro and Infosys. Despite these factors, the domestic IT market is minimal, accounting for less than 20% of Bangalore’s output, hinting that even greater growth is possible as India develops.

The rise of Bangalore has attracted considerable scholarship concerning the development of innovation systems, particularly on the efficiency of growth in regional clusters. The evidence points to the ideas discussed above: the kernel was established almost incidentally, just one of many efforts to promote technology development in India, but the density of firms and talent along with low costs created a state of positive feedback, coupled with the rapid emergence of the global IT industry in the 1990s.

**Discussion**

The development of the innovation system in India is deeply connected to the economic policies instituted postindependence. In the first decades, a centrally planned economy went along with a government run S&T agenda. This was likely necessary to quickly build up industry, infrastructure, and talent, but rather than leading to a sustainable integrated economic engine, the License Raj eventually led to widespread systemic inefficiencies. In developing countries with more open policies, firms could access and quickly utilize the newest available technology, but in India, they had to rely on each other’s inferior products.

In 2006, R. A. Mashelkar, then president of the Indian National Science Academy, remarked on this subject to the U.S. National Academy of Science, saying “there was no competitiveness because we were a closed economy. Industry produced gums that did not stick, yet people bought them. We produced plugs that did not fit, and yet we bought them.”

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194 Taube, Sonderegger, et al.

195 Athreye.

196 Parthasarathy.


The creation of the India Institutes of Technology in the 1950s is an interesting case of undirected foresight, but they suffered from academic isolation. Although staffed with productive, and in many cases foreign, trained faculty, research was not focused on national needs. The official priorities of government R&D were likely inspired by the rapid innovation happening in the U.S., Soviet Union, and the rest of Europe during this time, but without a clear national goal beyond emulating these countries’ space and atomic energy programs.

Nevertheless, India had an advantage over some other developing countries in placing an importance on S&T early on in its development, even if the systems in place were not able to fully take advantage of the capacity it was building. Even towards the end of the first phase and the beginning of the second, India had prepared for future opportunities by building a core of educated scientists and engineers who would be ready to capitalize on the coming changes in the national innovation system. However, there are currently two competing phenomena that resulted from this history.

First, Indians with high qualifications are moving to other countries in Europe as well as the U.S. Students who study abroad often do not return after completion of their courses, which leads to a loss of knowledge in the country. About 2% of India’s population—20 million people—live abroad, where they earn the equivalent of two-thirds of India’s GDP.\(^{199}\)

Second, some authors have argued that innovation growth in India is socially driven, that is, personal connections are paramount for attracting outside investment. The people driving this process were termed the New Argonauts by Annalee Saxenian because they freely move between foreign contexts and India, bringing along ideas and relationships.\(^{200}\) However, outside investment is not and should not be the only driver or metric of successful innovation in developing countries. Moreover, it is easily argued that personal connections are mainly useful for building the initial momentum needed to become self-sufficiently innovative.

A survey of businesses has shown that there is a perception of India having unique qualities that attract investment.\(^{201}\) The country beat out all others in the survey by substantial margins, including the U.S., in three critical categories: availability of highly skilled labor, R&D activities, and outsourcing potential. It was also a leader in one other category: availability of low-cost labor.

This situation is currently advantageous but could either benefit or harm innovation and the economy in the long run. Indian talent is effective but may quickly become less affordable. It will be a challenge for the government to maintain foreign confidence in Indian capabilities as costs inevitably rise, although the situation is promising.

There is also a deeper question of the ability of the long-term availability of talent. The 2003 S&T Plan recognizes that there is a sharp drop-off between technically skilled professionals and most workers in India. There is a concern that India doesn’t have the appropriate labor base to meet future demands. Only 16% of Indian manufacturing firms offer in-service training, compared with 92% in China. The Indian firms that provide in-service training are 23 to 28% more productive than those that do not. Moreover, gross enrollment in higher education is only 12% in India, compared with 90% in Korea and 68% in the Russian Federation.\(^{202}\)

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\(^{202}\) Dutz.
The recent growth in private sector innovation in India is tied to the evolution of foreign investment since the 1991 economic reforms. The first R&D centers were secondary organizations, destinations for the outsourcing of repetitive tasks and testing under the supervision of a foreign corporation. As they matured, labs were able to develop their own local networks and partnerships and begin to influence the direction of research. Currently, some centers are gaining considerable autonomy, being seen more as equal partners in innovation and free to pursue “true collaborative R&D,” but this is not yet the norm. 203

The trends in patent generation suggest that the pharmaceutical industry is alone in making significant technological advances. While IT and related technologies also have significant patent activities, foreign companies are almost exclusively responsible. However, innovation takes place in the office and the lab. Many innovations in high technology are trade secrets or internal procedures that would not be accurately reflected by patent data. On the other hand, business process outsourcing focuses on routine tasks and puts little demand on technology innovation.

The rapid rise in innovation capacity in the last several years is frequently lauded, but India had the potential to be far ahead of its current state. During the first two phases of India’s innovation history, many of the important pieces of a successful innovation system existed—established industries, quality education, and ample national R&D funding—but there were not the necessary linkages between these, “to foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects—pure, applied, and educational.”204 Industries were focused on being imitative to keep up with the demands of the import substitution policy; the IITs were training professionals who had to then work in an environment that did not challenge their skills and they had little incentive to create new technology; the national R&D programs did not fund the type of work that industry needed or of which IIT graduates were prepared to take advantage.

If the previous success of innovation in India is intrinsically tied to the high rate of economic growth—not just growth, but fast growth—the country has been experiencing, this might be a major weakness. A task to ensure future success is to decouple innovation and growth, such as has been done in the U.S. and Europe. There, sustained levels of innovation are linked to more modest figures of growth and are not dependent on large supplies of foreign capital. Innovation is deeply established in the business culture and education on a complete spectrum from basic science to business processes. Promisingly in India, this phenomenon appears to be emerging in the biotechnology and pharmaceutical industries. But, a pervasive culture of innovation is still nascent, although the trends are promising for India’s future. If it is able to absorb and adapt the influx of knowledge to the unique Indian circumstances, it may become the world power it aspires to be.

203 Krishna and Bhattacharya. The discussion in this paragraph draws directly on this work.
204 Ministry of Science and Technology.
Lessons Learned

India has grown significantly and may eventually become an equal player—and eventual leader—in the global innovation system, but it still has several barriers to overcome.

- Although India has seen significant growth in their knowledge-based industries, it is not perfectly represented as a clear trend in the measurable indicators of innovation.
- India’s combined planned economy and innovation system provided stability and growth in the first decades after independence, but they were outpaced by more open systems in the rest of the world.
- Technological self-reliance as a goal in itself can inhibit innovation, particularly in industry, due to limited competition and a reliance on technology imitation. The recent growth in innovation is less about a strong national innovation policy than it is the late flowering of a long-handicapped potential.
- The more recent success comes from effectively tapping into the existing globalized innovation systems via foreign multinational corporations and globally dispersed Indian professionals.
- Success has also come from their evolving role in these relationships from one of support to one of increased true collaboration. It remains to be seen if India has actually internalized the knowledge gained from these relationships or if innovation-by-proxy remains the main driver.
- Support functions by themselves do not lead to increased indigenous innovation. The prime Indian example is business process outsourcing.
- High-quality education in scientific and engineering disciplines is essential to access economic growth through innovation. For India, focusing on education early on has allowed it to quickly grow after more recent regulatory reform.
- Participation in the global innovation economy demands trusted and complete IP law.
- Low labor costs, from unskilled to technical, have been a major draw of foreign investment. It is unknown if the technical ability of India’s professionals is enough to retain interest if labor costs rise.
- India has not seen the same growth for all parts of society. Educated talent is small relative to the size of the country. It is not clear if the growth in R&D and other technical activities will be able to raise the standard of living for the majority in the long term. The large population may limit the degree to which the growth can continue.
- Bangalore rose to prominence in IT because of the early availability of an educated workforce and infrastructure that lead to the establishment of a cluster of domestic firms.
- To achieve its goal of 2% of GDP spent on R&D, India will have to find a way to grow industry participation to levels similar to the U.S. or China.
- India has shown that it is possible to build a very large and profitable high-tech sector that exists almost entirely separate from the domestic national economy.
Executive Summary

Taiwan was chosen for this analysis due to its rapid economic development as the result of targeting value-added segments of global industries. While Taiwan’s computer and semiconductor industries have attracted much attention, Taiwan also developed by upgrading industries in more mature, traditional product markets, such as bicycles and sewing machines. This chapter derives the following lessons learned and cautionary lessons learned from the analysis of Taiwan.
### Taiwan’s Innovation System at a Glance

#### Key Institutional Elements

<table>
<thead>
<tr>
<th>Institution</th>
<th>Year established</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Ministry of Economic Affairs (MoEA)</td>
<td>1949, by the Executive Yuan</td>
<td>Oversees the overall development of manufacturing (and economic growth) within Taiwan</td>
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<tr>
<td>National Science Council (NSC)</td>
<td>1959, by the Executive Yuan</td>
<td>The main governmental promotion and funding body for science research in Taiwan</td>
</tr>
<tr>
<td>Industrial Development Bureau (IDB)</td>
<td>1970, by the MoEA</td>
<td>Promotes the development of the machinery, food, petrochemical, textile, and motor industries</td>
</tr>
<tr>
<td>Industrial Technology Research Institute (ITRI)</td>
<td>1973, by the Ministry of Economic Affairs</td>
<td>Conducts R&amp;D in applied technologies to advance private sector growth</td>
</tr>
<tr>
<td>Science and Technology Advisory Group (STAG)</td>
<td>1979, by the Office of the Premier of Taiwan</td>
<td>Advises the Office of the Premier of Taiwan on developments in S&amp;T</td>
</tr>
<tr>
<td>Office of Science and Technology Policy (OSTP)</td>
<td>1979, by the MoEA</td>
<td>Coordinates technology development responses to technological upgrading among small and medium-sized businesses through small R&amp;D projects</td>
</tr>
<tr>
<td>Hsinchu Science-Based Industrial Park</td>
<td>1980, by Executive Yuan</td>
<td>Encourages the development of technology and the creation of high-technology companies in Taiwan by providing space, infrastructure, and services</td>
</tr>
<tr>
<td>Department of Industrial Technology (DoIT)</td>
<td>1993, by the Ministry of Economic Affairs</td>
<td>Advances industrial development through the funding and coordination of industry</td>
</tr>
<tr>
<td>Small Business Innovation Research Program (SBIR)</td>
<td>1999, by the DoIT</td>
<td>Supports R&amp;D capabilities and competitiveness of small and medium-sized businesses in Taiwan</td>
</tr>
<tr>
<td>Innovative Technology Applications and Services Program</td>
<td>1999, by the DoIT</td>
<td>Improves the service aspects of Taiwanese business by funding the development of unique business models, applications, and processes</td>
</tr>
<tr>
<td>Multinational Innovative R&amp;D Centers in Taiwan Program</td>
<td>2002, by the DoIT</td>
<td>Fosters the development of R&amp;D centers within Taiwan and encourages domestic companies to set up R&amp;D centers through joint ventures with multinational corporations</td>
</tr>
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#### R&D Tax Incentives

The Taiwanese government enacted the Statute for Upgrading Industries, offering tax holidays and credits to companies performing R&D within Taiwan. Specifically, the statute offers a 30% tax credit for qualified expenses. At the moment, the government supports R&D efforts through tax credits in the amount of more than NT$20 billion (US$635.08 million) per year. Also, the Taiwanese government was a pioneer in the implementation of duty-free manufacturing and export processing zones (EPZs), giving firms more incentive to come to Taiwan.
Taiwan Gross Domestic Product (Billions of Current US Dollars)
Source: Market Information and Analysis Section, DFA

Taiwan Foreign Direct Investment (Balance of Payments in Billions of US Dollars)
Source: Market Information and Analysis Section, DFA
Lessons learned:

- It is possible to have a “top-down” strategy for developing innovation if government institutions and industries have a clear understanding of global industries and their respective value chains.
- Existence of a political period of martial law did not interfere in the development of the innovation sector.
- For “fast-follower” locales, it is critical to develop the capability to rapidly assimilate and manufacture new products.
- Public-private partnerships can be designed to encourage industries with low R&D intensities to become more innovative.
- Multinational corporations can act as drivers for creation of an innovation sector.
- Government can play an important role in helping to organize and fund groups of small companies to develop new technologies; these companies often do not have the resources to conduct high-level R&D or to work among several companies.
- Enabled with strong leadership, flexible rules, funding, and a clear, long-term, industry-driven mission, it is possible for government institutions to spin off globally competitive companies.
- Applied R&D is critical to the development of fast-follower locales, but basic research, aligned with applied goals, is the foundation for new, revolutionary products and technologies.
- Stimulation of procurement of locally-produced components can drive investment.
- National high tech projects, like the conversion to color TV broadcasting, can attract investment.

Cautionary lessons learned:

- Government procurement policies cannot be implemented effectively without a clear understanding of the market and indigenous industry.
- A sole focus on become a “fast follower” and neglecting basic research funding may hamper future efforts to develop new, indigenous technologies.
- When government creates new industries/companies, it should be careful not to compete with existing businesses and thus de-motivate entrepreneurs.
- Practices that worked to develop one industry sector do not necessarily transfer to a different industry sector.
- Multinational companies are an important source of new technologies and advanced business practices, but without a sustained and focused effort to transfer these technologies and practices to local companies there is little carry-over effect.
Early Development

In 1949, the Kuomintang leadership of the Republic of China (ROC) were defeated by the People's Republic of China (PRC) and fled to the small island east of the mainland known as Formosa. While the island now known as Taiwan had been controlled by a succession of countries, including the Dutch, the Chinese, and the Japanese, it was the arrival of the ROC that initiated its modern history. Skirmishes between ROC-controlled Taiwan and the PRC-controlled mainland continued well into the early 1960s, and martial law was a constant only lifted in 1984.

