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TECHNICAL REPORT

Creating an Innovation System for Knowledge City

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Summary

Guangzhou exemplifies the explosive economic growth that has taken place in China since the country's dramatic economic reforms started more than three decades ago. A major trading center even 2,000 years ago, Guangzhou was named one of China's 14 open coastal cities in 1984 and has become a global center of manufacturing. One of China's largest and richest cities, it is now focused on leading the way toward a high-technology and innovation-based future.

At the heart of this effort is a new project being carried out by the Guangzhou Development District (GDD) and Singbridge of Singapore, the creation of the Sino-Singapore Guangzhou Knowledge City. Knowledge City is to be a new environmentally and technologically advanced city that hosts innovative industries and their associated knowledge workers. To achieve this goal, GDD will need to create a system that supports research, innovation, and the commercialization of new and better products and services.

This report presents RAND's detailed analysis of innovation systems and the steps GDD will need to take to make Knowledge City a success. It is based on analysis of relevant data and documents, interviews with technology entrepreneurs in GDD and international business people and investors operating in China, three detailed case studies of innovative areas, and a formal survey of GDD technology firms.

The report consists of three sections. Part I discusses the concept of an innovation system and the formation of clusters and provides an overview of the innovation system in GDD. It then presents a portrait of high-technology firms in Guangzhou and compares Guangzhou with other Chinese cities—those likely to compete with it for innovative firms and talented workers. Part II describes the factors leading to success for three innovative clusters: Silicon Valley, the life sciences corridor in Maryland, and the information and communications technology corridor between Tel Aviv and Haifa in Israel.

Part III applies lessons learned from the three case studies, as well as from the broader literature on entrepreneurship, innovation, and cluster formation, to GDD and Knowledge City. It assesses existing conditions in GDD, first discussing taxes, nontax incentives, and intellectual property rights, and then considering other innovation assets. The lessons learned are then compared with existing conditions in GDD in a gap analysis.

Part I: Introduction to the Guangzhou Development District and Knowledge City

Innovation does not happen in a vacuum. Researchers who focus on innovation have identified the presence of an *innovation system* as being important for innovation and its role in economic development. Innovation systems consist of both *actors* and the *connections* among them. Innovation policy can be defined as "a set of policy actions to raise the quantity and efficiency of innovative activities" (European Commission, 2010). Although the discussion of innovation systems and innovation policies is often narrowly focused on science and technology policy, innovation systems and policies can include many types of social, political, and economic activities and institutions, particularly in the context of economic development (Lundvall et al., 2002; Liu et al., 2011).

Innovation Systems and Innovation Policy in China

China's innovation system has undergone a major transformation over the past 30 years. It has moved from a system dominated by a few large, government-affiliated actors toward a more decentralized system and has made progress in developing many environmental factors that support innovation, including a venture capital market and an enhanced talent pool. China's innovation policies have also shifted from being focused solely on science and technology to coordinating science and technology policy with industrial, financial, tax, and fiscal policies (Liu et al., 2011). The key components of the current medium- to long-term plan for science and technology are to increase research and development expenditure to 2.5 percent of gross domestic product (GDP) by 2020, to shift toward "indigenous innovation," and to make the business sector the key force behind innovation (Schwaag Serger and Breidne, 2007).

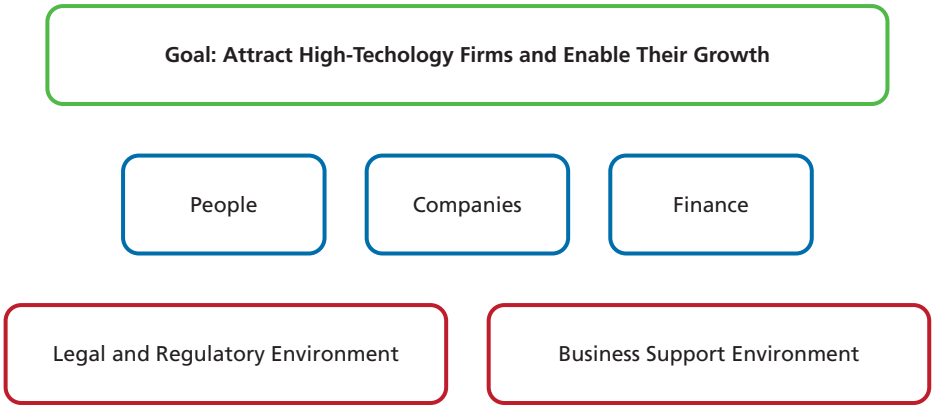
At a provincial level, Guangdong Province has a number of other innovation policies, focused on such areas as creating innovation networks, improving training and education, establishing research institutions, and implementing an intellectual property rights strategy (Kroll and Tagscherer, 2009). Although Guangdong Province is one of the top three regions in China in terms of total patent applications (Kroll, 2010), there are several challenges to its innovation system, including scarce venture capital, weak implementation of intellectual property rights, and a paucity of top universities and research centers. The extreme concentration of research and development in the field of electronic and telecommunications equipment, and in particular in one large telecommunications firm (Huawei), may also be a concern (Kroll and Tagscherer, 2009).

A Framework for the Knowledge City Innovation System

For purposes of the GDD-RAND Knowledge City Project, we consider the innovation system to have a base that includes the legal and regulatory environment and the business support environment, the latter of which can also be thought of as a set of specific GDD policies. We also include the companies themselves, the institutions that provide the physical and organizational space in which innovative activities occur; human talent, the people who carry out the innovative activities; and financing, the flow of money that enables companies and human talent to operate (Figure S.1). Ideally, these will combine into the creation and growth of firms that innovate.

The key reason to define and understand an innovation system is to find leverage points to spur innovation. These could involve government interventions regarding regulation, taxa-

Figure S.1
The Innovation System Framework



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tion, or financing or they could involve interventions regarding how the different elements of the innovation system interact. These interventions collectively amount to innovation policy.

Clusters and Innovation

Industrial clusters are found throughout the world. Clusters may be described as geographic concentrations of interconnected companies and institutions in linked industries, including supplies and customers. A number of scholars have argued that when firms in the same industry are clustered together, the cluster contributes to innovation. In addition, the formation of clusters can be considered an outcome of successful innovation-based economic development policy and would be a sign of success in Knowledge City.

The formation of a cluster may be advantageous for individual firms by providing them with access to natural regional advantages, common infrastructure, lower transportation costs among customers and suppliers, access to a specialized labor pool, information, reputational effects, and the ability to coordinate marketing efforts. The formation of clusters, in turn, can be advantageous for the local area in terms of increasing output and incomes, providing better job opportunities, and expanding the local tax base.

