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PUBLIC FINANCIAL SUPPORT FOR COMMERCIAL INNOVATION

Europe and Central Asia Knowledge Economy Study Part I

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(ECSPF)

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CONTENTS

ABBREVIATIONS AND ACRONYMS

BEEPS	Business Environment and Enterprise Performance Survey
CIS	Commonwealth of Independent States
CORFO	Corporación de Fomento de la Producción
E.U.	European Union
ECA	Europe and Central Asia
ECAKE	Europe and Central Asia Knowledge Economy Study
ECSPF	Sector Unit for Private and Financial Sector Development, Europe and Central Asia Region
ESTD	Early Stage Technological Development
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden, United Kingdom
EU-8	Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovak Republic, Slovenia
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GPTs	General Purpose Technologies
IBM	International Business Machines
ICA	Investment Climate Assessment
ICT	Information and Communications Technology
IPR	Intellectual Property Rights
IT	Information Technology
ITC	Innovation and Technology Centers
ITRI	Industrial Technology Research Institute
K4D	Knowledge for Development
KAM	Knowledge Assessment Methodology
KEA	Knowledge Economy Assessment
KEI	Knowledge Economy Indicator
LN	Natural logarithm
M&E	Monitoring and Evaluation
MNCs	Multinational Corporations
MRI	Magnetic Resonance Imaging
NIS	National Innovation System
OECD	Organization for Economic Co-operation and Development
R&D	Research and Development
SBIC	Small Business Investment Company
SBIR	Small Business Innovation Research
SII	Summary Innovation Index
SMEs	Small and Medium-sized Enterprises
S&T	Science and Technology
TFP	Total Factor Productivity
U.S.	United States
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
USPTO	U.S. Patent and Trademark Office
VC	Venture Capital
WDR	World Development Report
WEF	World Economic Forum

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Chapter 1. Introduction

The Europe and Central Asia (ECA) Knowledge Economy Study aims to offer ECA policy makers options to increase and maintain productivity and growth by creating an environment conducive to the application of knowledge in the economy via innovation and learning. The tradition of excellence in learning and basic research in several ECA countries provides some basis for hope that commercial innovation could be adopted and built "on the shoulders" of the past. Translating this research foundation into economically productive commercial applications, however, remains a critical missing link in ECA countries. Against that background, this study focuses on public policies for building institutions and creating an incentives framework for the support of commercial innovation. Basic research policies are outside our scope.

Part I of the ECA Knowledge Economy Study (ECAKE I), which is submitted in this report, focuses on the rationale, financial instruments, and institutional requisites for effective public support for commercial innovation. We review the set of institutions and conditions in the various ECA countries with the aim of determining which countries are ready for public support for commercial innovation and which are missing some critical institutional requisites. We evaluate the appropriateness of the financial instruments that have been used in Organisation for Economic Co-operation and Development (OECD) countries and internationally to encourage innovation by the private sector. The planned follow-up study, ECAKE II, will cover absorption and diffusion of knowledge. Improving the absorptive capacity—the ability to tap into the world technology pool—is an important channel to increase productivity growth. The effectiveness of trade flows, mobility of people, licensing of codified knowledge, and foreign direct investment as conduits of knowledge absorption will be studied in the proposed ECAKE II study.

The distinction between innovation and absorption in this study is as follows. *Innovation* is the development and commercialization of new unproven technologies and untested processes and products. *Absorption* is the application of existing technologies, processes, and products proved and tested in a new environment in which the processes have not yet been tested and the markets and commercial applications are not fully known. This distinction does not preclude important complementarities between innovation and absorptive capacity. Innovation promotes absorptive capacity because human capital generation and knowledge spillover effects associated with the innovative process build absorptive capacity. The ability of an economy to research and develop new technologies increases its ability to understand and apply existing technologies. Vice versa, the absorption of cutting-edge technology inspires new ideas and innovations. Yet, the adoption of existing technology via trade, FDI (Foreign Direct Investment) or licensing is not guaranteed or cost free.[1] Firms and countries need to invest in developing "absorptive" or "national learning" capacity, which in turn is a function of spending on research and development (R&D). Therefore, domestic R&D has a role in developing a firm's ability to identify, assimilate, and exploit knowledge from the environment, i.e., enhancing the *absorptive capacity* of the economy. The latter will be a major topic of analysis in the proposed ECAKE II follow up to this study.

[1] Cohen and Levinthal (1989); Kinoshita (2000).

In addition to distinguishing between innovation and absorption, it may be helpful to clarify the differences between innovations undertaken by individual entrepreneurs or de novo firms, with no existing market power, versus those by incumbent firms with market power. It is the new entrants or the firms with no existing market power that are popularly claimed[2] to be more likely to undertake the most dramatic and revolutionary innovations. However, worldwide, most successful innovations are born, bred, and brought to market in larger incumbent firms with market power; often these innovations are more evolutionary, but nonetheless critical for sustained growth and job creation.