Some 2 million ROC-affiliated individuals fled to Taiwan, including soldiers, political leaders, scientists, and businessmen. The Taiwan they founded was agrarian and poor with little in the way of modern infrastructure. While the 1950s were marked by uncertainty and an ever-present threat of attack, the mid-1960s brought a period of relative peace and stability to the island. The government took this opportunity to focus on the development of Taiwan’s economy, understanding that an economically strong Taiwan would be more resilient and better able to defend itself.

Armed with grants from the U.S. Agency for International Development, Taiwan pursued an aggressive economic development strategy that sought to target and attract foreign multinational corporations. The Ministry of Economic Affairs (MoEA) began to collect and compile detailed information about companies and their leadership in Japan and the U.S., building a political and business network of contacts. Senior company executives were vigorously recruited to visit the island and were typically treated like dignitaries. The government marketed Taiwan as a stable locale with a nearly unlimited supply of cheap, reliable, hard-working employees in a growing consumer market.

Furthermore, the government established two programs important to Taiwan’s growth. First, it created an Industrial Development Bureau (IDB) in the MoEA to oversee the overall development of manufacturing (and economic growth) within Taiwan. Second, it also created the NSC in 1959 to promote S&T development. While Taiwan conducted little R&D, it did have the well-regarded National Taiwan University and had recently reestablished the National Tsing Hua University in 1956 and National Chiao Tung University in 1957, both in the Hsinchu area. The NSC began providing modest R&D grants to these universities and organized conferences to discuss ways to develop research capacity as part of a larger Taiwanese technology and economic development strategy.

The initial multinational corporation recruitment strategy worked; in 1961, in response to the establishment of a Fairchild Semiconductor final assembly plant in Hong Kong, Phillips Electronics of Holland established a plant of their own in Taiwan, and they were followed by General Instrument in 1964. As part of their aggressive multinational corporation recruitment efforts, the government created duty-free manufacturing areas in 1965. These so-called export-processing zones helped attracted 24 U.S. firms within 2 years of their creation. Furthermore, small Taiwanese firms were assembling and/or providing components for a host of other manufactured products, such as shoes, textiles, bicycles, and sewing machines, during the 1960s.

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206 Breznitz.
208 These universities were originally established on the mainland but were closed by the PRC and reopened in Taiwan, in some cases by the same faculty that had presided over the mainland institutions.
The 1970s and Creation of ITRI

The 1970s and Creation of ITRI

The strategy of attracting multinational corporations to Taiwan and developing local supply chains through import substitution regulations proved to be very successful through the 1960s. From 1966 to 1971 the export of electronics grew 58% annually, with 37% of all components manufactured locally. However, during the 1970s the convergence of several factors precipitated a rapid shift in these government policies. Oil shocks and stagflation in the U.S. spurred a global economic crisis, and Taiwan, where wages were rising, faced increasing competition from lesser-developed countries concerning low-value-added products, including electronics components. With these increasing costs, not only did the FDI slow, but also Taiwan quickly learned that most U.S. companies had no intention of upgrading or locating value-added, R&D-intensive activities within Taiwan. Finally, PRC-controlled China emerged on the global political scene, culminating with the “derecognition” of Taiwan by the United Nations in 1971.

Taiwanese political leadership knew that in order to sustain economic growth it would have to focus on upgrading the technological capabilities of domestic Taiwanese manufacturers; Taiwan was too small to compete on low-value-added products. In 1973, Yun-Hsuan Sun, then the Minister of Economic Affairs and later the Premier, oversaw the establishment of the Industrial Technology Research Institute (ITRI). ITRI was created by restructuring and combining three government labs and by transferring responsibility for electronics R&D from the Ministry of Telecommunications. ITRI was located in Hsinchu near two leading engineering universities, National Chiaotung University and National Chinghua University, in hopes that these institutions would play a key role in its development. ITRI was created with little policy fanfare, its funding was very modest, and its operations were similar to those of a research-oriented national lab.

While the overall operations of ITRI evolved, a small group of national leaders wanted to develop Taiwan’s capabilities in emerging high-technology fields, especially semiconductors. In 1974, Wen-Yuan Pan, a Chinese-American engineer at RCA’s Sarnoff Labs and friend of Minister Sun, established

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210 Amsden and Chu.
211 Breznitz.
212 Breznitz.
a working group of (Chinese) semiconductor engineers in Princeton, New Jersey. This group, also known as the Technical Advisory Committee, was charged with creating a plan to develop a Taiwanese semiconductor industry. As part of their plan, the group recommended the establishment of the Electronic Research Service Organization (ERSO), an organization within ITRI that would study various parts of the semiconductor value chain—typically managed by U.S. multinational corporations—and develop technologies to help Taiwanese firms compete within these markets.

ERSO was staffed with the top materials scientists and electrical engineers in Taiwan, and their first mission was to learn how to fabricate integrated circuits and obtain the technology necessary to do so. In 1976, ERSO scientists negotiated an agreement from RCA to transfer its obsolete integrated circuit technology to ITRI. RCA had recently decided to get out of the semiconductor industry and saw ERSO’s interest as an opportunity to earn royalties from the complementary metal oxide semiconductor fabrication technology that it had developed. In order to fully transfer the technology, a group of 40 Taiwanese engineers spent a year in RCA facilities in the U.S., with ERSO building its first fabrication facility shortly thereafter with RCA’s continued assistance. The transfer of technology was so complete that by 1979, the ERSO team enjoyed better manufacturing quality and yields than RCA had ever achieved and began to sell small quantities of integrated circuits to offset its capital costs.\(^{213}\)

Three major events occurred around this time—the late 1970s—that were important to the development of the Taiwanese semiconductor industry.

- **Spinoff of UMC.** In 1978, the head of ERSO and a team of its semiconductor engineers recommended the creation of a public corporation based on the technologies and manufacturing capabilities developed during the RCA acquisition project. MoEA convinced a consortium of local companies to acquire a 51% stake in the new venture, with the government investing in the remaining portion of the company, and in 1980, the United Microelectronics Corporation (UMC) was established. The company was staffed by ERSO employees and allowed to use ERSO’s fabrication facilities during its initial growth phase. UMC was important not only as the first of several ITRI/ERSO spinoffs but also as the first semiconductor fabrication company.

- **Creation of the STAG.** Kuo-Ting Li, Minister of Finance, oversaw the creation of a Science and Technology Development program that included a permanent advisory body of industry, education, and government leaders dedicated to S&T issues: the Science and Technology Advisory Group (STAG). Created in 1979, the STAG was initially chaired by Li and reporting directly to the Premier with the goal of recommending specific public investments and infrastructure to promote R&D intensity among Taiwanese industries.

- **Creation of Hsinchu Science Park.** In 1980, the NSC established the Hsinchu Science-Based Industrial Park. The park was envisioned as a high-technology development zone and was organized specifically to include ITRI and the two nearby technical universities, National Chiao Tung University and National Tsing Hua University. The Science Park was specifically designed to duplicate what was “perceived to have happened around Stanford University”\(^{214}\) with the development of Silicon Valley.\(^{215}\) Hsinchu Park only accepts firms with significant R&D operations but, in turn, grants tax holidays, exemptions from the equipment import duties, low-interest loans, and matching R&D funds.

\(^{213}\) Breznitz, p. 106.

\(^{214}\) Breznitz, p. 106.

\(^{215}\) While Stanford has always played a very important role in the development of Silicon Valley, unlike MIT, far more companies were spun out of existing companies than the university. For more information see Kenney, M., *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region*, Palo Alto, CA: Stanford Business Books, 2000.
While UMC and its public and private sponsors were anxious to serve market needs, U.S. semiconductor consultants advised Taiwanese companies to steer clear of capital-intensive markets, such as the dynamic random access memory chips, and instead focus on the rapid design and manufacture of custom chips. Specifically, Taiwanese business and government leaders together chose to focus on application-specific integrated circuits, allowing Taiwanese companies to differentiate themselves from Korean and Japanese companies. Taiwan had already done this in other, less complex industries, such as bicycles and sewing machines, and so it seemed to make sense to become a “fast-follower” producer of application-specific integrated circuits and pursue the necessary technologies required for their manufacture.

In 1983, the Taiwanese government launched a 5-year, $72.5 million effort in support of this application-specific integrated circuits manufacturing approach. The primary focus was to develop the technical capability needed to design smaller integrated circuits with ever-increasing number of components, otherwise known as very-large-scale integration. ERSO was again asked to take the lead and, after 3 years of rapid technological progress combined with growing success from UMC, decided to again spin off this technology project into the Taiwan Semiconductor Manufacturing Corporation. While the government also accounted for a substantial part of the Taiwan Semiconductor Manufacturing Corporation’s initial investment, private companies again provided nearly half of its financing (48.3%), including a 27.5% stake from Philips.

Established in 1986, TSMC was the first Taiwanese company to employ the “pure-play foundry” model, a technically oriented contract manufacturing model in which custom chips are rapidly fabricated for a growing number of electronic and computer applications. Later ERSO foundry spinoffs include Taiwan Mask Corporation in 1988 and Vanguard International Semiconductor in 1994, among others. Foundries not only allowed the advancement of final assembled products, such as toys, phones, and appliances, but also created a demand for specialized integrated circuitry design. In both the U.S. and Taiwan, “fabless” design houses emerged quickly, bringing innovative application-specific integrated circuits designs to market with limited financial resources. In Taiwan along, 65 design firms had emerged by 1994—mostly in Hsinchu Science Park—due to the rise of foundries, their proximity, and the rapid evolutionary pace within the industry.

The foundry-design house relationship is symbiotic, and both segments have maintained close relationships with ITRI, especially with its Computer and Communications Lab, to maintain open channels to new, relevant systems and technologies. Interestingly, although ITRI possesses advanced technological capabilities, most design houses do not rely upon “cutting-edge” IP but instead on their ability to deliver moderately sophisticated custom chips vis-à-vis the nearby foundries more rapidly, cheaply, and reliably than their competitors. They do not expect to overtake large, advanced companies such as AMD or Intel but instead market less-developed platforms and markets in China and elsewhere.

Software Development in Taiwan

While Taiwan is the world leader in the foundry model and has built a world-class semiconductor design sector, development of the software industry arguably presents a less-dynamic example. Taiwan seems to have deep and capable software programming capacity, as evidenced by the emergence of the gaming industry and, given the presence of the integrated circuits design industry, enormous demand for specific industry applications. However, by most accounts, the Taiwanese software industry has not experienced the growth that observers might have expected, especially compared to the emergence of vibrant software

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216 Entry into DRAM markets not only required enormous capital investment, Korean and Japanese companies had already made substantial investments and market share in a segment where profit margins continued to decline.
Taiwan Software Development in Taiwan

clusters in Israel, India, and Ireland. Experts blame a lack of understanding with regard to the industry structure and misguided public policy for the lack of growth within the Taiwanese software industry.

In 1979, shortly after the creation of ITRI, the Taiwanese government established the Institute for Information Industry (III). The III had two objectives: to promote the emerging software industry and to assist in the modernization of government administrative processes through the installation of computers and supporting software programs. Based on the modest but steady stream of revenues that ITRI had already earned from licensing its technologies, III was also asked to generate enough revenue to cover most of its activities. Unfortunately, this institutional design combined with the existing structure of the Taiwanese software industry led to a missed opportunity.

When III was established, several growing software firms already existed that were focused specifically on software development for large organizations and that were already developing their own technological solutions. This was in contrast to the creation of ITRI, where no Taiwanese foundries existed until they were spun off by ERSO later after the fabrication technology was developed. So, when the government directed III to develop necessary software for government administration, this was arguably a substantial opportunity loss for Taiwanese firms. Furthermore, given III's need to earn revenue, the government essentially created a large, sanctioned competitor to existing software firms.

Many experts lament the lost market opportunity because, at the time of III establishment, there were no Chinese versions of Western software packages such as Windows or Office applications. Several small companies had approached III asking for assistance to develop Chinese language applications that might be adopted in the emerging Chinese market, providing the scale needed to compete with a large company such as Microsoft. The companies were rebuffed by III, and their development efforts were dropped. In general, Taiwanese software companies responded by not investing in development areas that competed with the emerging competitor. Ironically, U.S. multinational corporations, including Microsoft, have since invited Taiwanese companies to serve as subcontractors on development projects in mainland China. 217

Taiwanese companies established after the creation of III (and those that managed to adapt) have focused on banking applications, gaming, and security trading systems, market niches of little interest to III. For example, in the gaming sector, firms focused their games on unique Chinese “stories” and concepts that were appealing in both domestic and international markets. Development was relatively cheap, and products gained acceptance and popularity through marketing and distribution of the games in convenience (7-Eleven-type) stores. Unfortunately, the gaming industry has been especially hard hit recently with the emergence of online gaming and diffusion of CD read/write technology, enabling games to be easily copied. Taiwanese gaming firms approached III for development assistance but were also rebuffed; lacking the scale and the technology and market intelligence analog of ITRI, Taiwanese gaming firms have been rapidly surpassed by Korean firms. 218

For applications software firms that emerged after the rise of the Taiwanese hardware industry, the picture is much brighter. These firms supply the computer hardware industry (discussed below) with software that adds functionality, such as antivirus products and application development tools but that is too expensive to buy from foreign vendors. Or, they design software for specific computer peripherals, such as scanners, cameras, or other image processing devices, typically in cooperation with larger

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218 Unlike III, ITRI was important to the development of design testing and Electronic Design Automation software tools important in the semiconductor industry.
hardware manufacturing companies. Software firms in this sector rely primarily upon technology and development along with new business models to compete, and they have enjoyed success—albeit on a small scale—for doing so.

**Trends toward Technological Upgrading**

The spinoff of both UMC and TSMC from ERSO, combined with government support of application-specific integrated circuits had a substantial impact on the peer culture of ERSO, prompting many engineers and scientists to launch spinoffs of their own. Furthermore, individuals who had left Taiwan for school and to pursue economic opportunities abroad began to slowly return now that viable high-technology employment opportunities were emerging. With these trends, government policy gradually shifted from one emphasizing technology and enterprise incubation to one prioritizing the technological upgrading and support of existing industries, high-tech and otherwise.