To take advantage of such potential benefits, policymakers in a number of regions around the globe have attempted to foster the creation and growth of innovation-based clusters. Policy might help to form clusters in a number of ways, especially by providing local public goods that firms need but cannot provide for themselves and by creating conditions beneficial to specific, targeted industries. However, the literature suggests that policies to encourage clusters are neither necessary nor sufficient for cluster formation.

High-Technology Firms in GDD

RAND and GDD jointly developed a survey of high-technology firms in GDD, the GDD-RAND Knowledge City Innovation System Research Project Survey ("the GDD-RAND Knowledge City Project Survey"). GDD staff delivered approximately 1,500 surveys and 305 survey responses were received.

Most high-technology firms in GDD are concentrated in two industries: electronics and information technology, and biological and pharmaceutical technology. There are also smaller

groupings of firms in the manufacture of new materials and in the optical, mechanical, and electronic integration sector. The concentration of firms in these industries, especially the first two, raises the question of whether those sectors have an advantage in GDD and therefore whether GDD should concentrate on focusing on these sectors or diversify into other technology areas.

The majority of high-technology firms in GDD were originally founded in GDD or Guangzhou, although one-quarter of firms, accounting for approximately one-third of employment, are subsidiaries of firms located both in China and abroad. This suggests that GDD has gained much of its recent success from providing a fertile environment for domestic entrepreneurs. This does not rule out the importance of continuing to attract companies from outside, whether they are relocating companies or new subsidiaries of existing outside companies. However, it does highlight the importance of not ignoring the opportunities for local entrepreneurs.

Guangzhou in Comparative Perspective

Compared to its peer competitors in China, GDD does well in terms of the assets it has available for innovation. We compared Guangzhou (the jurisdiction in which GDD is located) with Beijing; Shanghai; Tianjin, site of Sino-Singapore Tianjin Eco-City; Suzhou, site of the China-Singapore Suzhou Industrial Park; Hangzhou, site of the Zhejiang California International NanoSytems Institute; and Shenzhen, one of China's first four Special Economic Zones and Guangzhou's neighbor (Table S.1).

Table S.1
Rankings of Guangzhou and Major Peer Competitors

	Guangzhou	Beijing	Shanghai	Tianjin	Suzhou	Hangzhou	Shenzhen
Population	4	2	1	3	5	7	6
GDP	3	2	1	6	5	7	4
Per capita GDP	3	5	4	7	2	6	1
Transportation infrastructure	2	5	1	4	7	6	3
College enrollment	1	3	4	5	6	2	7
Ranked universities	4	1	2	4	6	3	7
Science spending	6	2	1	4	5	7	3
Number of patents granted	7	3	1	7	2	4	5

SOURCES: *China City Statistical Yearbook*, 2009–2011; National Bureau of Statistics, 2011; Shanghai Ranking Consultancy, 2011; statistical yearbooks of individual cities.

NOTES: For the rankings, 1 signifies the highest, most, or best. Population and per capita GDP are from the 2010 census; GDP is calculated from the population and per capita GDP figures; transportation infrastructure includes airports, seaports, and inland waterway facilities; college enrollment includes enrollment in universities and junior colleges in 2008; and science spending reflects expenditures for any science and technology purpose. For ranked universities, we started with universities ranked 50 or higher in the 2011 Shanghai Rankings (Shanghai Ranking Consultancy, 2011) and in the Chinese Academy of Management Sciences rankings (2011). We computed our overall rankings by awarding five points for each university in the top five, two points for each university ranked six through 10, and one point for each university ranked 11 through 50. Under this system, Guangzhou was fifth in the Shanghai ranking and fourth in the Academy of Management Sciences ranking, and Tianjin was fourth and fifth in those same rankings. We therefore tied them at four. Results were similar for other scoring systems.

Guangzhou appears to have a younger population, better transportation infrastructure, and higher per capita GDP than its peer competitors in China, and many of its other assets are similar. However, the lack of top universities and lower ranks on selected science and innovation indicators are concerns. The similarities in assets suggest that Guangzhou can best differentiate itself through capitalizing on its location in southern China near Hong Kong and Southeast Asia and through its current industrial base and associated human capital, its transportation infrastructure, and better government policies and performance.

Part II: Three Case Studies of Innovative Clusters

Case Study: Silicon Valley

Silicon Valley is located in the San Francisco Bay Area in Northern California (Figure S.2). Santa Clara County, just south of San Francisco, can be considered the heart of Silicon Valley. Although Silicon Valley has a number of high-technology industries, it is best known for its success in information and communication technology (ICT). It is characterized by "creative destruction" (progress that occurs through the continuous birth and death of new ideas and new firms), by a high rate of spinoffs (new firms that started by former employees of major firms and universities in the area), and by its leading position in patenting.

The history of high-technology firms in Silicon Valley dates back to 1909, when Stanford graduate Cyril Elwell formed the Federal Telegraph Corporation. Stanford played an important role in Silicon Valley's growth. One of its faculty members, Frederick Terman, encouraged his students, perhaps most famously William Hewlett and David Packard, to be entrepreneurial (Leslie, 2000; Saxenian, 1994; Sturgeon, 2000). During and after World War II, the key firm founded was Fairchild Semiconductor, which was itself founded by employees from another firm in Silicon Valley, and which spawned a large number of spinoffs.

Silicon Valley faced a crisis during the 1970s and 1980s when the semiconductor industry, in which it was a leader, became commoditized. Silicon Valley survived this crisis by moving into other areas and creating new firms. During this time, the "network" structure of Silicon Valley also developed. To survive, firms specialized in the design of high-value-added semiconductors while outsourcing manufacturing to other companies. This unbundling of production, along with an effort by new firms to avoid the previous models of large, "cumbersome organizations," helped to create a network of interdependence among firms that persists to this day (Saxenian, 1994).

Financing. During its early years, individual angel investors financed a number of firms in Silicon Valley. Many other firms were supported by purchase orders from the government. During the 1950s, a small group of investors formed an investment group (called "The Group") that collectively invested in startup firms. The first privately funded, limited capital partnership in California (Draper, Gaither and Anderson) was also established during this time (Kenney and Florida, 2000; Leslie, 2000). In the late 1970s, two federal policy reforms encouraged the growth of private venture capital. First, the U.S. Congress reduced the capital gains tax rate from between 40 and 50 percent (depending on specific situations) to 28 percent (Tax Policy Center, 2011). Second, the U.S. Department of Labor loosened its fiduciary responsibility guidelines for institutional investors, opening up venture capital funds as a suitable investment for pension managers. Today, Silicon Valley receives much more venture capital than other leading metropolitan areas in the United States and around the world.