Integrating the complementarities and distinctions between innovation and absorptive capacity discussed above, we use the widest definition of R&D, which includes improvements in existing processes or products as well as the imitation and adoption of knowledge and it is not restricted to original innovation. The OECD defined R&D to "comprise creative work undertaken on a systemic basis in order to increase the stock of knowledge and the use of this stock of knowledge to devise new applications." Following the literature, R&D should be understood as "the process by which firms master and implement the design and production of goods and services that are new to them, irrespective of whether or not they are new to their competitors—domestic or foreign." R&D is to be differentiated from commercialization of R&D. *This study will focus on R&D and on commercialization, and it will differentiate instruments by their applicability in both stages of the innovation process.*

The choice to focus on public support of commercial innovation in ECAKE I is driven primarily by the increasing attention policy makers in the ECA region are directing toward enhancing investments in R&D in their respective countries, in other words, "client demand" for an analysis of the R&D commercialization support systems. The European Union's (EU) Lisbon Strategy has prompted the EU accession countries and other ECA countries to consider implementing financial instruments to promote innovation, especially venture capital schemes, with little consideration for the necessary institutional requisites or appropriateness of the instrument. In a number of countries in the former Soviet Union (e.g., Russia, Ukraine, Kazakhstan) and its satellites and in the former Yugoslavia (Serbia, Croatia), the legacy of research and human capital also provides an incentive to revive their research capacity. However, absorptive capacity remains an issue in all ECA countries. Some of the countries are likely to have higher productivity returns from investments in building absorptive capacity than in commercial innovation.

The current allocation of research funding contributes to the apparent lack of collaboration between the science and business sectors. The aim of the financial instruments recommended in this study is to address those problems through the encouragement of private R&D in companies by providing incentives for collaboration through the cofunding of "consortia" of firms and universities/research institutes to implement innovative projects. Nonfinancial instruments, such as business support services, incubators, and economic support zones, are discussed in the study as complementary components of the financial instruments. However, a full review of these types of instruments that support knowledge and technology transfer will

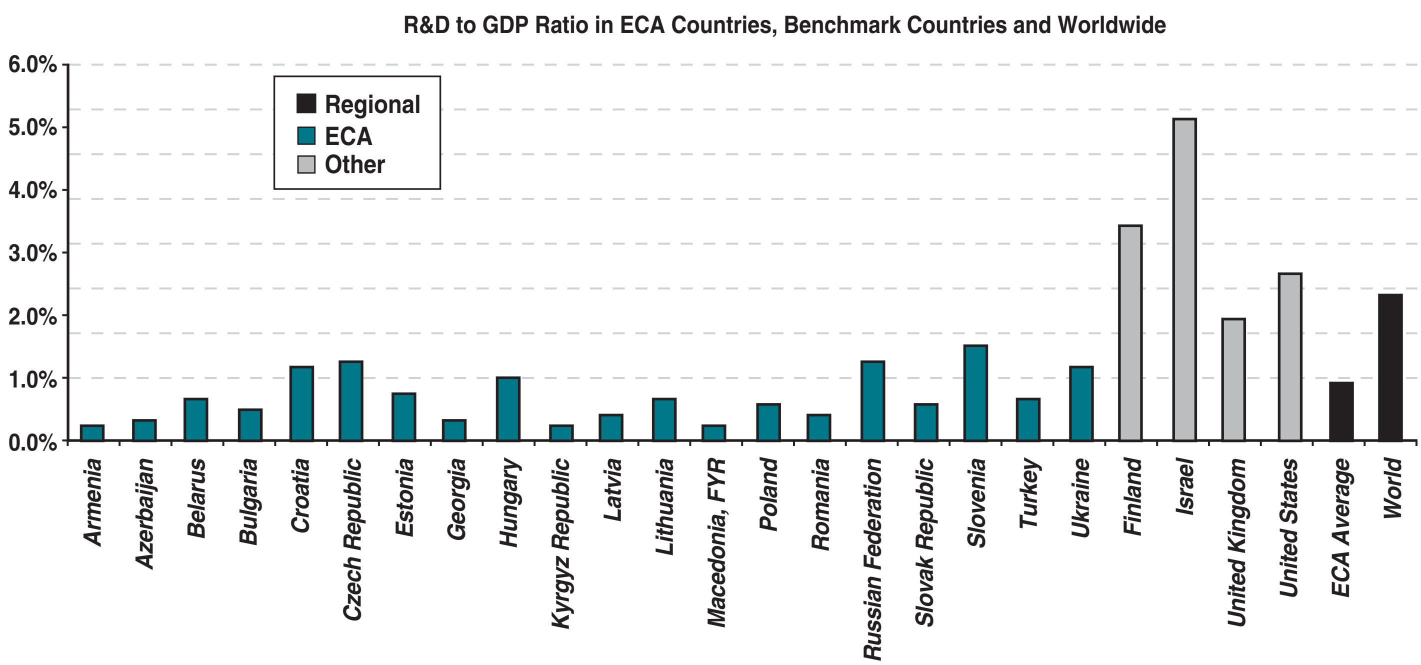
[2] A recent article in *The Economist* on Japanese innovation (Dec 17, 2005) highlights the distinction between U.S.-style blue-sky research approaches that foster many start-ups to experiment with new techniques and business models versus the more incremental learning-by-doing found inside large Japanese companies, with these two types of innovation possibly being appropriate for different technologies—software and biotech versus cars and electronics—with corporate Japan now also focusing on robotics, aerospace, and environmental technologies.