In 1979, the government created the Office of Science and Technology Policy within the MoEA. The purpose of the Office was to coordinate a broader technology development response to technological upgrading among small and medium-sized businesses by first understanding their technology needs and then through the funding of discrete R&D projects—typically through ITRI—in response. These Technology Development Projects (TDPs) were meant to reduce the risk of technology development while helping to improve performance of the small and medium enterprises (SME).

TDPs have been especially important for the development of the desktop, laptop, and computer peripherals industry. These Taiwanese original equipment manufacturer-original design manufacturer (OEM-ODM) companies both produce components by specification and often design (or evolve to design) their own unique components, typically to sell to other companies to market under their respective brand names. Sometimes, these firms emerge to sell products under their own brand name.

Unlike semiconductors, ITRI's role with OEM-ODM firms has been to continuously upgrade existing firms, many of which have been around for some time. For example, in 1983 Acer—now a leading producer of computer laptops and smart phones—approached ERSO with a request to help develop a PC through a TDP. Another example occurred in 1990 when a group of Taiwanese companies, working with CCL, formed the Taiwan Laptop PC Consortium to develop technologies and applications to make Taiwanese companies the most advanced manufacturers of laptops in the world. Other well-known upgrading efforts have occurred with ICT-related TDPs targeted for CD-ROM and TFT-liquid crystal displays.

Upgrading was not just limited to ICT firms, however. For example, the Taiwanese bicycle assembly and component manufacturing industry was one of the first manufacturing industries in Taiwan. In the early 1980s ITRI formed the Bicycle Industry R&D Center, created to help Taiwanese manufacturers produce increasingly value-added components. In 1987, the Materials Research Lab of ITRI helped Giant Manufacturing Company, one of the world’s leading producers of bicycles and an internationally recognized brand, develop a carbon fiber bicycle frame, and later (in 2000), an electric bicycle and high-end derailleur. While the most advanced components continue to be imported, these are typically only for the purpose of remaining competitive in the most advanced markets (such as the U.S. and Western Europe), but the majority of components for developing markets (such as China) are developed within Taiwan, often with ITRI’s assistance.

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219 After these government-led efforts, ramp-up of peripheral components was incredibly rapid. For example, in 1994, Taiwanese companies accounted for 1 percent of world output of CD-ROMs. Five years later this number was 50 percent. See Amsden.
Contemporary Technology Policy

In the 1990s, direct export promotion and substantial tariffs, used by Taiwan to protect fledgling industries, were prohibited under World Trade Organization rules. Furthermore, the Taiwanese government passed the Critical Components and Products Act in 1992 that specified 66 inputs for import substitution to reduce Taiwan’s trade deficit with Japan. Most of these components constituted some of the most value-added parts within final products assembled in Taiwan. Faced with the need to overcome much more advanced technical challenges, the government instituted a series of policy reforms designed to encourage and support R&D investments among private Taiwanese firms that had, until then, relied primarily on ITRI and other government-funded labs for their advanced technologies.

While the government continued to invest in R&D within public laboratories, its goal was to encourage the private sector to substantially increase its R&D spending. The effort began by transforming the S&T Advisor’s office within MoEA into the existing Department of Industrial Technology (DoIT). Established in 1993, the purpose of DoIT is to advance industrial development through the funding and coordination of industry-led (as opposed to ITRI-led) R&D partnerships, although projects are often reviewed or staffed by ITRI employees. DoIT currently carries out its mission through specialized TDPs, including the following:

- **The ITDP.** Created in 1997, the ITDP is a public-private match partnership to help larger Taiwanese firms or consortia of firms develop technologies important to their international competitiveness. Projects are submitted by industry and reviewed by MoIT for approval; approved projects required a cost-share match from companies. ITDP has invested more than NT$13.58 billion ($420 million USD) in 536 projects with 864 companies. MoIT states that the program has created 15,000 jobs and attracted NT$9.32 for every NT$1 invested.

- **SBIR Program.** Fashioned after its U.S. namesake, the SBIR program is designed to strengthen the R&D capabilities and competitiveness of small and medium-sized businesses in Taiwan. Created in 1999, the program has competitively funded more than 3,000 SME R&D projects and is credited with stimulating more than NT$12.1 billion in industry R&D investments. Like its U.S. counterpart, SBIR disburses funds in two phases. Phase I awards up to NT$1 million ($30,000 USD) for up to 6 months to explore the technical merit or feasibility of a specific technology. Phase II is an R&D phase in which companies are competitively awarded up to NT$5 million ($310,000 USD) to further develop a technology. However, unlike the U.S. program, the program differs in the fact that companies can apply for a phase II award without having applied for a phase I award, and all SBIR funds must be matched by the awardees.

- **Innovative Technology Applications and Services Program.** Created in 1999, ITASP is designed to improve the service aspects of Taiwanese companies, based on the understanding that services are the fastest-growing segment in the global economy and this sector offers excellent growth potential. The Program does this by funding the development of unique business models, applications, and processes. ITASP has cofunded more than 370 projects and has been credited with creating 6,500 jobs and attracting more than NT$12 billion ($373 million USD) in private sector investment.

- **Multinational Innovative R&D Centers in Taiwan Program.** In 2002, the government launched a major effort to foster the development of R&D centers within Taiwan. It has encouraged

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domestic companies to set up R&D centers on their own or in the form of joint ventures with multinational corporations, with the government providing subsidies to offset their cost. The program is credited with the establishment of more than 100 R&D centers for domestic companies and 29 that include international companies, attracting NT$35 billion ($1 billion USD) in private R&D funds.

Focus on Universities and Basic R&D

The Taiwanese economy continued to expand in the 1990s, led by rapidly growing high-tech companies such as TSMC, Acer, Quanta, and others. While ITRI has received much of the credit for Taiwan’s emergence, the universities have also been important for the development of new technologies. Taiwanese universities are well respected and have successfully educated a generation of scientists, managers, and entrepreneurs. Furthermore, National Chiao Tung University and National Tsing Hua University are located within the Hsinchu Science Park and have conducted critical research, for example, in the development of the semiconductor industry.

Critical to this evolution was the passage of the Basic Law on Science and Technology in 1999, patterned after the U.S. Bayh-Dole Act of 1980. Previously, the NSC not only funded the majority of university research but also owned the IP. The Basic Law on Science and Technology reorganized the ownership and management of university IP. In 2001, MoEA also created a series of state-funded programs to further encourage technology transfer from universities, including technology transfer centers and incubators.222

In 2001, MoIT also created the Themed Industrial Technology Innovative R&D Center program, an effort to encourage universities to focus on research fundamental to advancing key Taiwanese industries. The program provides direction and follow-on funding to NSC-funded research projects or accepts proposals from university research teams for specific development projects. The program is also credited with a number of outputs, including 422 patents, 188 international licensing agreements, and 79 joint ventures with industry, as well as a rapid increase in industry-sponsored research. An example is the Systems on Chip program. The Systems on Chip program was established in collaboration with ITRI to focus university research on foundation research important for creating advanced processing systems on the micro- and nanoscales. To this end, the government has funding 85 new faculty positions in predefined subfields of specialization important to the Systems on Chip program.

While Taiwanese universities have played the role of industrial development partner well, a larger concern is the role of universities in the innovation system as it relates to long-term competitiveness. While Taiwan has accomplished stunning growth within the course of 60 years, most Taiwanese companies have yet to develop the capability to create completely new technologies and instead have continued to focus on being fast followers employing second-mover advantage. While Taiwan has world-class capability for rapidly manufacturing technologies obtained abroad, its innovation system still lacks the basic science capability important to the creation of new industries and revolutionary new technologies.

Many experts credit the historically generous funding of basic research within U.S. universities for the sustained creation of original, path-breaking technologies. Taiwanese government officials have been concerned that the research and mission of Taiwanese universities has been too applied, to the detriment of basic science and fundamental discovery. While the NSC has traditionally funded basic science within universities, many experts have observed that the overarching technological goals of Taiwan are still

defined by the state, and academia is seen as a subsidiary tool that is used to achieve these aims. The universities, therefore, are urged to develop their faculty and departments in accordance with the state’s S&T industrial policies.

Taiwan has recently placed a decided emphasis on organic innovation by increasing public spending for basic research, along with the aforementioned efforts to encourage technology transfer. Furthermore, new career path and tenure regulations placing greater emphasis on publication and basic science indicate that Taiwan’s universities may be better situated to be partners in the development of new technology and innovation capabilities, as opposed to a “cog” in development. While these seem to be important steps, it remains to be seen if they will help Taiwan become a locale that can move from a fast-follower to a leader in the production of new, original technologies.
Analysis and Lessons Learned
Taiwan

Taiwan is often heralded as one of the “Asian Tigers” and an icon for rapid, sustained economic and political development. Taiwan became what’s called a fast-follower or late-comer locale by creating the unique capability to exploit scale economies through its innovation system that emphasized advanced manufacturing within key economic sectors, high-tech and otherwise. Taiwan began this evolution by recruiting multinational corporations to set up facilities to take advantage of cheap wages. However, after they were established, Taiwan quickly transitioned through a series of policies and programs designed to capture increasingly value-added segments of global industries.

The results have been phenomenal. In addition to being one of the fastest growing locales for the past 60 years, Taiwanese companies have been world leaders in semiconductor design and manufacturing, the design and manufacture of computers, components, and peripheral, and in other areas, such as chemicals, bicycles, and services.

Positive lessons learned from these policies include the following:

- Taiwan was successful in helping its companies gain an early understanding of global supply chains combined with the benefits of targeting specific, value-added market segments through import substitution regulations and by encouraging entrepreneurship (indirectly) to take advantage of these opportunities.
- The creation of MoIT, ITRI, and other public programs demonstrates the importance of public institutions dedicated to market intelligence, coordination and technological capability to emerging, fast-follower economies. Furthermore, the government has flexibly adjusted its policies as markets and the needs of Taiwanese companies and its innovation system have evolved.
- The establishment of ITRI as the lead high-tech institution for both continuous industry upgrading and the spinoff of new, innovative business models based on technologies acquired from abroad has been critical to the competiveness and establishment (respectfully) of key Taiwanese industries. ITRI was established with a clear industry-oriented mission and staffed with Taiwan’s best and brightest scientists and engineers;
- Government programs were guided by the maxim of spurring innovation (upgrading) within an industry. Furthermore, upgrading was not limited to firms within “sexy”, high-tech industries, such as semiconductors and laptops, but also focused on creating new technologies for more mature sectors, such as bicycles, sewing machines, and services.

Concerns and opportunities about the Taiwanese economy include the following:

- While ITRI has played a critical role in the Taiwanese economy, there has to be a careful balance with the need for private companies to develop their own R&D capabilities. While recent efforts are encouraging, there is concern that industry has become too reliant on ITRI and other government programs.
- The creation of III and the experience of the Taiwanese software industry (negatively) illustrates the importance of understanding market structure and ensuring that new policies and programs will support, not suppress or compete with, existing firms and their evolving strengths.
- There is a great deal of concern that Taiwan will be unable to transition from a fast-follower to one whose companies produce new, original innovations within global markets. Central to this concern is the traditional role of universities in serving government-directed industry needs and their relative lack of focus on basic discovery, an element that has been deemed critical to the creation of new technologies.
Executive Summary

The Russian government is implementing new policies to modernize Russia and to transform its economy into a knowledge-driven one. In doing so, old institutions have been reformed, new institutions have been created, and new policies to promote innovation have been adopted. However, Russia has not yet succeeded in creating an independent, self-sustaining Russian innovation ecosystem. This chapter examines the transition from the Soviet period and catalogs the innovation efforts to date as a prelude to making a series of recommendations to strengthen and improve this process.
This chapter sets out the following general characteristics of the Russian innovation system:

- The Soviet Union had a highly developed infrastructure for integrating science and technology that was driven by State orders and was focused primarily on military and national security needs.

- Demand for domestic Russian science and technology collapsed with the dissolution of the Soviet Union. Many talented scientists either left the country or left science. The Russian Diaspora constitutes a source of potential strength for the future innovation economy.

- The existing Russian economy does not provide sufficient internal market demand for Russian science and innovation. Russia is poorly integrated into the world market for technology and innovation due to very weak mechanisms for commercialization of Russian IP.

- Russia retains fundamental strengths in intellectual and human capital, particularly in the areas of physics and math and in sectors such as space technology and atomic energy.

- The university system has recently begun to be reorganized with the goal of making it more relevant to the demands of a modern economy. So far, fundamental scientific research remains the domain of the Russian Academy of Sciences.

- The Russian government has implemented policies to stimulate entrepreneurship through creation of new physical infrastructure programs for incubators, special economic zones, and technology parks.

- The Russian government has also acted to stimulate investment through creation of government-funded finance and development agencies. Despite progress in these areas, critical institutional gaps still exist, including the inability of Russia’s State-funded investment organizations to fully participate in international markets and their lack of expertise in doing so.

- The Russian government procurement process does not efficiently support demand for innovative goods and services due to lack of standards requiring government agencies to purchase based on best product available and effective procedures combating unwritten preferences for large companies and bribe-givers.

- A critical weakness in the Russian innovation system is the very limited organizational support and financing for early-stage companies.

- Implementation of Russian government policy for innovation is inconsistent and often results in contradictory policies among different ministries and from national to local government.

  - There is no clear consensus on whether to focus on traditional large enterprises or on small to medium enterprises as the drivers of innovation.

  - There is no consensus on whether to create a dispersed set of innovation ecosystem regional clusters or whether to focus on one centralized national innovation hub and centralized innovation policies that preempt regional initiatives.

  - There is no consensus on the relative weights of public and private sector contributions and their interactions in creating the ecosystem, leading to inefficiencies on both sides.

  - Furthermore, there is no consensus on whether exports or internal domestic demand should be the primary driver for innovation.