Figure S.2
Map of Silicon Valley

SOURCE: Map generated by RAND using ArcView GIS, Version 10.0, Redlands, Calif.: Environmental Systems Research Institute, Inc., 2011.

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Human Capital. The population in Santa Clara County is relatively well educated, with 19 percent holding a graduate or professional degree, and nearly 45 percent holding at least a bachelor's degree. These levels are much higher than levels in California or in the United States as a whole. Stanford University and the University of California, Berkeley, have provided skilled talent to the area for more than a century. Immigration is another important source of talent in Silicon Valley.

Quality of Life. Quality of life and the availability of amenities are thought to be potential ingredients in cluster formation, but there is limited empirical evidence. However, there is the "California puzzle." California's growth has been approximately on par with growth in the United States as a whole during the past 30 years, even though California ranks poorly in terms of taxes and costs. Kolko, Neumark, and Mejia (2011) show that in the case of California, mild climate, dry weather, the composition of existing industry, population density, and proximity to a coast have outweighed the potential negative effects from taxes and costs.

Other Factors. Silicon Valley has developed a support structure for startup firms. An entrepreneur can find a number of specialists to guide him or her through the process, including venture capital firms with significant experience working with startups, law firms well versed in relevant fields and willing to offer creative payment options to small firms, patent brokers, staff search companies, and other firms to which such functions as sales, marketing, and accounting can be outsourced. Social networks also play a crucial role in Silicon Valley. Saxenian (1994) points out that many entrepreneurs share ties from attending the same university or having worked for the same employer.

Government Policies. Intellectual property rights (IPR) are not generally discussed in case studies of Silicon Valley. However, the literature on university spinoffs and IPR suggests that allowing both universities and individual inventors to share some of the benefits from invention may be helpful in encouraging entrepreneurship. In Silicon Valley, Stanford University uses 15 percent of cash royalties to cover administrative overhead; patent filing fees are also deducted. The remaining royalty income is then evenly divided between the inventor, the inventor's department, and the inventor's school. Similarly, after deducting 15 percent of equity to cover overhead, equity is shared between the inventor and the university. The university's share goes to a research and fellowship fund (Stanford University, 1999). At the University of California, Berkeley, the inventor retains 35 percent of net royalties and fees plus another 15 percent for use in the inventor's campus or lab (University of California, Berkeley, 2011).

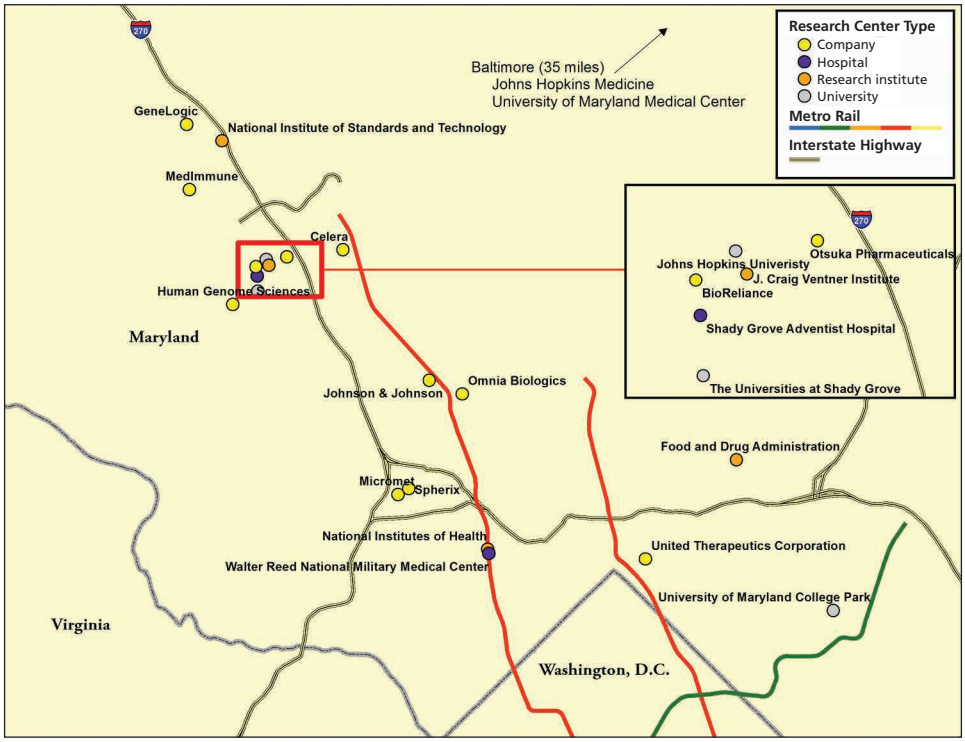
Another reason for Silicon Valley's success is thought to be the fact that California does not allow the enforcement of noncompete clauses, thus allowing employees to move freely between firms. Even in California, however, trade secret law prohibits employees from disclosing an employer's firm-specific trade secrets, although they can take their general and industry-specific human capital with them when they leave (Gilson, 1999). The empirical evidence suggests that labor mobility is much higher in California than in other parts of the United States.

Finally, the State of California and the cities of San Jose and San Francisco currently have a number of policies designed to encourage investment. Most of these policies were not in place during the formation of the Silicon Valley cluster, and none of the evidence or case studies we reviewed suggests that state or local government policies contributed significantly to the growth of the Silicon Valley cluster. The federal government can be seen as having played a larger role in cluster formation by acting as a major purchaser of technologies developed in Silicon Valley during its early years.

Case Study: Maryland's Life Sciences Cluster

Maryland's life sciences cluster is located just north of Washington, D.C., on the East Coast of the United States (Figure S.3). It is situated around a number of federal government laboratories and agencies, which provide the local area with a deep research base. Montgomery County, in the heart of the cluster, also specializes in other industries including information technology

Figure S.3
Map of the Maryland Life Sciences Cluster



SOURCE: Map generated by RAND using ArcView GIS, Version 10.0, Redlands, Calif.: Environmental Systems Research Institute, Inc., 2011.

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and defense. In our case study, we focus on the life sciences cluster, which includes biotechnology, pharmaceuticals, and medical devices.

The share of biotechnology in Montgomery County's economy is approximately 10 times the share of biotechnology in the U.S. economy as a whole. Although this area does not record as many patents as Silicon Valley, it does rank fairly highly among other metropolitan areas in the United States. One key reason why the biotechnology industry is considered desirable by business development officials in Montgomery County is that the average compensation per employee is twice as high as overall average compensation and is also higher than the compensation among professional and scientific services industries as a whole.