be undertaken in the ECAKE II study. Further elaboration on the different types of innovation and a more detailed analysis of the complementarities (and differences) between innovation and absorption as well as the policy implications of these differences and complementarities will be undertaken in the next ECAKE II study.

The focus of this study on R&D and on commercialization is consistent with the view, which will be elaborated in chapter 2, that commercial innovation and R&D are key factors driving *self-sustained*, long-term economic growth and, moreover, that these factors are generated from within the economic system, responding to economic incentives. In figures 1 and 2, ECA countries are compared with the rest of the world in regard to the share of R&D in gross domestic product (GDP) and the share of researchers in the population. The average R&D-to-GDP ratio in ECA is 0.9 percent. Of the 28 ECA countries, only 6 countries had a ratio of 1 percent or more.

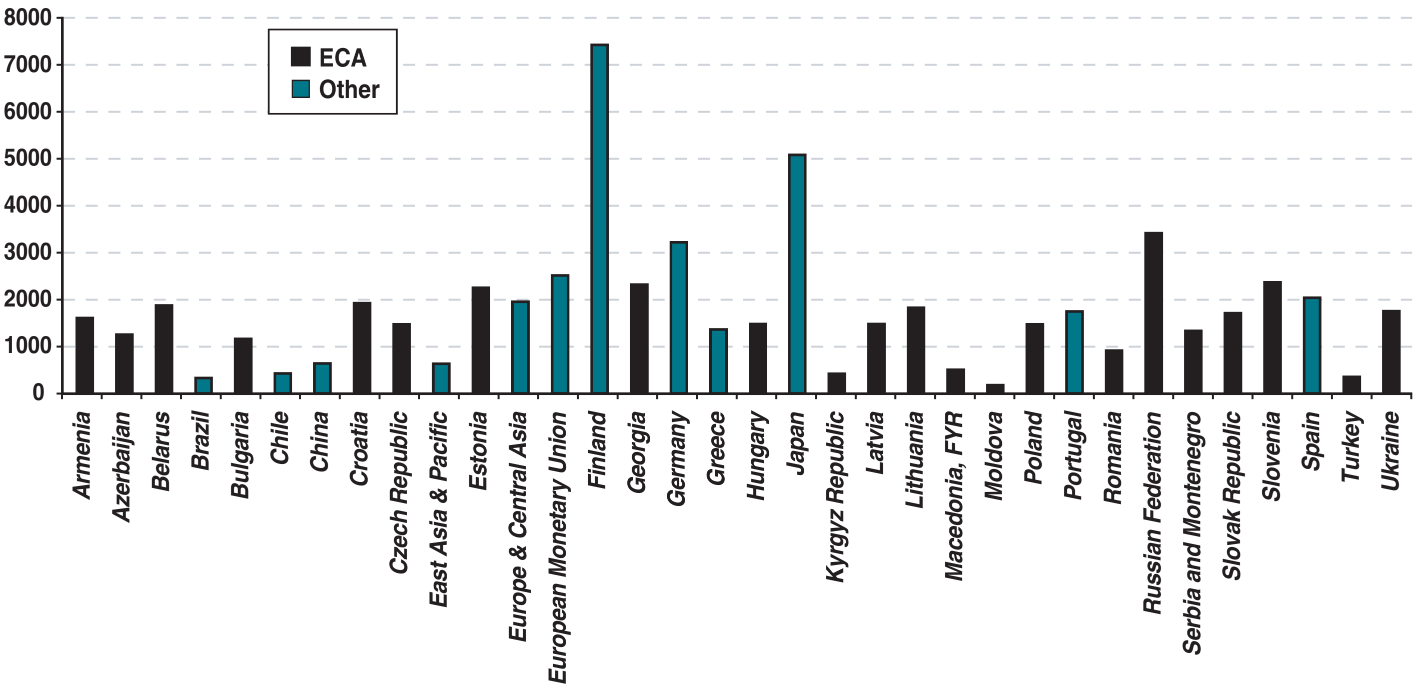
Financial support to stimulate commercial investment in R&D by firms is important in ECA because the average R&D-to-GDP ratio mentioned above does not reveal the whole picture of the structural misallocation of resources between private and public sectors and between basic and commercial R&D in the transition economies. Typically, the bulk of R&D spending in ECA, as much as 2/3 of the 0.9 percent of GDP, is financed by governments; whereas only about 1/3 is financed by the private sector. By contrast, in countries with high rates of R&D expenditure, such as Japan, the United States, Sweden, Finland, Ireland, and Germany, the share of industry-related R&D spending ranges from 65 percent to 70 percent, whereas government spending amounts to only 20 to 30 percent (OECD 2002). The share of researchers remains relatively abundant in the ECA region, with an average of nearly 2,000 R&D researchers per million. Russia continues to have the highest ratio of researchers to its population,