- As a society, Russia has many talented entrepreneurial people, but it does not have an established culture of entrepreneurship to support them and to promote entrepreneurship as an important societal function.
Soviet Background

The Soviet system was successful on its own terms in many areas for the application of science to society, particularly in power generation, atomic energy, military production, and space technology. The Soviet centrally planned economy created demand through administrative fiat. It was very effective in large-scale engineering projects, such as power generation, energy development and transport, space technology, and nuclear energy. It was also very effective in the application of basic science to the defense industry. This system created separated institutional “silos” of science and expertise that were coordinated by the central ministries on a nonmarket basis. There was no invisible hand of the market, only the visible hand of the state.

The collapse of the Soviet Union brought the complete collapse of the domestic market for innovation in Russia. The centrally planned economy had created chains of supply and distribution between enterprises across the expanse of the Soviet Union. There was extreme specialization of supply chains in large-scale, often geographically separated enterprises. With the collapse of the Soviet Union, these chains of industrial production and supply also collapsed. Design bureaus, institutes, and production facilities no longer were linked by central ministries and in many cases were now separated by national borders of new countries. Market-based supply chains simply did not exist. For instance, when McDonalds entered the Russian market it had to create its own local supply chain for food and packaging materials that corresponded to its own quality standards. Under these conditions, the existing links between science and industry were completely severed.

Russia in the 1990s

With the early stages of integration of Russia into the world economy, enterprises that could afford to modernize did so by purchasing foreign equipment. For the most part, Russian manufactured equipment was not competitive by world standards, and if an enterprise had sufficient funds, it would almost always choose foreign technology over Russian. The trend of purchasing foreign equipment has been very visible in the oil and gas industries, where, for example, Russian companies purchase Russian technology that has been repackaged by foreign oil service companies at exponentially higher prices.

In sectors where Russian products were internationally competitive, there were other difficulties that prevented large-scale success. Business-related obstacles to a competitive presence in international markets included lack of familiarity with foreign business practices and cultures, poor marketing materials, inferior packaging, lack of exposure to and conformance with market standards, unclear ownership of IP, and complex currency regulation and payment processes. All of these business problems were compounded by the poor image of Russia and Russian products internationally and the lack of support for Russian international economic activities from the Russian government itself.

One exception, and an exception worth noting, came in software outsourcing and software products, where Russian companies were able to successfully enter international technology markets. Russian software outsourcing companies grew out of the crisis in the early 1990s in Russian universities, during which university funding disappeared. Academics, particularly mathematicians, who had foreign ties and who had an entrepreneurial character began to create small companies to provide software outsourcing services for foreign clients. These small companies gradually accumulated experience with foreign business culture, foreign market requirements, project management, and foreign market presence that allowed them to steadily grow in size and revenue. Today, the largest of these companies compose a significant technology-based industry sector for Russia. Leading companies include EPAM, Luxoft, Artezio, Exigen Services, Auriga, and many others. As the industry has matured, they have formed RUSSOFT, a private industry association to promote their interests internally and in foreign markets.
An analogous process has taken place with the development of Russian software product companies, which have become successful in selling their products in foreign markets, often while not promoting their Russian origins. Successful companies in this sector include Kaspersky Labs, ABBYY, Acronis, Parallels, and SoftLab-NSK. All of these companies derive a significant portion of their revenue from sales in the world market.

The development of both software outsourcing and software product companies was significant as a demonstration of the entrepreneurial spirit that arose in Russia in response to very difficult living conditions for members of the scientific intelligentsia in post-Soviet Russia. These companies were almost entirely self-financed and grew without the benefit of any government support or encouragement. As the least capital-intensive form of technology companies, the IT services sector was able to overcome the instability of the Russian environment, which undermined long-term investment in other technology sectors. Over time, these companies became highly integrated into world markets.

It is also notable that these companies established themselves in world markets virtually without any assistance from the Russian government. The structure of government assistance for Russian business in international markets remains virtually the same as it was under the Soviet system. The foreign trade offices are not sophisticated in trade promotion, and the Russian government offers little export finance support or marketing support.

A second outlet for unemployed academic scientists was working for multinational companies. In the 1990s there was a significant movement of talented Russian scientists, researchers, and mathematicians to the U.S. or Europe. Later, a few forward-looking international companies established their own sales and services operations in Russia. In many cases sales offices led to the addition of R&D centers in Russia. The basis of these development centers in Russia was the availability of highly trained Russian intellectual talent, with Russian development centers integrated into overall international operations. Notable in this regard are Intel, Boeing, Cisco, EMC, Schlumberger, PriceWaterhouse and Motorola. By employing significant numbers of Russian staff these multinational corporations created a pool of people who understood international business and operational procedures. In this manner, multinationals are directly or indirectly contributing to the creation a new base for technology and entrepreneurship in Russia.

The movement of world-class Russian scientists and researchers to foreign countries has created an extensive worldwide Diaspora of Russian-speaking scientists and entrepreneurs. This Diaspora is a potential source of entrepreneurial talent and expertise for modern-day Russia if properly approached and incentivized.

Within Russia in the 1990s, many scientists were unable to support themselves and their families by working as scientists and they gave up their scientific work.

The result of the combination of movement to other countries and movement out of scientific fields inside Russia is that Russia now has a demographic hole in its age distribution of scientists, with preponderance of old and young. This creates a gap in the transmission of scientific knowledge and experience.

**Russia in the Early 2000s**

Russia emerged from the turbulent 1990s with solid economic growth from 2000 until the 2008 worldwide economic crisis, which was driven largely by increasing prices for oil and other natural resource commodities. During the crisis, the Russian economy declined by 1.3%, but growth in 2010 has been 6%. The impact on Russia of the economic crisis was cushioned by large government reserves that were used to finance government deficits, maintain and increase social benefits for retirees and
veterans in particular, and support key industrial and financial institutions. Despite a prolonged period of economic growth after the crisis of 1998, the total output of the Russian economy is still only 85% of the output in 1987. The impact of the crisis has added an additional stimulus to examine the shape of the future Russian economy and a diversification from the reliance on production and export of raw materials.

Throughout this period of growth, Russia did not spend as much as its emerging market rivals in modernizing its economic infrastructure. In the period from 2000 to 2007, fixed investment in Russia remained at about 20% of GDP; during this period China was averaging 40% and India 30%. As a result, internal private market demand for modern equipment and innovative products has lagged. Russian and foreign economic commentators take it as an article of faith that the majority of Russian business leaders are not interested in investment in their own productive facilities but prefer to make as much short-term profit as possible. They tend to avoid long-term capital investment both because of uncertainties about the future and because they can continue to make reasonable profits through exploitation of existing facilities. Limited competition in the domestic market also reduces the push for efficiency through investment in innovation. Russian-owned companies operating in international markets appear to adopt innovation at the same rate or better than their competitors, indicating that the lack of investment inside Russia is not some kind of Russian cultural aversion to innovation but a business calculation. Most likely it indicates a lack of trust in the Russian business environment, a lack of management expertise inside Russia or the belief that having good products often does not guarantee sales.

Under these circumstances, the impact of Russian government expenditures, referred to as “budget money,” has become one of the main drivers of domestic demand for innovation. The importance of government spending in the domestic innovative sector was dramatically illustrated by a 30 to 40% drop in the IT sector in 2009 that was attributed to a decision by the Russian government to suspend spending in the private market for e-government programs and to give these funds to the State-controlled telecom company, Rostelecom.

The most direct impact of government spending is on military industrial production, which, after a period of lapsed activity, has reestablished the Soviet tradition of demanding the most innovative and competitive weapons systems. However, as opposed to other countries, it appears that increased military spending has no positive impact on the general innovation ecosystem in Russia. There is no evidence of spin-offs from military spending. In contrast, it appears that spending in the military sector merely provides an economic alternative that eliminates the need for creating start-ups.

The Russian space program is a source of national pride in Russian technological achievement, and it is arguably the worldwide leader in space-related technology. Russia has also revived its Soviet-era satellite and satellite telecom sectors, in particular strengthening Glonass, its own satellite navigation system.

There also have been a number of quiet successes in commercialization of Soviet and then Russian technology in international markets. Companies like IPG Photonics in laser technology (www.ipgphotonics.com) and NT-MDT in precision instruments and scientific equipment (www.ntmdt.com) have demonstrated the commercial viability of Russian technology and intellectual capability without wide recognition or appreciation of their Russian connections. It is probably a product of the period of their development that these companies thought it better not to emphasize the Russian connection. However, Russia’s image in world markets would be well-served by a broader understanding of these successes.

President Medvedev was elected with the promise of reform in the four “Is,” innovation, institutions, infrastructure, and investment, and the widely acclaimed promise to modernize the Russian economy.
He initially focused on streamlining government policies, eliminating duplication and misalignment of economic policy by identifying five areas of concentration for the innovation economy:

- Biotechnology and life sciences
- Cleantech (i.e., new energy sources)
- IT and supercomputing
- Space and telecommunications
- Nuclear technology

The five areas of concentration present a mixture of sectors in which Russia has traditional strengths, like space and nuclear technology, areas in which it is weak, like Cleantech, and areas where it believes it needs to develop to stay competitive in the world, like biotechnology and supercomputing.

Success in this transition will depend upon the success in creation of a Russian Innovation Ecosystem. Elements of this system have been introduced by borrowing innovation policies and institutions from around the world as interpreted through a Russian institutional and historical lens. Listing and evaluating these elements of the innovation ecosystem are critical to any process of developing recommendations.

**Elements of the Russian Innovation Ecosystem**

**Human Resources: Education and Training**

Human resources in the form of skilled and creative scientists and technical workers are critical for the success of the proposed transition of the Russian economy. The current institutional basis of S&T in Russia reflects the legacy inherited from the system constructed by the Soviet Union. The institutions promoting and developing S&T under the Soviet system were divided into four general categories:

- **The Russian Academy of Sciences.** The highest level was that of research institutes grouped into the Russian Academy of Sciences, which carried out roughly two-thirds of the basic research. The Russian Academy of Sciences predates the Soviet Union and is actually the product of an earlier period of modernization under Peter the Great. In 1990, there were 535 institutes of the Russian Academy of Sciences. In the post-Soviet period these institutes suffered greatly from lack of funding and began contracting. Sectors like biology seem to have suffered more from the effects of this period, while physics and mathematics suffered less so.

- **Higher education.** The second group was composed of the higher education sector, primarily universities, which were responsible for training scientists, engineers, and researchers. Universities carried out far less basic research but did carry out contract research with enterprises and institutes. In the beginning of 1992, there were 450 educational institutions carrying out scientific research on a contract basis. These institutions also suffered a disastrous decline from lack of funding in post-Soviet Russia.

- **Industrial sector R&D.** These were sector-specific institutes connected with the economic ministries of the centrally planned economy and as such were the centers of applied research for each specific sector. All of the enterprises under a particular ministry would receive their technology and innovation from the institute of their ministry. In 1990, these industrial R&D institutes accounted for 75% of the applied research, 88% of the development research, and 78% of total research conducted in that year. Most of these institutes have either disappeared or have transformed themselves into real estate companies; others became affiliated with large corporations.

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• **Enterprise R&D.** These institutes were attached to a particular industrial enterprise and were responsible for adapting the technologies developed by the industrial sector R&D institutes to the particular conditions of that enterprise. Some of these institutes have made a transition to profitable R&D organizations, particularly in the oil, gas, and some natural resource sectors. It is worth noting that while universities are generally the center of scientific research in other advanced economies; the institutes associated with the Russian Academy of Sciences have historically been the center of fundamental research in Russia. Universities have been high-level educational institutions but not the center of advanced research. Only the most advanced universities, like Moscow State University, Moscow Engineering Physics Institute, Moscow Institute of Physics and Technology, Moscow State Technical University (Bauman), Novosibirsk State University, and St. Petersburg State University, were integrated with research institutes of the Russian Academy of Sciences for the purpose of conducting fundamental research.

An important specific aspect of the Soviet S&T institutional design was the geographic dispersal of secret science cities that were developed to carry out fundamental research tasks. More than 50 closed science cities were created in the Soviet period. Most were located near a city but were separated by high security from the local area and had no relationship to the local economy. These cities were concentrated collections of scientists supported directly by the central government and integrated into the overall economy through the ministries of the centrally planned economy. Since they had no independent economic base, when the Soviet Union was disbanded they also faced very difficult times. This dispersal must be taken into account when designing policy for the creation of market-based innovation ecosystems.

According to the Russian Ministry of Education and Science, currently the ratio of students to the overall population is 500 students per 10,000 members of the general population, compared to 200 students per 10,000 inhabitants during Soviet times. This means that the proportion of students in the population is more than 250% larger than during the period of the Soviet Union. However, it is generally true that the knowledge and skills obtained by students in the institutes of higher learning often do not meet the needs of employers. Some 50% of graduates from institutes of higher learning do not find work in their academic specialty and end up performing work requiring considerably lower qualifications than what their degree would indicate. As universities made the transition to market conditions of tuition-based revenue, the quality of education was often diluted, particularly in newly introduced disciplines like law and economics in which they had little expertise.

The Russian university system has gone through a recent reform, with the goal of facilitating more practical interactions related to the needs of the real economy. Moscow State University and St. Petersburg State University have been designated as Presidential universities, meaning that their rectors are appointed directly by President Medvedev. They are directly funded from the State budget, and they can set their own standards, independent of the Ministry of Education.

There are now seven Federal Universities, often the result of consolidations of existing universities, with rectors appointed by the Prime Minister. They are subordinate to the Ministry of Education and have to re-compete for their status every 5 years. They are the Siberian Federal University in Krasnoyarsk, the Southern Federal University in Rostov, the Northern Federal University in Arkhangelsk, the Volga Federal University in Kazan, the Urals Federal University in Yekaterinburg, the Northeastern Federal University in Yakutia, and the Far Eastern Federal University in Vladivostok.

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224 Ibid, p. 10.
There are also a number of research universities, which are previously existing institutions that have been designated to be research centers. All of these schools are to have a research-based curriculum and all can set their own standards.

As part of the reforms of the university system, regional governments are not allowed to provide financial support for their local universities. This inhibits local initiative, flexibility, and the possibility of additional financial support from progressive regional governments.