Approximately 60 federal government agencies and laboratories are located near the Maryland life sciences cluster, including the National Institutes of Health (NIH), the National Institute of Standards and Technology, and the Food and Drug Administration. In addition, two major universities, the University of Maryland College Park (UMCP), and Johns Hopkins University, are located nearby. UMCP is located in the neighboring county, and Johns Hopkins University is located approximately 55 kilometers north of the cluster, in Baltimore, Maryland. The existing research base, in particular the federal laboratories, gave rise to a large, existing supply of private businesses in the life sciences fields.

The life sciences cluster began to take off during the late 1970s and early 1980s. Our interviews indicate that during this time, the Montgomery County government decided to

capitalize on the research taking place at the nearby federal laboratories by setting up a Life Sciences Center business park. The county government's vision for the business park was to have a hospital and direct medical services at the center, surrounded by firms performing related research.

At the beginning, the county offered only two financial incentives for firms moving into the business park: inexpensive land and a subsidized interest rate on bonds. The county also offered land to the University of Maryland in 1984 and to Johns Hopkins University in 1986.

Tax Incentives and Government Finance Programs. Firms in the cluster have access to a number of tax credits, although business development officials indicated that most of them are not used because many companies that could qualify do not have any profits and thus do not pay state taxes. Officials noted that "refundable tax credits," which allow firms without profits to carry over the tax credits until they do have profits, or to receive cash from the state, are more popular among firms but are more difficult to provide, since they require more state revenue. Other tax credits include property tax credits in certain areas and a Maryland investment tax credit for investment in an early-stage biotechnology firm. Firms also have access to loan and grant programs through the government and the University of Maryland.

Facilitating Private Financing. The Washington, D.C. – Maryland – Virginia metropolitan area, in which the cluster is located, receives a significant amount of venture capital, much of it from other states. A number of officials and entrepreneurs indicated that they feel there is a gap between research funding and late-stage funding. One solution has been the establishment of two angel investment networks, one through a state-funded agency and one through the University of Maryland. State agencies also operate or participate in several programs aimed at providing venture capital.

Human Capital. The population in Montgomery County is extremely well educated, with 30 percent holding a graduate or professional degree and nearly 60 percent holding at least a bachelor's degree. Montgomery County attracts an extremely educated population partly because of the proximity of the NIH and other federal research laboratories and agencies, which directly employ thousands of researchers and which attract private contractors to the area. Another reason cited by officials and entrepreneurs is the excellent quality of life in Montgomery County.

Quality of Life. Montgomery County has a good public school system, with two high schools in the top 100 and five in the top 250 nationally (Newsweek, 2011). Institutions of higher education, while perhaps not including many top research institutions in science and engineering, are plentiful. Besides the University of Maryland and Johns Hopkins University, regional universities include George Mason University, Georgetown University, and George Washington University, among many others. Urban and cultural amenities are also plentiful in the local metropolitan area.

Government and University Policies. Aside from financing, the local and state governments and the University of Maryland have a number of policy measures to encourage the life sciences cluster. These include business incubators and even a program that allows faculty members who start companies to keep their faculty jobs while working part-time on the start-ups; courses and workshops in entrepreneurship, as well as business plan competitions; and technical assistance programs. Montgomery County has taken steps to make it easier for firms to set up a new business by creating a Technical Advisory Board, a formalized group designed to coordinate county activities so that new buildings can be approved efficiently. The county is also making efforts to market its brand. Finally, although intellectual property rights are

designated somewhat differently at the University of Maryland than at Stanford and the University of Calfornia, Berkeley, they generally follow the principle of sharing between inventor and university.

Other Factors. Business development officials, as well as some entrepreneurs, expressed concern that the business culture in Montgomery County is risk-averse, particularly when compared with Silicon Valley. One potential reason is that government laboratories, while providing a rich pool of skilled researchers, also compete with private industry for talent. A researcher may prefer a stable job at NIH to an uncertain startup opportunity.

Another aspect of the culture concerns the local universities. Johns Hopkins University and University of Maryland representatives indicated that the university culture has not historically encouraged entrepreneurship; in the past, faculty members who started businesses were frowned upon. Today, university officials are making efforts to change the culture; more junior faculty members are interested in starting companies, and universities are trying to facilitate faculty participation in technology businesses.

Case Study: Israel's Information and Communication Technologies Firms

Beginning in the 1970s, the corridor from Tel Aviv to Haifa in Israel has become a center for ICT firms (Figure S.4). The main clusters of ICT firms are located in Herzliya and Ra'anana (just north of Tel Aviv), as well as in Haifa (about 100 kilometers to the north). In 2010, the ICT sector employed 7 percent of the Israel's workforce and accounted for 27 percent of the total value of Israel's exports (Israel Central Bureau of Statistics, 2011).

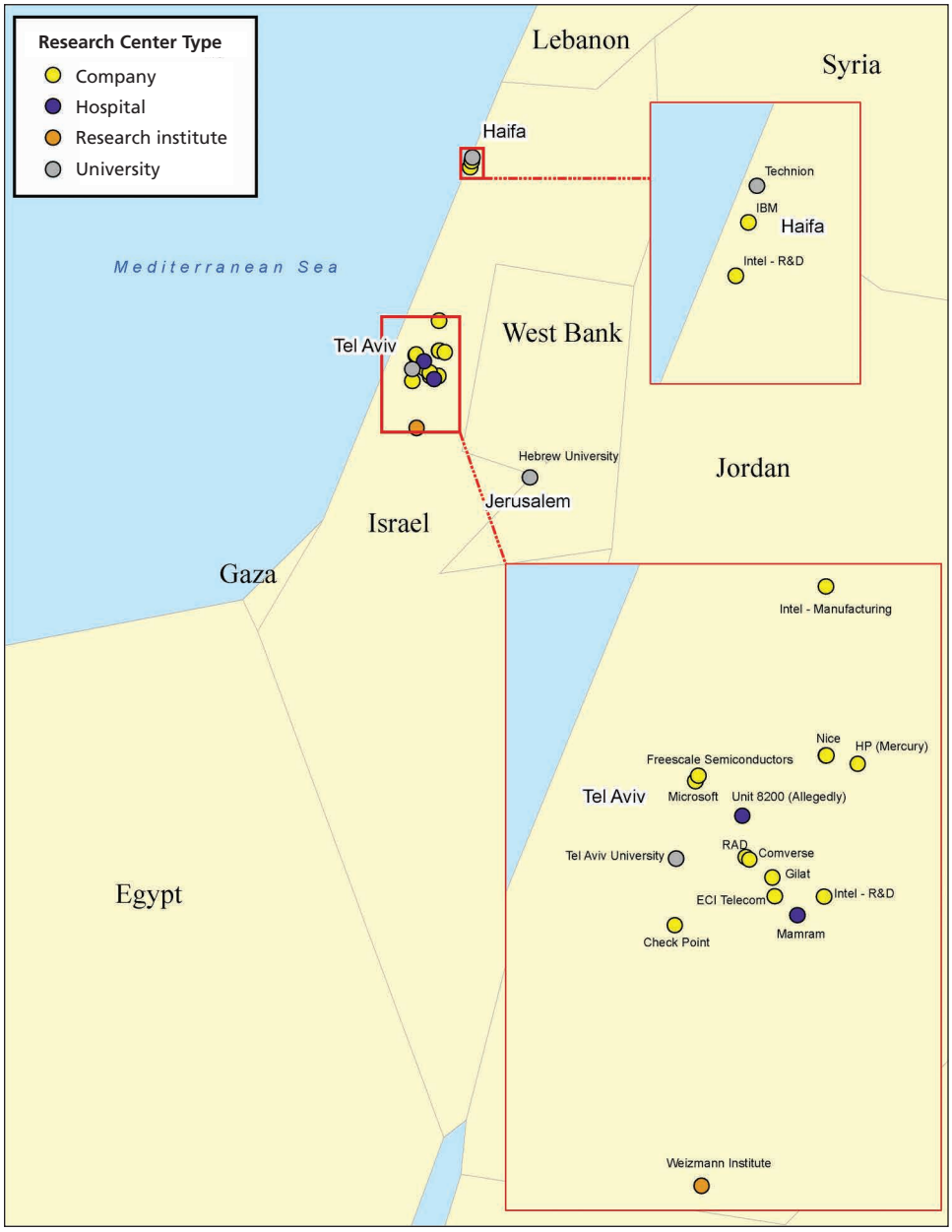
Multinational corporations (MNCs) played a large role in the development of Israel's ICT cluster and continue to be major employers and exporters. As in Silicon Valley, spinoffs have been important and there has been active patenting activity. The number of patents granted by the United States Patent and Trademark Office (USPTO) to inventors in Israel has risen sharply since the mid-1980s. In 2010, Israel accounted for approximately 1 percent of all patents granted by the USPTO.

Both home-grown and foreign firms were important in the development of the Israeli ICT cluster. During the 1960s, several Israeli high-technology firms were established; one of these firms, Elron Electronics, is sometimes considered similar to Fairchild Semiconductor in Silicon Valley in terms of its importance in generating future growth of the cluster. In 1964, Motorola set up a research and development (R&D) facility in Israel, followed by IBM and Intel in 1974.

The ICT boom accelerated in Israel during the late 1980s and 1990s. Our interviews suggest that many factors played a role in triggering this boom, including:

- Economic reforms of the 1980s and 1990s. During this period Israel made a number of structural changes to move toward a less regulated economy.
- Research taking place inside the Israel Defense Forces (IDF). The military does not have a noncompete policy for its former members and does not prevent former members from working in similar fields, with the exception of cryptography.
- The massive influx of Soviet immigrants who arrived in Israel during the early 1990s. Although they did not often become entrepreneurs themselves, they provided talented technical personnel.
- Multinational corporations such as Microsoft and Intel, which opened locations in Israel.

Figure S.4
Map of Israel's ICT Corridor



SOURCE: Map generated by RAND using ArcView GIS, Version 10.0, Redlands, Calif.: Environmental Systems Research Institute, Inc., 2011.

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Financing. Three stages of financing have played a role in the ICT cluster: R&D funding, precommercialization funding, and venture capital.

Today, Israel has the highest gross domestic expenditure on R&D as a percentage of GDP among countries belonging to the Organisation for Economic Co-operation and Development (OECD). It also has the highest fraction of R&D expenditure by business enterprises (nearly 80 percent), and the share of R&D expenditures borne by the government (less than 5 percent)

is one of the lowest in the OECD (OECD, 2011). The Office of the Chief Scientist, a government body responsible for subsidizing commercial R&D projects, provides R&D support to firms that meet certain criteria. The R&D fund was originally designed to be industry-neutral but has shifted to providing higher subsidies to biotechnology and nanotechnology. Despite this, it is unclear whether Israel can be competitive in these fields.

In the realm of precommercialization support, the Office of the Chief Scientist also established a Magnet Program in 1993 to encourage joint industrial and academic partners to create "generic, pre-competitive technologies" (Trajtenberg, 2000).

The first venture capital fund in Israel was set up in 1985 by three private entrepreneurs (de Fontenay and Carmel, 2004). Between 1989 and 1992, several additional venture funds were established. In 1993, the government established its own venture program called *Yozma*. Government funds amounting to $20 million were invested directly by a state-owned venture fund, later privatized in 1997 (Avnimelech and Teubal, 2004). The *Yozma* program also created 10 private funds, in which it invested $8 million each on a matching basis. Each private fund had to combine a well-established Israeli financial institution with a foreign financial institution. In total, *Yozma* funds raised $250 million and invested this money in more than 200 firms (Avnimelech, Schwartz, and Bar-El, 2007). Our interviews suggest that the *Yozma* program was considered important in spurring the growth of the Israeli venture capital industry for two reasons. First, it provided the first boost to the domestic venture capital industry. The firms that received *Yozma* funding had an easier time obtaining outside funding. Second, it provided a bridge to the venture capital industry in the United States, including expatriate Israelis and diaspora Jewish communities. Today, Israel is one of the top recipients of venture capital investment in the world.

Human Capital. Our interviews indicate that the IDF is perhaps the most important training ground for technical talent in Israel. The IDF not only has first choice of the recruits who present themselves for national service, but it also uses a battery of psychometric tests to evaluate and place candidates. The IDF has a number of technology-oriented units and programs, and recruits compete to be placed in many of these programs. Our interviews suggest that many former IDF members who go on to form companies were part of the technologically focused "Unit 8200," which does work on signals, interception and interpretation, and more generally electronics and technology. A number of other programs result in the creation of a highly skilled technical workforce.

The IDF contributes to human capital development in other ways. Recruits are required to undertake a significant amount of responsibility at a young age, to work within and to manage teams, to think strategically, and to achieve goals rather than simply to carry out orders; this training provides them with important entrepreneurial skills. The military structure is fairly flat, and the culture encourages young recruits to communicate with, and even challenge, more senior members (de Fontenay and Carmel, 2004; Senor and Singer, 2009). Then, after serving in the military, many Israelis attend college. Our interviews suggest that technical education at the universities is considered to be excellent, but formal business and entrepreneurial education still leaves considerable room for improvement.