In 2009, Russia passed legislation that was intended to mimic the U.S. Bayh-Dole Act and enable Russian universities to establish their own commercialization offices. To date, some 475 commercialization offices have been registered by universities and institutions of higher education. It is believed that most are not active at this point.

Russia has a grant system to support research in certain areas, but it tends to be bureaucratic in its evaluation of grants and grant results. Often grants become just another form of budget finance rather than an instrument of obtaining competitive scientific results. There is some interest in examining grant systems used in other innovative country university environments.

In the opinion of many experts, there is far too little modern business education and little practical entrepreneurial training, except for the Skolkovo Business School. Most of the best MBA programs are in Moscow, which increases the pull of business talent away from the Russian Regions.

As already indicated, the Russian Academy of Sciences has historically been the center of basic research and continues to defend this role for itself in current times. The Russian Academy of Sciences has been wary of foreign companies and Russian entrepreneurial business diverting its best young students and faculty away from the pursuit of basic science and thus has not appeared to facilitate commercialization.

**Government Bodies Guiding Innovation Policy**

Russia has a clearly stated intention to modernize its economy and promote innovation. In carrying out this intention, it has established three top-level bodies that reflect the dual nature of the Russian political structure, with two bodies centered in the Presidential Administration and one in the Russian government. These bodies are as follows:

- **The Presidential Commission for Modernization and Technological Development of Russia’s Economy** (http://i-russia.ru/). The Commission Chairman is President Dmitry Medvedev. It has working groups on energy efficiency, nuclear technologies, strategic computer technologies and software, medical equipment and pharmaceuticals, space technologies, and telecommunications.

- **Government Commission on High Technology and Innovation** (http://government.ru/eng/gov/agencies/138/). The Commission Chairman is Prime Minister Vladimir Putin. It is responsible for development of government policy in modernization and implementation of new technology in economic development.

- **Presidential Council for the Development of the Information Society in Russia** (www.iis.ru/eng). The Council oversees creation of e-government and the use of modern information technology in health care, social protection, culture, education, science, and disaster management. The Council also looks at bridging the digital divide between Russian regions, international experience of development of an information society development, legislation in the information society, and overall development of the information industry.

Innovation policy is primarily implemented by the following ministries, which report to the Prime Minister:
Ministry of Education and Science (http://eng.mon.gov.ru/). The Ministry of Education and Science has broad responsibility for policy creation and regulation in education and research. The Ministry has developed a *Strategy for Development of Science and Innovation in the Russian Federation till 2015*. The goals of this policy include creation and expansion of a competitive R&D sector, creation of an effective national innovative system, development of institutes of application and legal protection of results of R&D, and modernization of the economy on the basis of technological innovation. However, the Ministry has no formal responsibility for commercialization of research.

Ministry of Economic Development (including the Department of Special Economic Zones and Project Finance) (http://www.economy.gov.ru/minec/main/). The Ministry of Economic Development operates within the framework of the *Concept of Long-Term Social and Economic Development of Russia till 2020* and the *Basic Directions of Government Activity till 2012*. The activities of the Ministry with regard to innovation include stimulation of innovative activity of existing enterprises, assistance in creation of new innovative companies, stimulation of demand for innovative production, and support of orientation towards innovation in the science and education sector. The Ministry has an approved *Plan of Activities on Stimulation of Innovative Activity of Enterprises*. The Ministry has within it a Department of Special Economic Zones and Project Finance (http://www.economy.gov.ru/minec/activity/sections/specialEconomicAreasMain/index.html) that is responsible for special economic zones (SEZs).

Ministry of Telecommunications and Mass Communications (www.minsvyaz.ru). In addition to its general responsibilities, the Ministry is responsible for administering the network of high-tech parks and e-government programs and expanding adoption of information and communication technologies across the country.

In a formal sense, official policy as reflected in the activities of these ministries shows a clear intent to promote innovation. There is no one person or agency responsible for the innovation ecosystem as a whole or for administering programs for adoption of new technologies within public institutions and state-controlled companies.

As a result, official policies administered by other ministries for other purposes do not promote innovation. As an example, the current Russian tax structure favors extractive industries with high capital expenditures and relatively low percentages of expenditures for salaries. There is a very low flat tax on personal income but a very high social benefit tax that must be paid for every employee. As a result, those industries that rely primarily on the intellectual activity of their work force, like the software engineering industry, pay very high taxes.

**Initiatives for Physical Infrastructure to Support Innovation: Incubators, SEZs, and Techno Parks**

Over the past decade the Russian government has adopted a series of institutional measures to build a new physical infrastructure to support new businesses, including business incubators, SEZs, and technology parks.

Business incubators have been widely developed across Russia with varying degrees of success. In general, they have not been connected with all of the elements necessary for success of innovation and therefore have not attracted many entrepreneurs. In general, incubators are not run as self-supporting businesses and have no incentive to promote the success of the companies they serve.

The Russian government has set up a program for SEZs, defined as a geographically closed area where there special regulations to encourage entrepreneurial activities. There are special time-limited...
Incentives and tax privileges for residents of an SEZ, including a reduction in corporate income tax and exemptions from customs duties and property and land taxes. There are several types of SEZs, including industrial production zones, technology development zones, tourism and recreation zones, and port zones.

So far several SEZs have been established, including:

- Industrial-manufacturing: Lipetsk Region, Republic of Tatarstan
- Technology development: Saint Petersburg, Zelenograd, Dubna, and Tomsk

The SEZs have had limited success in promoting innovative businesses. They have very complex procedures for entry, inconvenient internal operating procedures, and no special protection for investment made within the framework of the system. They are much more successful in supporting industrial production and assembly and, in some cases, R&D subsidiaries of Russian companies, rather than supporting startups.

In addition to SEZs, the Russian government has created a program for a network of high-technology parks, or “techno parks.” A techno park is supposed to become a small town of between 10 and 15 thousand residents as a full-fledged scientific and technological cluster, where the distance between the academic sciences and business is minimized. The techno park also includes residential space to upgrade the living conditions of researchers and scientists. Each techno park is developed around a large educational institution or a leading scientific institution. Unlike a SEZ, a techno park does not offer any special customs or tax benefits. It is an open, commercial environment.

Within the government initiative, the following new techno parks are planned or in the beginning stages of implementation:

- Chernogolovka Technopark (Moscow Region): chemistry, information technology
- Technopark “Idea” (Kazan, Tatarstan Republic): information technology, petrochemicals
- West-Siberian Innovation Center (Tyumen): oil and gas exploration and production technology, information technology
- Novosibirsk Akademgorodok Technopark “Academpark” (Novosibirsk): biotechnology, information technology, electronics and scientific instruments, nanotechnology
- Obninsk Technopark (Obninsk, Kaluga Region): nuclear technology, information technology, biotechnology, medical technology
- Nizhny Novgorod Ankudinovka Technopark (Nizhny Novgorod): information technology, biotechnology
- St. Petersburg IT Park: information technology
- Kemerovo Technopark: coal safety technology, chemistry
- Technopark of the Republic of Mordovia: microelectronics, telecommunications

Inconsistent government support and implementation of the high-tech park program have meant that only two of the planned networks of high-tech parks are in actual operation as of 2010. Both of these, in Novosibirsk and in Kazan, are fully occupied, indicating real demand for this type of facility.

In contrast to the incubators and SEZs, the techno parks were designed to be self-supporting commercial enterprises that are to operate as real estate development entities specializing in supporting innovative businesses.

Business incubators, SEZs, and techno parks do not necessarily operate separately from each other. There is a growing use of business incubators within an SEZ or techno park, for instance. These instruments of physical infrastructure support for innovation are all relatively new, and there is a lot of experimentation and discussion about how to use them most effectively.

A major difficulty for Russian start-ups is the lack of facilities for prototyping. Traditionally in the Soviet Union, all parts of the chain of production were done in-house within large industrial enterprises.
As a result, there are few custom machine shops or production facilities to prepare prototypes. The lack of independent and small-scale production facilities means that when a new company needs to produce a small run or prototype, it has to either buy expensive equipment that it may not need in the future or find a foreign service provider. The inability to produce prototypes is a major factor in the inability to show proof-of-concept for innovative companies and is something that is being addressed by some of the techno parks. The Bortnik Fund recently announced plans to fund such a program, but amount committed does not seem adequate to the scale of the problem.

While there is recognition at a policy level that small and medium-sized business must be stimulated to assist in the creation of innovation in Russia, the Russian economy remains dominated by large enterprises and government entities prefer to buy from them. This was clearly stated by President Medvedev at a session of the Council of State:

“Today, small business contributes 17% to the GDP. The share of innovation business is very small, about 1%. The number of small businesses in science and information technology is minimal (we are talking about few per cents), such business accounts for a few per cents in public health and few per cents in education.... We need to develop business activity in industry, construction and public utilities. Today, almost 50% of small businesses we have deal with commerce. And we are aware that today we need quite different small businesses.... We have to create incentives to allow small business into industries directly associated with economy, knowledge economy, in the first place. And today such businesses could take on the functions of commercialization and marketing of new technological ideas.”

The Skolkovo Project

The current centerpiece of Russian government innovation policy is construction of a new technopolis city in the Moscow suburb of Skolkovo (www.i-gorod.com). Popularly referred to as the “Russian Silicon Valley,” the exact model of the new technopolis will probably differ substantially from its U.S. West Coast prototype. The project will create a new ultramodern town of around 20,000 permanent residents. It will include educational facilities, research facilities, incubators for small business, and R&D facilities of international companies. It is expected to take from 3 to 7 years to complete. The general concept is to create an analog to the leading centers of innovation in the world as a jump start for Russia into innovation and as a means of propelling Russian S&T achievements into the top ranks for the world in these areas.

Skolkovo will be governed under special legislation that establishes special tax, customs, and land regulation, along with its own police force and local administration. The intention is to create a truly international project at Skolkovo that will be managed by an international board that includes both Russians and foreigners. In June 2010, the Skolkovo Foundation and MIT signed an agreement to explore areas of possible cooperation within the Skolkovo project, including establishing a new international university and cooperation in new research labs.

Public or Quasi-Public Funding for Innovation

In order to stimulate funding of innovation in Russia, the Russian government has established a number of state-sponsored funding vehicles, including the following:

Private Funding for Innovation

Private funding for innovation in Russia is extremely limited. Private equity funds usually do not invest in technology companies. The financial institutions of VC and angel funding have begun to establish themselves in Russia, despite a weak legislative basis. The most important Russian VC organization is the Russian Venture Capital Association (www.rvca.ru/en). The most prominent angel investor organization is the Union of Business Angels in Russia (http://www.russba.ru/language/en/). A number of VCs have announced joint projects with Russian financial structures, for example DFJ-VTB-Aurora. Some of the private equity funds like Barings Vostok and Russia Partners have shown interest in

- **Russian Venture Company** (RVC; http://www.rusventure.ru/en/). The RVC is a government fund of funds that acts as a development institute for the Russian Federation and is intended to be one of Russia’s key tools in building its own national innovation system. RVC has authorized capital of around $1 billion dollars. As of February 2010, RVC-backed funds held a portfolio of 27 companies, with invested capital of approximately $149 million dollars.

  Originally, it was planned that the RVC would establish local venture funds in the Russian regions, but this led to a fractured investment policy and was deemed to be inefficient, so the idea of individual regional funds was abandoned. As an alternative, RVC has signed seven cooperation agreements with different Russian regions, with 3 agreements in the pipeline and another 12 to be signed by late 2010, covering 30% of Russian regions.

- **Russian Corporation of Nanotechnologies** (RUSNANO; www.rusnano.com). RUSNANO was established in 2007 to develop and promote nanotechnology as a priority of the Russian government policy and was initially capitalized with $5 billion dollars and another $5 billion dollars in guarantees. RUSNANO can co-invest up to 50% ownership in nanotechnology industry projects that have high commercial potential or social benefit. Projects go through a two-stage approval process, beginning with review by a scientific-technical committee and, if approved, financial review by the oversight committee. RUSNANO also participates in building nanotechnology infrastructure, including nanotechnology centers of excellence, business incubators, and investment funds. RUSNANO tends to invest in large-scale projects rather than start-ups.

- **Russian Technologies Corporation** (http://www.rostechlogii.ru/en/). The main functions of the Russian Technologies Corporation are assistance in developing and producing innovative high-technology industrial products, promotion to and sales in the domestic and foreign markets of innovative industrial products, associated by-products, and IP, and attraction of investment to different sectors of innovative industry. It is most closely associated with the military-industrial complex and other traditional industrial enterprises.

- **Rosinfokominvest**. Rosinfokominvest is a $150 million sovereign investment fund founded in 2006 to invest in projects in ICT. It is fully owned by the Ministry of Communications. As of the middle of 2010, it had failed to begin any investment activity.

- **Bortnik Fund** (http://www.fasie.ru/Default.aspx). The Bortnik Fund was founded in 1994 to support small business in the S&T sphere. It provides seed grants through the Старт program and R&D grants through the ЎМНХК program. As of June 1, 2010, it had reviewed some 20,000 projects and provided support for 7,000. The Bortnik Fund is a critical financial resource for start-up companies and is unique in providing grant financing at that level. The Fund is not a true commercialization fund and does not involve itself with the next stages of startup company development.

Private Funding for Innovation
Russia Impacts on Start-Up Companies

Russia Impacts on Start-Up Companies

Russian technology projects and are sufficiently large and control substantial investment portfolios to manage those investment opportunities that interest them.

In addition to weak legislation, the principal obstacle to development of private funding for innovation is the lack of exit opportunities. Only a handful of technology companies are publicly traded, so exits through IPOs are not realistic. Exits are usually through merger or acquisition. This makes financing through private equity companies very restricted. The alternative would be to organize exits through Western IPO’s, which substantially reduces the role of Russian finance and forces registration outside of Russia.

The weakness of the innovation ecosystem as a whole leads to a deficit of projects available for investment. VCs have a difficult time constructing a project pipeline and finding investable projects. Statistics from the Russian Venture Capital Association show that 80% of investment capital is dedicated to financing restructuring or business expansion and only 20% is earmarked for early-stage financing of new companies. VC firms have to look primarily for export-oriented or consumer-oriented business, like internet or telecom businesses. This seriously limits the pipeline of projects.

Several of the leading Russian funds have searched for an answer by investing in international projects or by copying Western projects without any real technological innovation. The best example of this is the fund Digital Sky Technologies, investing in Facebook, ICQ, Vkontakte, Mail.ru and others. In total this indicates that the problem is the lack of investment projects that fit the investment criteria, rather than an absolute lack of sufficient volume of investment capital.

The deficit of early-stage financing is particularly pronounced in the Russian regions because the VC companies tend to be located in Moscow. Like VC firms elsewhere in the world, Moscow VC firms want geographic proximity to their investments in order to monitor and assist the companies in which they invest.

There is also a potential danger from establishment of nominal VC firms by wealthy individuals who have limited or no experience with VC, which could spoil the image of VC as a necessary institution in the innovation process. In this regard, international expertise is necessary to help properly develop the institution of VC in Russia.

Impacts on Start-Up Companies

The weakness of private funding means that Russian start-ups need to become profitable almost from the beginning of their existence, limiting their ability to develop technology. This may include companies that require relatively small amounts to fund their first prototype.

In addition to the lack of initial capital, it is a well-known fact that Russian technology start-ups lack experience in developing business plans that reflect the fundamentals required for equity investment and they lack access to affordable legal, accounting, and consulting services that are required to prepare an “investable” business plan and to properly protect their IP.

The lack of early-stage funding and assistance in business development is a major impediment to the development of large numbers of innovative start-up companies.

Culture of Entrepreneurship

Individual business was not only discouraged but illegal in Soviet times. In response, Russians developed very sophisticated networks to “get” what they needed and very creative solutions to difficult problems. However, this ingenuity is not the same as the process of starting a business as an entrepreneur.

With the dissolution of the Soviet Union, entrepreneurship began to appear. As a result of the privatization of State property, a small number of highly successful people came to dominate business at
all levels of the economy. Scientists and engineers entered into business as some of the few people who had a culture of competition during the Soviet period. At the same time, a large number of people began to start small businesses out of economic necessity. It was an era in which kindergarten teachers became food importers. Russian business in this era was characterized by short-term thinking, fast money from rapid turnover of trade goods, and a determined effort to hide profits from the government and tax authorities. So, while Russia developed its own class of entrepreneurs, this form of entrepreneurship had little connection to innovation. As a result there are few successful serial entrepreneurs or mentors for innovative entrepreneurs.

As a general matter, talented people tend to seek the security of working for large companies and institutions, rather than taking the risk of starting their own business. However, entrepreneurship as a social force in Russian society is gaining momentum, particularly among young people. The most visible indicator of this activity can be seen in youth camps and gatherings like Seliger in Tver, Bar Camps across Russia, and the Interra International Youth Innovation Forum in Siberia. All of these activities indicate to a certain extent a spontaneous striving towards a more innovative future for Russia.

There have been a few notable successes in commercialization and technology transfer, but overall there is very little expertise in commercialization of Russian IP.

## Specific Geographical and Cultural Factors

In considering Russia’s innovation policy, it is important to take into account certain specifics of its geography, cultural makeup, and position in the world. Like the U.S. and India, the Russian population is made up of a very diverse set of cultures, ethnic groups, and languages. The existence of these diverse cultures inside the country provides the opportunity for culturally based links with surrounding countries and, like the existence of the Russian Diaspora, could become important in building economic ties.

Also like the U.S. and India, Russia is a very large country, spanning Europe and Asia. Russia borders a vast and diverse set of countries, ranging from Europe to the Middle East to Asia. As such, it is a potential land bridge and transportation link for the Eurasian land mass and the growing Pacific Rim economies.
Summary of Strengths, Weaknesses, Opportunities, and Threats

**Strengths**
- Strong base of human intellectual capital and S&T institutions recognized for their excellence around the world.
- Large internal market.
- Significant government investment and initiatives in high-technology sectors.
- Geographical position and historical links in the heart of Eurasia with direct access to European, Asian, and Middle Eastern markets.

**Weaknesses**
- Underdeveloped demand for innovation in its internal market.
- Poor physical facilities (office space, housing for scientists, communications, etc.).
- Underdeveloped financial system, with limited private financing for investment and lack of possibility of public sale exits to encourage private investors.
- Tax and legal systems misaligned with the requirements of high-technology businesses.
- Lack of international entrepreneurial experience and traditions.
- Poor knowledge of international markets, limited experience in global technology trade, language barriers, and underdeveloped networking capabilities.
- Poor international business image and negative examples from some foreign investments.

**Opportunities**
- Worldwide demand for innovative products and IP.
- Large undeveloped capacity to absorb innovation in the Russian domestic economy.
- The disconnection between Russian strength in science and the ability to turn that science into products and new companies provides the potential for rapid growth through installation of commercialization processes.
- Government-implemented infrastructure projects (e.g., Skolkovo Project, techno parks, SEZs, and technology clusters).
- Government-supported development institutions actively developing international cooperation and promoting investment domestically (RUSNANO, RVC, Rosinfocominvest).
- Growing interest in innovation among Russian elites in business and government.
- Recession in developed countries providing fewer employment opportunities, opening a window to attract world-class talent to Russia.
- Global investment institutions and VCs expanding and looking for international opportunities.
- The large Russian Diaspora, especially in the U.S. and Israel.

**Threats**
- Uncontrolled rapid growth of operating costs, including salary and facilities costs.
- Competition with international companies.
- Movement of talented people out of the country and a shortage of managers and experienced business people in Russia.
- Corruption and administrative barriers.
- Aggressive and often unscrupulous competitive behavior of large Russian companies.
- Inconsistent government policies.
Governments worldwide are increasingly looking to innovation as an important, if not crucial, pathway for the quality of life, consumption, and personal prosperity for their people. While many countries and regions of the world have pursued policies and programs to spur innovation, only a handful has arguably succeeded. This report explores the experiences of a few of these countries/province, focusing on context, assets, public policy, evolution of policy and, in some cases, fortune, from which the themes below were derived.

However, a few words of caution are warranted. First, the themes presented in this paper are not meant to be one-size-fits-all policy prescriptions but rather directional considerations for the Russian government as it undertakes its own efforts to spur innovation. Themes such as building on traditional industrial strengths and creating a robust understanding of international markets are seemingly ubiquitous. However, the success or failure of these policy efforts, among others, will depend on the quality of their implementation and how well they take into account specific contextual, political, and mission-oriented challenges. In short, new innovation policies must reconcile Russian realities and take into account the specifics of Russian geography, history, and culture.

As mentioned in the introduction, efforts to calibrate a national innovation system must be placed within the broader context of country-specific reforms, such as taxation, rules of law, bankruptcy, and trade. A specific example in this report related to taxes is the Life Sciences Tax Incentive Program established in Massachusetts to incentivize life sciences companies to create new long-term jobs in the region. The Act provides incentives that address the significant capital expenditures associated with the life sciences R&D cycle and the high costs of translating research into commercially viable products. With regard to trade, for example, India’s early decision to implement License Raj had a profound negative impact on the competitiveness of its industry, while Taiwan’s competitive, innovation-based import substitution efforts were stunningly successful.

It is tempting to see innovation-based economic growth as a destination instead of a “journey.” In other words, the same interconnectedness and market dynamics that enable countries, regions, and companies to capture or grow segments of international innovation value chains also make sustaining long-term competitive leadership much more difficult. All the locales examined in this review are concerned about their competitiveness and have or are undertaking significant innovation policy reforms. For example, Taiwan is concerned that it will not be able to transition from a fast-follower region to one where

Background

Russia differs from Israel, Finland, and Taiwan in that it is beginning its innovation policy decisions with existing S&T institutions that were developed in the Soviet period and that have been partially transformed over the past 20 years since the dissolution of the Soviet Union. It further differs in that it has a potentially large internal market, which is analogous in this regard to the U.S. Aspects of the conditions for success of innovation policy outlined in the study are already in place in Russia; however, additional measures are advised to fully utilize the potential of Russian S&T for the transformation into a knowledge-driven economy.

One of the clear and unequivocal lessons of this study is that in every case government has a critical role in developing innovation through correct and flexible policies supported by adequate funding. In no case has any innovative ecosystem developed without government involvement. This emphasizes the critical importance of the Russian government “getting it right.”

As a general observation, many of the institutional elements of an innovation economy have been recently introduced into the existing institutional framework. In some sense, time itself will be necessary to allow these institutions to become established and find their path(s) to success through trial and error. Russia will not be transformed overnight or in 3 or 5 years, which is the economic equivalent of overnight. While it would be a mistake to expect such a dramatic change, it is also necessary to continually monitor, refine, and revise the measures that have been implemented and the institutions that are newly founded. So, in the Russian context, a firm, long-term political commitment to the overall course of transition to a knowledge-driven economy will be critical.

There are very important institutions that are essential for an innovation economy which are weak or are absent, as will be specified in the following recommendations. Beyond those weaknesses, what appears to be missing currently is an active engagement of the various institutions of an innovation ecosystem with each other in a mutually reinforcing system of institutional relationships that support entrepreneurship and innovative technology.
15 Steps to Take

Define and create mission-oriented grand challenges based on the needs and strengths of the country.

Funding of mission-oriented research aligns leadership and resources behind a common goal. In Taiwan, Israel, and the U.S., this approach proved incredibly successful in the defense sector, spurring key technology developments primarily in ICT. In the case of Taiwan, a grand challenge to upgrade technology in small and medium-sized businesses was declared, and this was met through aligning these businesses needs with government-funded R&D.

The Russian government has already identified five areas of grand challenges: biotech and life sciences; Cleantech (new energy sources); IT and supercomputing; space and telecommunications; and nuclear technologies. These areas have been carefully selected as the areas of the most promising and critical technology sectors for Russia within the current state of technology worldwide. But Russia needs to also identify specific areas of technology where, based on its competitive advantages, it can become a clear leader and not just on an equal plane with other advanced countries.

Russia should leverage existing S&T strengths and traditional industries, not limited to high technology; natural resources should not be ignored. Finland’s paper industry is a good example of leveraging a natural resource. The Finnish paper manufacturers produced high-value niche products, such as glossy paper coated with new varieties or combinations of chemicals, eventually overtaking its Swedish counterpart. Taiwanese examples of innovation in bicycles and sewing machines are also illustrative. Russia should also consider how innovation can take place in areas of traditional strengths, not just new start-ups.

The Russian government should consider reformulating its goals in the five areas of technology to clarify them and where possible focus on areas of specialization where Russia can be a world leader, as a natural outgrowth of its existing sectoral, scientific, and geographic strengths. More specifically:

Energy (combined Cleantech and atomic energy)

- Become a world leader in transformative energy technology in gas, oil, and atomic energy. As the world’s largest energy-producing country, Russia should utilize the strength of this sector to adopt transformative technology and innovative solutions to the most pressing problems facing humanity. The fires of the summer of 2010 in Russia, the catastrophic oil spill in the Gulf of Mexico, and increasing weather-related disasters worldwide are precursors to even more serious problems that Russia must take the lead in solving.
- Become a world leader in all related areas of earth science and climate change research. Due its unique combination of deep scientific knowledge and vast territorial diversity, Russia can become the premier laboratory for the application of science to solutions of problems related to humanity’s natural environment.

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228 Sabel and Saxenian, p. 38-39.
229 Sabel and Saxenian, p. 27.
15 Steps to Take

- Dramatically boost Russia’s domestic market for energy efficiency and clean tech by leveraging the ongoing housing and utility reforms and utilizing government purchasing power to install the most advanced energy-efficient technologies.

Communications, transportation, telecomm, and space technology (expanded space and telecom):
- Become the world’s logistical, transport, and cultural bridge. Territorially, Russia is the crossroads of Europe, the Middle East, Asia, and the Pacific Basin. Historically, periods of peaceful trade within this Eurasia space have been periods of worldwide prosperity.
- Augment strengths in space and telecommunications and in rail transport by expanding technologically advanced roadways, pipelines, and ports that would link world markets more efficiently than current sea traffic through construction of high-speed rail lines linking Europe and Asia and Asia and North America, and through a redesign of the Russian national highway system. This would act as a catalyst for regional development and cutting-edge technologies in sectors where Russia has traditional strengths, such as satellite communications, and promote change in sectors where Russia has dramatic need for technological improvement, such as road construction.
- Promote Russian culturally diversity as an asset for a Eurasian country serving as a common ground for the cultural interaction necessary for greater stability and peaceful economic growth in the world within the conception of use of soft power. Political development in this direction will bring a competitive advantage to Russian entrepreneurs entering international markets.

Biotechnology and life sciences:
- Reform the standards of Russian drug development, testing processes and clinical trials so that they are accepted internationally as reliable and compliant.
- Support the development of the entire production chain for leading-edge biotechnology and pharmaceuticals, from support of biological and chemical research, to commercialization, to preclinical and clinical testing, and manufacture.
- Emulate Indian policy to rebuild the pharmaceutical industry through focusing on production of generics and providing preferences in government purchasing for locally produced generics.
- Utilize incentives and leverage government purchasing power and set-asides in order to bring manufacturing of leading-edge drugs by leading multinational pharmaceutical companies to Russia.
- Develop supportive government legislation and policy for particular requirements of biotechnology companies.

IT and supercomputing:
- Provide adequate government funding for leading-edge supercomputing facilities.
- Improve the quality of education of software engineering graduates by training professors in modern business practices in the software industry and utilizing software company professionals to teach university-level training courses.
- Allocate funds to promote Russian software and product companies at international trade shows and IT-related seminars and conferences.
- Adjust the tax structure to support high-technology businesses, whose main expenses are salary and thus pay disproportionately high social welfare taxes.
Solicit feedback from stakeholders to define grand challenges.