MNCs played, and continue to play, an important role in providing human capital for Israel's ICT cluster. Our interviews indicate that Israelis working for foreign companies have been important in a number of firms' decisions to locate in Israel. Historically, the MNCs also served as de facto educational facilities, providing training that would not otherwise be available without going abroad. The wave of approximately 800,000 Soviet immigrants to Israel in

the early 1990s also provided a large pool of technical talent (de Fontenay and Carmel, 2004; Senor and Singer, 2009).

Quality of Life and Networks. As in the Silicon Valley and Maryland clusters, quality of life appears to play a role in the specific locations of high-technology firms in Israel: The major high-technology clusters are generally considered the most desirable places to live in Israel. A variety of networks, including specialized supplier and support networks, have grown up in Israel during its high-technology boom of the 1990s. Some of these networks are oriented toward providing connections between Israel and its largest market, the United States, through the Israeli diaspora and through the operation of MNCs in Israel. As in Silicon Valley, social networks play a key role in Israel's high-technology cluster. However, unlike in Silicon Valley, the IDF plays a critical role in network formation. Startup teams are often identified with, and made up from, former colleagues in the army (de Fontenay and Carmel, 2004). Our interviews suggest that these networks are propagated by continued service in the reserve forces, which brings former IDF team members together periodically for training.

Government Policies. A number of government policies to encourage financing were discussed above. Here, we outline additional, nonfinancial policies that may be relevant to innovation-based cluster formation and growth.

Israel offers corporate and dividend tax reductions to both local and international companies that are considered "industrial" and "internationally competitive." However, our interviews indicate that tax concessions were not likely to have been the major driver in attracting MNCs to Israel. Rather, a combination of Israel's skilled workforce, along with encouragement from Israeli employees, was likely more important in attracting MNCs.

Israel also offers grants to investors, and these have been considered helpful in the development of the country's technology corridor. An incubator program started by the Office of the Chief Scientist between 1991 and 1993 also appears to have helped foster new firms. However, our interviews indicate that there is a concern that the incubators were not as effective as they could have been because they were run by bureaucrats rather than entrepreneurs, and they required too large a share of equity in the firms they helped establish. In addition, the incubators did not teach the skills required to become entrepreneurs.

The government has also tried to foster international cooperation. In 1977, the governments of Israel and the United States founded the Israel-U.S. Bi-national Industrial Research and Development Foundation. The program contributes up to 50 percent of the cost for joint U.S.-Israeli research efforts, up to $1.5 million. Although many successful ventures grew out of this program, it is not clear how much of an impetus the foundation provided to the overall growth of the Israeli ICT cluster (de Fontenay and Carmel, 2004). Israel has also established relationships with other countries including Canada, Korea, and Singapore.

Part III: Applying Global Practice to Knowledge City

GDD can draw guidance from the three case studies as well as from the broader literature on entrepreneurship and cluster formation. We compare lessons learned with existing conditions in GDD that were identified throughout our research, supplemented by findings from the GDD-RAND Knowledge City Project Survey. We start by focusing on taxes, nontax incentives, and IPR policies and then move on to a number of broader issues, including human capi-

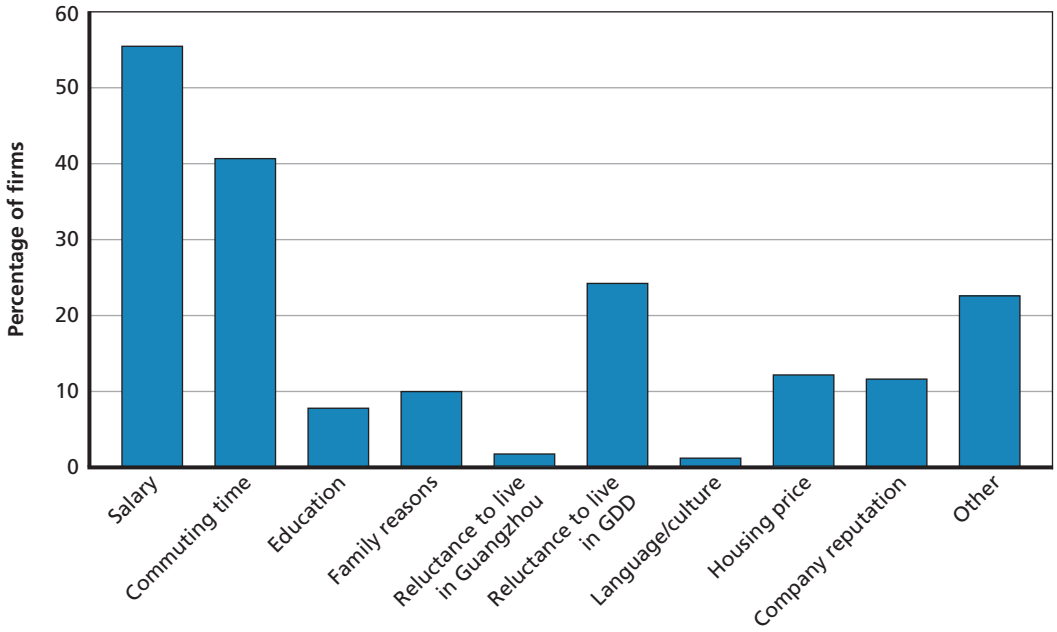
tal, infrastructure and business climate, networks, quality of life, and marketing Knowledge City.

Overview: Key Messages

Our findings lead us to a number of suggestions for the success of Knowledge City.

- There appears to be a gap in early-stage financing. In the GDD-RAND Knowledge City Project Survey, only 25 percent of firms reported receiving any outside funding. Bank loans appear to be the dominant source of outside funding, with very few firms reporting investment from angel investors or other types of private investment funds, even when additional funding rounds are considered. GDD may be able to help fill this gap by encouraging the formation of angel investor networks. Guangzhou has many successful, wealthy individuals who may be willing to invest in new firms but may not know how or where to find opportunities for investment. GDD may be able to draw on lessons from local development agencies and university organizations in Maryland, which have fostered such networks.
- We see a potential opportunity for GDD if it can become a zone of strict IPR enforcement, aggressively helping GDD companies protect their IPR throughout China and letting it be known that top innovators in China and abroad will have their rights protected if they locate in GDD. GDD may also wish to provide additional incentives to encourage companies to apply for international patents. Given the survey findings, which suggest that labor mobility is accepted in GDD, it is particularly important to ensure that IPR enforcement is strong so that firms' trade secrets are not divulged by former employees.
- To the extent possible, GDD should shift its emphasis more toward improving the living environment of Knowledge City and less toward business incentives. In the GDD-RAND Knowledge City Project Survey, firms most commonly listed salary, commuting time, and reluctance to live in GDD among the top difficulties in recruiting staff (Figure S.5). Improving the quality of life may be helpful in attracting the very top researchers, particularly expatriate Chinese.
- Attracting an anchor institution will be very important for the success of Knowledge City. By an anchor institution, we mean a major company or institution that is well regarded and can serve to attract suppliers, buyers, and other tenants to the area; provide a source of talent; or serve as a source of research that can be commercialized or of spinoffs. In marketing Knowledge City to potential tenants, it will be important to emphasize those factors that highlight GDD's strengths, particularly if they are relatively difficult for other areas to replicate. Two important assets that most other areas cannot replicate are Guangzhou's proximity to a major port and its historic role as a center of global commerce in China. In addition, GDD may find it valuable to focus on factors that take time to replicate, such as a good business climate, a reputation for IPR enforcement, strong angel investor networks, and excellent quality of life and local schools. Creating a reputation for having these factors could assist in attracting innovation-oriented firms to Knowledge City; the presence of these firms would reinforce Knowledge City's reputation for innovation, thus attracting more innovation-oriented firms to the area and creating a virtuous circle that would make it difficult for other regions to catch up.