After identifying a national vision and priorities, it is necessary to explain these goals and choices to the general public and to create a shared commitment in society among critical stakeholders. Stakeholders include policymakers, investors, industry, and academia leaders from around the world. Government should consider appointing stakeholders to a high-level consultative organization, perhaps in the form of either a new Science and Technology Innovation Council or a reformed Commission for Modernization of the Economy to formalize this stakeholder advisement on innovation policy decisions, and this organization would report directly to the President. This will allow for organizing two-way communications and support for reform from “below” and also allow for proper positioning of Russia in the international arena.

One example is Israel. In the early 1970s, Israel recruited former industry scientists and business leaders to fill roles at the Office of Chief Scientist in order to better understand Israeli private industry. This organization played an instrumental role in transforming Israel’s civilian innovation system. Additionally, in Taiwan, STAG was created in 1979 and was charged with the goal of recommending specific public investments to promote R&D among Taiwanese industries.

In implementing this recommendation, Russia should:

- Establish an international Science and Technology Innovation Council to bring together politicians, business leaders, investors, and academics to continuously monitor and discuss progress in implementing grand challenges.

Establish long-term political commitment to meet the grand challenges.

Long-term political commitment proved critically important in the case of Finland. Recall that during its depression of 1991 through 1993, Tekes’ funding for R&D did not decrease despite the economic crisis. Many feel this was a major contributor to the economic success Finland has achieved.

To demonstrate long-term political commitment, Russia should:

- Create the position of National Chief Technology Officer, reporting to the President and responsible for coordinating procurement of new technologies by government agencies and organizations.
- Establish an international audit committee reporting to the CTO to review progress in adopting innovation in state-controlled companies and government agencies on an annual basis and link executive bonuses to adoption of innovation.
- Create the position of National Chief Information Officer, reporting to the President and responsible for implementing a vastly expanded program of e-government through public private partnerships. The CIO would also establish standards and lists of services to be provide through e-government developed by market players, not bureaucrats.
- Initiate an ongoing internet-based national dialog on the grand challenges and progress in addressing them.

STAG is the acronym for the Science and Technology Advisory Group, which is comprised of a permanent advisory body of industry, education, and government leaders dedicated to S&T issues. STAG is discussed in more detail in Chapter Five, covering Taiwan Province.
4 Align national, regional, and institutional policies behind grand challenges.

During Finland’s depression years of 1991 through 1993, the Finnish government launched a series of regional initiatives that were aligned with national innovation policy and were focused on policies that favored knowledge and R&D over capital investments. This is considered a very successful and impactful policy strategy. Coordinating national, regional, and even institutional policies maximizes the return on investment for a government.

As we have seen in the example of the decline of the computer industry in Boston, Massachusetts, not understanding the relationship of regional markets and broader technology market developments can lead to disastrous declines in local industry sectors.

In implementing a regional policy, Russia should:

- Create a technological development map for Russia that identifies competitive advantages and weaknesses for all regions, and select priorities for federal assistance.
- Develop regional policy that is based on actual existing regional strengths in science, technology and production, allowing for concentration of resources where specialties already exist and preventing a rush by each and every region to create its own innovation system. Innovation support resources should be concentrated where chances of success are highest.

5 Understand international and domestic markets.

For countries with large domestic markets, like the U.S. and India, such markets should be well understood and leveraged fully. Only small domestic markets existed in the cases of Israel, Finland, and Taiwan, and therefore their domestic markets were not as important in achieving the recognized economic gains. Thus, international markets became the primary focus. The experience of these countries shows that the choice whether to emphasize external or internal markets leads to different priorities in policy.

Taking account of the seriousness of the problem with internal market demand in Russia, it is possible to use the Indian approach of beginning with an international focus within special economic conditions and after achieving some success beginning a transition to focus on the internal market. It is specifically recommended that institutions be set up that are modeled after BIRD in Israel or VTT in Finland that will facilitate market entry for Russian companies into international markets and bring best technologies from international markets to Russia.

As discussed in the chapter on Israel, BIRD focuses primarily on understanding U.S. multinational companies’ needs and matching them with the technology capabilities of Israeli firms. In the case of Finland, VTT is the national laboratory with a recent focus on commercialization of research. As part of this technology transfer focus, VTT has dedicated resources to understanding international markets.

Implementation of these lessons for Russia should include:

- Prioritize international market entry and import best practices from abroad while developing local demand.
- Assign the National Chief Technology Officer the responsibility for developing sophisticated understanding of international technology trends.
• Establish a think tank to monitor technology trends worldwide and to develop corresponding mandatory technology policies for government agencies and government-controlled companies.
• Establish business development and commercialization offices that will act as intermediaries between Russian and international technology markets on a business basis and provide early stage assistance.
• Assist international VC firms to being operations in Russia, both organizationally and through Russian investment in these firms.
• Promote Russia internationally through trade shows, conferences, and by facilitating travel for Russian entrepreneurs to such events.
• Create a Russian national export support agency and review the current system of trade representatives.

6 Stimulate internal demand through world-class standards, regulation, and procurement protocols.

As an example of the profound influence of government policy on internal demand and competitiveness, it is important to look at how the Finnish government’s enactment of standards to promote competition and to set advanced operating standards in telecom set the stage for the emergence of the ICT industry in Finland. Another example of clear and transparent regulation cited in this paper is the Cambridge Biosafety Ordinance discussed in Chapter Three. This ordinance was established at a time when life sciences were a nascent technology rife with uncertainty. The ordinance provided transparency and clarity, proving to have a very positive effect for the Boston region.

In applying this lesson, Russia should:
• Mandate international standards and regulations rather than developing Russian ones in key grand challenge areas, such as the energy sector, for all new purchases and installations.
• Create a network of state procurement agencies, one for the federal government and one for each region, which allows for considerations of quality and local content as part of the criteria for selection of suppliers.
• Create a leasing company under Vnesheconombank for state procurements.
• Require a certain percentage of purchases by State-controlled companies to be from local suppliers, provided world-class standards are observed.

7 Establish a balance between large and small companies and between multinational and domestic companies with the understanding that all are necessary drivers for a successful innovation system.

The importance of this mix to maintain a healthy innovation system was discussed in more detail in Chapter Three (the chapter on the U.S.). Small firms can access market information and entirely new markets by drawing upon big companies, while big companies can access new technologies that aid the growth of a regional industry. Additionally, as in the case of Israel, a successful VC industry developed from this mix. There is a caution in the development of the Israeli VC industry, which has been criticized for not being “patient capital” enough to encourage the long-term growth and expansion of Israeli firms. As a result, today there are very few large multinational Israeli companies.
In working with international corporations, it is important to guarantee the long-term character of their interest in the country and to stimulate the transfer of their technology and business practice into the local economy. As shown by the experience of India, Taiwan and even Russia, international companies can leave a country when there is an economic crisis. Therefore, the demand for real and substantial investment inside the country is necessary to guarantee that they will remain and will stay active.

In seeking the appropriate balance, Russia should:

- Continue developing an innovation infrastructure through techno parks and Skolkovo that recruit all sizes of companies and a mix of multinational and Russian companies to establish the rich and complex innovation ecosphere necessary for success. Give different incentives for different types of companies: start-ups, existing Russian businesses, and multinational corporations.
- Develop effective incentives to continue to attract multinational R&D and manufacturing facilities to Russia.
- Require those companies who want to broadly sell their products in Russia to establish local technology capacity, local production, local technology supply chains or carry out significant R&D activity.
- Use tax and incentive programs to push large Russian companies to purchase and utilize innovative technology. Extend the VAT exemption for Skolkovo residents to the buyer side.

**Focus on basic research to ensure a pipeline of cutting edge technology and human talent for future market demands.**

This should be accomplished by the creation of a new institution or reform of an existing Russian organization, like the Russian Fund for Basic Research, which could house a modern science research infrastructure and provide research grant money through an international peer-reviewed process. This institution should adequately compensate its researchers and provide cutting-edge research opportunities while not discriminating in compensation between Russian and foreign researchers. The goal is to have researchers attracted by quality research opportunities and not exclusively by high wages. This institution should be located in an area that provides a good quality of life. This entity should be coordinated or even joined with the institution assessing market needs described in an earlier recommendation. A model for this type of agency can be found in Finland. Not only is the research peer-reviewed, but it is also done in the context of an international community. This engages top science and engineering talent internationally, including expatriates. Raising the quality of research will inherently increase the quality of the science and technology talent base as well. Additionally, a percentage of each grant should require an application focus, perhaps even requiring a business partner, in order to receive the grant money. Research oriented towards industry has been shown to be a successful model across all five of the locales reviewed, with institutions such as RAFAEL, VTT, DARPA, CSIR, and ITRI.

In continuing to develop its human capital, Russia should:

- Establish a new network of research labs with international participation dedicated to the problems of the grand challenges which will operate independently but engage with the traditional institutes of the Russian Academy of Sciences and universities.
Reform grant funding as follows:

- Change the procedure for allocating research to link financing to the total duration of projects, rather than annual allocations.
- Change the reporting procedure for grants from the current emphasis on the final grant report to a system in which results of a grant are the prerequisite for new funding.
- Establish international committees to assist in awarding grant funds.
- Make Russians and foreigners equally eligible for research grants, without any discrimination based on country of origin.
- Tie grants to individual scientists and researchers so that they can move between institutes or universities and bring the grants with them.
- Continue to reform university funding and operations.
- Allow regional governments to finance regional universities and research institutes.
- Mandate that all government universities establish endowments and provide initial funding for these endowments as a means of establishing financial independence for universities.
- Establish funds to pay for business people to teach technical, engineering, and business courses at universities.
- Fund cooperative exchanges with foreign universities in basic science and commercialization.
- Provide financing for publication of Russian scientific publications in international journals.
- Allow tax benefits for research, education, and university endowment donations, similar to those available in the U.S.

Create a research university to address the grand challenges.

Such a university would recruit the best and brightest international science and technology talent, work closely with industry, and seed an entrepreneurial culture. Quality of life should be a significant factor in deciding the location of the new institution. Models that should be considered include the Okinawa Institute of Science and Technology as well as the Institute of Science and Technology in Austria.\(^{231}\) Entrepreneurial teachings should be integrated throughout the institution to catalyze the creation of a more entrepreneurial culture, ultimately achieving an “MIT effect.”

- Establish a new university to promote the connection of science and industry, following the example of MIT, as part of the Skolkovo Project.
- Establish targeted, zero down payment, low-interest mortgage programs to support scientists, researchers, and high-tech company employees in obtaining satisfactory housing, and expand this program through Skolkovo to scientists and researchers across the country.

Establish clear IP ownership rules for government-funded research.

The establishment of clear IP ownership rules will aide in the promotion of research commercialization. The Bayh-Dole Act arguably provided the basis for research commercialization in the U.S. and is considered by many as the international best practice.\(^{231}\) These two institutions are not discussed in the report specifically but were discussed during the interview portion of our study.
Given the history of research institutions, it is important to establish ownership laws that promote dissemination of new knowledge and the commercialization of research.

Russia should take the following measures:

- Review existing law on technology transfer to allow IP revenues to be shared by universities without the necessity of engaging in costly and bureaucratic procedures. Do not require universities to sell IP, but allow licensing for royalties.
- Encourage filing and subsidize the fees for filing international patents through commercialization organizations.

**Establish trusted and complete IP law.**

This recommendation evolved from the study of India and is discussed in more detail in Chapter Four. In short, not providing strong protection inhibits innovation and diminishes the motivation to invent, because the invention can easily be copied by a competitor. The Russian patent system has a number of obsolete elements borrowed from the Continental patent system. Existing rights are poorly enforced and not internationally recognized. This system creates the illusion of protecting IP, but is insufficient and often dangerous for IP rights of Russian entrepreneurs in current conditions.

Russia should take the following measures:

- Conduct a general review of existing IP legislation.
- Declare a general amnesty on patent contests from the Soviet era to remove any remaining ambiguity on ownership of IP and allow for commercialization; the amnesty should be based on granting a right of ownership to the current holder or claimant, provided that they declare what government lab, institute, or institution was the original place of development and that they pay a small percentage of proceeds from commercialization to said institution.
- Create a national directory of IP linked with the name of the current owners and originating research institutions.
- Publicize examples of successful enforcement of IP legislation, especially with regard to foreign companies.

**Establish appropriate innovation infrastructure environment that includes both physical and institutional support.**

When establishing a physical infrastructure in which to house start-ups and small businesses, the supporting elements for business development, commercialization, and networking relations within the park environment are critical, i.e., a physical infrastructure is not enough to successfully build an innovation environment. Over time, operation of these physical facilities can achieve financial sustainability, thereby removing the necessity of ongoing public support or subsidy. In the case of Israel, 13 of 24 incubators became financially independent within several years of establishment. In the case of Finland, the Technopolis model of commercial management, providing common management for a number of parks and providing supporting services, has resulted in self-sufficient technology parks.

As Russia further develops existing techno parks in Novosibirsk and Kazan, initiates additional techno parks as part of its national program, and builds out Inno City as part of Skolkovo, the following should be considered:
Conclusions

15 Steps to Take

- Continue development of the operating techno parks in Novosibirsk and Kazan and provide the necessary funding for them to reach financial independence through construction of planned housing, infrastructure and social spaces.
- Develop techno parks in other cities that have been identified as having good prospects through the general plan of development of techno parks.
- Establish shared production and prototyping facilities at techno parks as part of a proof-of-concept program, modeled after the Despande Center.
- Use Inno City of the Skolkovo Project as a national innovation hub in cooperation with existing techno parks, universities, and institutes of the Russian Academy of Sciences and not as a competitor.
- Establish Inno City as a physical center for R&D, education, and incubation of new innovative businesses, but use the Skolkovo Project as a broader, country-wide system of promotion of innovation that is open to any innovative company.
- Pay attention to providing business services and business networking within the physical facilities.

Provide early-stage funding and business services to help develop new technologies and traverse the infamous “Valley of Death.”