Figure S.5
Top Two Reasons for Difficulty in Recruiting Staff



SOURCE: The GDD-RAND Knowledge City Project Survey.
RAND *TR1293-S.5*

Selected Policies: Taxes, Incentives, and Intellectual Property Rights

Taxes. Overall, the tax situation in GDD does not appear to be a major constraint on innovation. The literature suggests that lower tax rates can be beneficial in promoting entrepreneurship and investment. However, all three of our case studies indicate that when selecting a location, innovative firms are more likely to consider such issues as availability of highly skilled labor, quality of life, and proximity to suppliers and buyers than tax issues. Tax concessions may add some additional inducement for firms already considering starting or locating in an area, but they are unlikely to be a major factor in driving the formation of an innovation-based cluster.

Although various national preferential tax policies applicable to firms in GDD may also encourage entrepreneurship, these preferential tax benefits also apply to other economic zones in China. The challenge for GDD, therefore, lies in attracting innovative firms specifically to locate in Knowledge City rather than in another economic zone in China. GDD could examine various options for providing concessions. However, the benefits of such policies may be less than expected, as they may be eroded by tax competition from other jurisdictions.

These concerns suggest that GDD may find it more beneficial to compete with other regions based on other factors, such as quality of life, strong enforcement of IPR, and the overall business climate, which take time to develop, and may be more difficult for other regions to imitate.

Nontax Incentives. Robust financing is an important component of a successful cluster. In GDD, the main gap in financing appears to be in the early stages of business growth. Most high-technology firms in GDD that reported outside financing received bank loans; very few firms were financed by angel investors, who often fill the gap between basic funding for

research and development, which is often provided by governments, and later-stage funding, which is often provided by venture capital firms.

GDD may be able to help fill this gap by encouraging the formation of angel investor networks. Guangzhou has many successful, wealthy individuals who may be willing to invest in new firms but may not know how or where to find opportunities for investment. Our case study of Maryland's life sciences firms offers some suggestions for how GDD might facilitate such investment. In Maryland, both a state development agency and a local university entrepreneurship center have established angel investor groups. These organizations invite investors in their networks to attend regular sessions, during which a selected number of companies pitch their ideas. The angels are typically successful local entrepreneurs but may also include wealthy individuals who do not have previous entrepreneurial experience.

Our review of the literature and case studies indicates that, as with taxes, although nontax incentives from local government may add some additional inducement in terms of attracting firms to GDD, they are unlikely to be a major factor in driving the formation of an innovation-based cluster. Even though nontax incentives may initially attract high-technology firms to an area, without other conditions, such as availability of skilled labor and protection of IPR, such firms are unlikely to survive and grow. To the extent that GDD has the resources to provide nontax incentives, it may be worthwhile to concentrate those benefits on a few anchor institutions.

Intellectual Property. Protecting IPR is a crucial component in attracting high-value-added activities, as well as investment and international collaboration in such activities. We see a potential opportunity for GDD if it can become a zone of strict IPR enforcement, aggressively helping GDD companies protect their IPR throughout China and letting it be known that top innovators in China and abroad will have their rights protected if they locate in GDD. GDD may also wish to provide additional incentives to encourage companies to apply for international patents. Nearly all patents to Chinese-origin inventors are issued in China, whereas a large minority of patents to U.S.-origin and Japanese-origin inventors is issued outside their home countries. Patenting in economically advanced countries may push inventors in GDD to higher standards.

Our research on university IPR practices indicates that allowing both universities and individual inventors to share the financial rewards from invention is likely to be helpful in promoting commercialization of technologies developed at universities. The exact division of royalties and equity rights differs between institutions and may influence whether inventors tend to start their own companies or to license their technology; there is probably no ideal division. In our case studies, we reviewed the distribution of IPR at several major universities and found that all of them make an effort to divide royalties or equity among the inventor, the inventor's laboratory or department, and the university. Many top research institutions make their policies public; we briefly summarized the key policies from Stanford University, the University of California, Berkeley, and the University of Maryland in our case study report. Such policies could serve as a guide for GDD.

Other Aspects of the Environment for Innovation

Human Capital. It appears that firms in GDD are able to find most of the talent they need within Guangzhou or Guangdong. There may be a gap for the very top research talent; our interviews suggest that firms may need to recruit talent from abroad to fill this gap.

Our review of the literature indicates that an influx of returnees from Silicon Valley to Taiwan played a critical role in the success of the Hsinchu cluster. Similarly, Guangdong's large, expatriate population should provide a way to help fill the gap for the very top research talent. The Hsinchu cluster experience and our interviews in GDD suggest that some expatriates prefer to leave their families in the United States because of differences in housing, lifestyles, and educational systems between the United States and China. To the extent that being separated from family poses a challenge in attracting foreign talent, GDD may be able to mitigate that challenge by seeking to provide amenities associated with a higher quality of life in Knowledge City, including more diverse, excellent educational opportunities.

The ability of workers to change jobs easily can also lead to human capital formation; the movement of employees between firms can help promote information spillovers. However, employers may be concerned that employees may take trade secrets as well as accumulated human capital to competitors. One way in which many firms attempt to protect their intellectual property is by requiring that employees sign nondisclosure and noncompete agreements. The literature and our case studies indicate that labor mobility helps to promote information spillovers and that these positive spillovers outweigh any losses to individual firms.

GDD does not appear to have any major challenges in this area. Most survey respondents indicated that it is easy for employees to move between firms; that it would be acceptable for an employee to leave and work for a competitor, supplier, or buyer; and that they would hire employees who had previously worked for competitors, suppliers, or customers.