The “Valley of Death” is the period of technology development between basic research and proof-of-concept during which funding is difficult to obtain because the risk is still considered too high and private investors are reluctant to provide the necessary capital. The Israeli Office of Chief Scientist and U.S. programs such as TIP, SBIR, and DARPA are models in which the government initiates the creation of public-private partnerships to address this lack of financial capital and bridge technical hurdles. This funding should be coordinated with the market intelligence information garnered through the work of the institution, as outlined above in another recommendation.

- As a means of providing this necessary funding, Russia should consider establishing business development offices within the framework of the Skolkovo Project to administer government funds for support of early-stage companies, including business planning, legal and patent support, marketing, transitioning to next-level funding, and international market entry and technology transfer.

Support and expand the private investment sector.

VC firms follow entrepreneurs and exits. Therefore, seeding an entrepreneurial environment and building a pool of serial entrepreneurs is the best strategy for attracting VC capital to a region or country. Traditionally, VCs invest in their “backyards,” where they are close to the technology they are funding and interaction is easy and welcomed. The creation of Israel’s Yozma fund is a successful example of a nation fostering a VC industry, in this case, through supporting partnerships between Israeli financial institutions and foreign VC firms. Establishing a VC community through a combination of importing experience and domestic talent growth is important not only for providing the necessary venture capital but also, equally important, for providing the network of professional managers and entrepreneurs as well as their personal technical assistance. As discussed in the report, an exit mechanism for investors is also critical.
NASDAQ IPOs have provided VC firms with the opportunities they need to exit from their investments, realize their return, and invest in a new generation of start-ups.

To accomplish this task, Russia should:

- Make legislative changes necessary for VC and angel funding, including amendments to corporate and bankruptcy law. Of particular importance for the VC industry would be changes in the corporate law to allow for Russian limited liability partnerships.
- Establish a working system of “exits” for private investors through a “NASDAQ” for Russia. This could be accomplished either through creating a new exchange or through purchasing a foreign one. In either case the goal is to leverage the liquidity available in Russia to foster private funding of innovation.
- Subsidize costs for innovative companies to convert to international accounting standards and to list on Russian NASDAQ.
- Allow Russian pension funds and development banks to allocate up to 5% of their funds for investment in venture capital funds.
- Remove restrictions on RUSNANO and Russia Venture Company from investing in foreign companies and mandate a set percentage of funds to be allocated to investing in the Russian NASDAQ.
- Allow the Russia Venture Company to participate as a limited partner in foreign venture capital funds.
- Establish pilot programs with experienced foreign venture companies to bring potentially successful foreign technologies to Russia in partnership with Russians.
- Allow for zero capital gains tax for investments held for five years or more to encourage longer time frames for investment.

**Promote the culture of entrepreneurship.**

- Popularize entrepreneurship as a positive career path by highlighting success stories in the mass media.
- Support business education in Russian regions by establishing funds for successful international and regional entrepreneurs to teach in universities.
- Develop mentoring programs for young entrepreneurs, utilizing both Russian and foreign successful entrepreneurs.
- Develop acceptance of “failure” as a necessary part of entrepreneurship and often as a prerequisite for later success.
- Support and expand youth-oriented entrepreneurship events.
- Promote the example of successful entrepreneurs as a worthy social role model and distinguish self-made entrepreneurs from the generally negative public image of “Russian oligarchs.”

Although not included as a specific recommendation, a country’s overall image plays a certain role in enabling a country to attract investors, entrepreneurs, and other necessary talent and businesses. The public relations component should not be underestimated in the context of creating an innovation-based economy.

In order to complete the discussion of international experience and questions to consider as Russia develops its policy, there are other more ambiguous lessons to consider.
20 Pitfalls to Avoid

From Israel we learned:

1. **Individual or Institutional Leadership.** Strong leadership in development agencies is important early-on, but not sufficient. It must be institutionalized.

2. **International or Domestic Markets.** Failure to appreciate the technology transfer relationships of small companies to multinational ones can stunt the development of small domestic companies when there is low domestic market demand.

3. **Buy or Attract Diaspora.** Over-reliance on money – and not national pride and challenging work – will limit the effectiveness of a nation’s attraction of its Diaspora.

4. **Create or Force Demand.** Forcing private industry to purchase innovative products will fail, but Government procurement creates market demand.

5. **Expectations of Incubators.** Lack of tolerance of failure will inhibit the success of incubator development and physical infrastructure support.

From Finland we learned:

6. **Tech Parks – Subsidized or Self-Supporting.** Developing science and tech parks without planning for long-term self-sufficiency is a mistake that leads to an ongoing requirement of government support.

7. **Aid to Foreign Companies.** Government innovation support of foreign companies can be a policy option, as long as these companies benefit local economies by creating local jobs as a condition of government support.

8. **Reliance on National Champions.** Too much focus on one company as the national champion (e.g., Nokia) leaves the entire innovation economy vulnerable to market changes.

From the United States we learned:

9. **Government and Private Sector at Early Stage.** Trying to spur innovation without government-financed R&D and procurement is mistaken as it was a critical early stage stimulant to the touted ecosystems in California’s Silicon Valley and Boston’s Route 128 corridor.

10. **Universities and Innovation.** A strong university system is critical for providing a pipeline of technology and the human capital to fuel the innovation economy, but it only fulfills this function if it goes beyond basic research to include the application of research to private industry.

11. **Components of an Innovation Ecosystem.** Efforts to create innovation ecosystems in locations lacking some of the critical elements of an innovation ecosystem have had very limited success.

12. **Large Domestic Market and Necessity of International Outlook.** Although a large internal competitive market can be advantageous to spurring the creation of high
technology products, understanding international markets is important for long-term economic success.

**13 Large, Small, Domestic, International Companies.** Failing to create a mix of young and more established companies will hamper an innovation ecosystem’s capacity to adapt to market changes.

**14 Venture Capital – Self-Generated or Government-Assisted.** Ignoring the government role in financial markets may not result in a spontaneously-developed healthy venture capital sector. Government programs, like SBIC, were critical in early stage creation of venture funds.

**From India we learned:**

**15 Integration of International and Local.** The innovation sector, primarily software and business process outsourcing, can be established as a special environment linked primarily to international markets and independent of the structural problems of the local economy. However due to the separation from the local economy, it has not acted as an engine for growth of the country as a whole.

**16 Invite Multinationals in or Keep Them Out?** Protectionism has been shown to hinder innovation compared to an open system that is fully engaged with the global economy. But a government policy that favors local manufacturing and R&D facilities by international companies has had a positive effect on the domestic economy;

**17 Role of IP.** Flawed IP law will cripple participation in the global economy.

**From Taiwan we learned:**

**18 General Policy or Sector-Based Policy.** A “top-down” strategy for developing innovation is effective if the institutions and industries have a clear understanding of the international market for their industries and respective value chains. This top-down strategy can also result in failure if the successful methods used in one sector are mechanically applied to a different sector.

**19 Government Development and Private Sector.** Many small companies cannot afford to finance and manage of their R&D. So Governments that won’t step in to help – and then won’t turn the technology developed with their help back to the companies for commercial development – will jeopardize private initiative.

**20 Rely Completely on Multinationals or Not?** Multinational companies can act as drivers for creation of an innovation sector, but are not necessarily reliable long-term partners in economic downturns.

The themes discussed in this report have highlighted policies that were successful and those that were not successful in fostering innovation for the locales analyzed. In applying these lessons for Russia, The New York Academy of Sciences has tried to adapt this information to Russia, to offer practical recommendations to the Russian Federation on how to foster innovation in Russia.
Final Remarks

Within the relatively short time frame available for this study, the research team brought together by the New York Academy of Science has done its utmost to provide accurate and useful advice to the Russian government. We are extremely grateful for the opportunity to work on this project and to present our findings. This report establishes a robust foundation for ongoing discussion of how to successfully accomplish the ambitious goals set by the Russian government. The Academy stands ready to work as a long-term partner with the Russian government in this historic task.

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Because no general framework to develop the innovation economy has been presented to the general public by Russian authorities, the New York Academy of Sciences asked one of the contributors to this report, Ilya Ponomarev, Chair of the High-Tech Committee of the Russian State Duma, to take these lessons one step further and to produce a more detailed road map for implementing these lessons in Russia within President Medvedev’s existing “Four I” framework.

The “Four I” program provides a useful and already accepted format for viewing the creation and strengthening of the elements of a healthy innovation ecosystem for Russia. It should be a set of self-reinforcing measures that supports the interaction between the various institutions of the innovation sector and the overall economy. In making the specific recommendations here, the intent is to indicate the directions that should be taken and certain recommended actions that support those directions. There is no presumption that these are the only measures that should be taken or that the specific time frames or outcomes are precise. The measures listed below are intended to contribute to an acceleration of innovation activity, with the understanding that implementation will obviously be determined by the appropriate Russian government bodies.
Innovation: Technological Development.

It is recommended to slightly reformulate the list of five Presidential priorities to make the vision for the future Russian economy more clear and linked to existing national competitive advantages.

**Energy (Clean-tech and nuclear energy)**
- Enforce procurement in accord with energy standards through national and regional procurement agencies (2012).
- Establish energy research lab or labs to develop world-leading technologies (2011).

**Communications, transportation, and space technology**
- Define a strategy to transform Russia into a Eurasian transport and logistics corridor (2011).
- Reconstruction of highway system (2012 to 2020).
- Glonass compatibility required for all telecom and related navigational equipment in territory of Russia (2011).

**Biotech and life sciences**
- Rebuild Russia’s pharmaceutical industry through a focus on production of generics (2011 to 2015).
- Mandate production in Russia of leading-edge drugs by leading multinational pharmaceutical companies (2016).
- Develop supportive government legislation and policy for the particular requirements of biotechnology companies (develop in 2011, enact in 2012).
- Sponsor international clinical trials and permits (2012).

**IT and supercomputing**
- Provide adequate government funding for leading-edge supercomputing facilities (2011).
- Improve the quality of software engineering education by training professors in modern business practices in the software industry and utilizing software company professionals to teach university-level training courses (2011).
- Allocate funds to promote Russian software and product companies at international trade shows and IT-related seminars and conferences (2011).
- Adjust the tax structure to support high-technology businesses whose main expenses are salary and who thus pay disproportionately high social welfare taxes (2010).
- Establish a Russian national grid computing system (2012 to 2015).
Institutions

Legal
- Passage of law on Skolkovo, including system of special privileges for innovation companies throughout the country registering as part of the Skolkovo program (September 2010).
- Set up international advisory committee to review bottlenecks in legislation (2011).
- Review of technology transfer law (completed, February 2011).
- Amend corporate law to allow limited liability partnerships as a legal form (completed December 2010).
- Amend corporate law to allow stock options (completed 2011).
- Amend bankruptcy law to enable fast-track closure of high-tech companies (2011).
- Adoption of international product and quality standards (July 2011).
- Set up mechanism for patent amnesty and clarification of patent rights (first quarter 2011).

Administrative
- Create Export Support Agency (December 2010).
- Create position of National Chief Information Officer (January 2011).
- Create position of National Chief Technology Officer (January 2011).
- Create national patent registry (2011 to 2012).
- Create federal procurement office (June 2011).
- Create regional procurement offices (2011).
- Create a national leasing company (2011).

Tax policy
- Establish special tax regimen for companies listed as part of the Skolkovo Project, wherever they are in the country, allowing them to use Skolkovo as a customs gateway, including relief from social benefit tax, customs privileges, and preference for state procurement (completed by September 2010).
- Set up special zero long-term capital gain tax for capital investments in innovation companies after 5 years (completed by December 2010).
- Set up tax deductions for donations to research, education, or university endowments (first quarter 2011).

Infrastructure

Physical
- Continue development of techno parks in Novosibirsk and Kazan, including construction of common labs and production and prototyping facilities (2010 to 2014).
- Consider construction of new techno parks at a limited number of additional locations, possibly Tyumen, Nizhny Novgorod, or Obninsk (2011 to 2015).
- Complete planning for Inno City and begin construction (2010 to 2015).
The “Four I” Road Map

- Complete planning for creation of a new international technical university in Skolkovo and the network of international research centers (2010).
- Expand broadband penetration for internet in rural areas and small cities (2011 to 2013).
- Carry out an analysis of regional competitive advantage and choose priorities for technical development in various regions (2011).
- Special mortgage program to support scientists and employees of innovation companies (2011).

**Human Resources**

- Change procedure for allocating research to link financing to the total duration of projects, rather than annual allocations (2011).
- Change reporting procedure for grants from current emphasis on final or annual grant report to a system in which results of a grant are the prerequisite for new funding (2011, establish international peer review committees to assist in awarding grant funds).
- Allow Russians and foreigners to be eligible for research grants, without any discrimination based on country of origin (2011).
- Allow regional governments to finance regional universities and research institutes (2011).
- Mandate that all government universities establish endowments and provide state funds for these endowments (2012).
- Allocate funds to pay for business people to teach technical, engineering, and business courses at universities (2011).
- Expand cooperation with foreign universities in basic science and commercialization and establish funds for exchange programs (2012).
- Provide financing for publication of Russian scientific publications in international journals (2011).

**Investment**

- Found a Russian NASDAQ, either green field or through purchase (2012).
- Allow RUSNANO to invest in projects internationally and to purchase shares in high-tech companies listed on Russian stock exchanges (2010 to 2012).
- Allow RVC to invest in international venture funds and NASDAQ (2011).
- Mandate that RUSNANO and RVC allocate 20% of funds invested to Russian NASDAQ (2012).
- Establish business development offices to support start-ups and commercialization of Russian technology (2010 to 2014).
- Allocate funds to subsidize international patent filings for Russian companies (2010).
- Allocate funds within the Skolkovo Project for programs to promote Russian companies in international markets and to develop a positive image for Russia in world markets (2010).
- Audit of State corporations (2011).
The New York Academy of Sciences is the world’s nexus of scientific innovation in the service of humanity. For nearly 200 years – since 1817 – the Academy has brought together extraordinary people working at the frontiers of discovery and promoted vital links between science and society. One of the oldest scientific institutions in the United States, the Academy has become not only a notable and enduring cultural institution in New York City, but also one of the most significant organizations in the international scientific community.

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