Most of the literature on labor mobility is based on findings from the United States, where IPR protection is strong. Our case studies were conducted in the United States and Israel, which also has strong IPR enforcement. Firms' trade secrets are therefore protected even when employees leave and take their industry-specific human capital with them. Given the apparent acceptance of labor mobility in GDD, IPR enforcement needs to be strong so that firms' trade secrets are not divulged by former employees.

Infrastructure and Business Climate. Our preliminary analysis suggests that GDD has excellent infrastructure and that the overall business climate is fairly conducive to growth by innovative firms. Nonetheless, the case studies, interviews, and survey results suggest two areas where GDD may be able to improve its business climate.

First, 85 percent of firms indicated that it is not easy to lay off employees, and 40 percent indicated that it is not easy to shut down a firm. Given that creative destruction is an important component of innovation, GDD could improve its environment for innovation by addressing these two issues. Although GDD has no control over national regulations regarding layoffs and firm closures, it can seek to assist local firms to navigate the process of downsizing or closure more efficiently.

Second, although policymakers often focus on the supply side when encouraging firms to grow, our review of the literature and our case studies indicate that the demand for products created by innovative firms may play a key role in their success. Our interviews in GDD suggest that there may be a lack of demand for innovative products and services in the area. Support for initiatives by high-technology firms in Knowledge City to market their products in Hong Kong, Taiwan, Korea, and Japan, including actions to strengthen representative offices, encourage entrepreneurs to attend trade fairs in each location, and sponsor special events, may help companies find buyers of highly innovative products.

Networks. Networks are a key component of a cluster. They tend to be driven by social and business interactions among individuals rather than by alliances among firms or other insti-

tutions. Our case studies suggest that individuals often draw on their networks, which stretch across firm, industry, and regional boundaries for a variety of business purposes, including hiring talented employees, obtaining expert advice in a particular area, or starting a company.

The dominance of individual over institutional ties appears to be the case even when networks are based on relationships developed through shared formal institutions. One case in point is illustrated by the ICT cluster in Israel, in which one main source of network formation is common military service. After completing their military service, former members of the military appear to draw on their network through personal contacts rather than through formal channels.

Overall, our preliminary findings suggest that although networks initiated through official channels may be useful in certain contexts, it is more likely that the most important networks will be created by individuals as the cluster develops. It may be most valuable for GDD to focus its efforts on creating certain specific types of networks, such as angel investor networks, that may be less likely to form spontaneously.

Quality of Life. Our preliminary analysis suggests that GDD should shift its emphasis more toward improving the living environment of Knowledge City rather than just offering business incentives. As discussed above, some tax or nontax incentives may be useful, as would improving IPR enforcement as well as certain aspects of the business climate. However, innovators also want short commutes, good schools for their children, high-quality consumption opportunities, and entertainment opportunities. Our review of the literature and our case studies suggest that quality of life plays a role in determining where highly skilled people choose to live. Moreover, the survey of high-technology firms confirmed that such quality-of-life issues as commuting and, more broadly, a "reluctance to live in GDD" are potentially major impediments to attracting top talent. These issues are likely to be more pronounced for Knowledge City, since it is located farther from the center of Guangzhou than are other parts of GDD.

Although quality of life is important, the extent to which it precedes the creation of an innovation area versus the extent to which it is an outgrowth of an innovative area with highly educated workers is uncertain. Convenient commuting opportunities may precede the creation of an innovative area, whereas cultural opportunities, which need an audience to survive, may be an outgrowth. Nonetheless, GDD can take a number of steps to increase the quality of life as Knowledge City gets started. GDD should explore providing incentives to attract quality schools and quality shopping to induce technical talent to settle in Knowledge City along with their families. In addition, careful master planning of Knowledge City, including the provision of an attractive living environment, as well as human-scale designs for neighborhoods, will be an important element of success.

Marketing Knowledge City. Attracting an anchor institution will be very important for the success of Knowledge City. By an anchor institution, we mean a major company or institution that is well regarded and has top-quality innovation workers. The anchor institution may play a number of roles. First, suppliers, buyers, and other tenants may be attracted to Knowledge City because of the reputation of the anchor institution, or because other companies wish to collaborate with the anchor institution or to draw on its workforce. Second, the anchor institution may provide a source of talent, either by drawing skilled workers to the area or (in the case of a university) by producing skilled graduates. Third, the anchor may be the source of research that can lead to commercial products or spinoffs.

Our preliminary analysis suggests that GDD should shift its emphasis more toward the general innovation environment rather than only focusing on specific sectors. Our case study

of Maryland provides some evidence that sector-specific targeting may be able to attract the types of firms that policymakers want but only when the targeted sectors are in keeping with the local area's existing advantages. Attempting to target sectors in which the local area does not have an advantage may simply result in failure to attract firms to the area or a failure of any firms that start up or move into the area to thrive. In particular, we recommend that GDD draw on its existing strong base of tenants to see if one or more of them can be induced to set up research and development operations in Knowledge City.

GDD already has a number of policies in place that can assist in attracting anchor institutions and other innovative firms to Knowledge City and in encouraging entrepreneurs to start firms there. In the marketing plan, it will be important to emphasize those factors that highlight GDD's strengths, particularly those that are difficult for other areas to replicate. Two important assets that most other areas cannot replicate are Guangzhou's proximity to a major port and its historic role as a center of global commerce in China.

In contrast, there are factors that can be easily replicated elsewhere in China. As our case studies show, tax concessions and nontax incentives could be classified in this category, since many areas can match incentives offered by GDD. Although providing these incentives might assist in attracting a particular tenant who is already considering Knowledge City, the risk of entering into a competitive bidding contest is quite large, threatening to erode the value of attracting the firm because of the high cost of the subsidies offered to attract it.

GDD should also focus on factors that may eventually be replicated, but would likely take some time to do so: infrastructure, a good business climate, a reputation for IPR enforcement, strong angel investor networks, and excellent quality of life and local schools. Focusing on these factors during the creation of Knowledge City, and emphasizing them in GDD's marketing efforts, would create competitive advantages for GDD. First, it takes time to create these types of institutions, making it harder for other regions to compete with GDD, at least until they develop similar advantages. Second, clusters are often formed around areas that have a first-mover advantage—those that originally began creating a product or service, often through historical accident. If GDD creates a reputation for having these factors, this reputation could help to attract innovation-oriented firms to Knowledge City. The presence of these firms would reinforce Knowledge City's reputation for innovation, thus attracting more innovation-oriented firms to the area and creating a virtuous circle that would make it difficult for other regions to catch up.