Figure 1. R&D-to-GDP Ratio—ECA and the World, 2002



Source: World Development Indicators

Figure 2. Researchers per million of the population, 2002



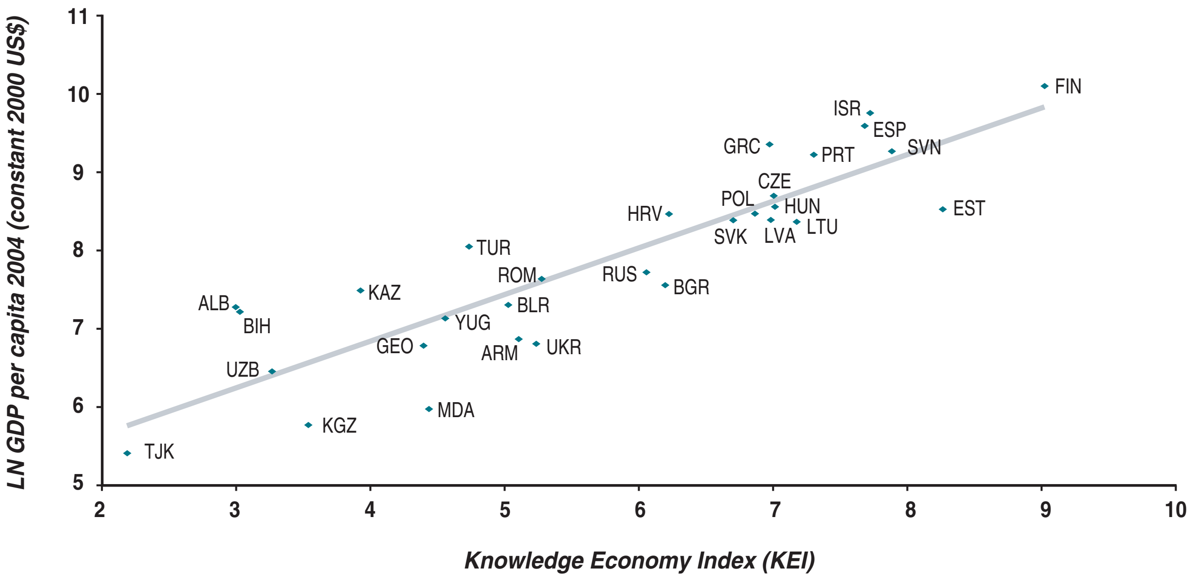
Source: World Development Indicators

with more than 3,400 per one million people. In chapter 4, we will elaborate on the relationship of growth, innovation, and R&D to economic incentives, education, and infrastructure.

The study's major goal is to provide countries with a general guide for evaluating the instruments to support innovation and the necessary institutional requisites for its effective application. Another key message of the study is that ECA countries need to analyze the state of their national innovation systems before embarking in the adoption of many of the financial instruments pursued by EU countries to support innovation. Some countries may not meet the basic institutional requisites, such as economic incentives, education, and information infrastructure, to absorb innovation instruments effectively. Other countries may have institutional bottlenecks that need to be addressed before or concurrently with embarking on an innovation program. As illustrated in figure 3, by using knowledge economy index (KEI) indicators from the World Bank's knowledge assessment methodology, the study provides a grouping of ECA countries according to their readiness for various innovation instruments. The readiness is based on an average KEI *and* on the scores in the individual institutional requisites mentioned above to identify and prioritize interventions targeted at specific *bottlenecks*. This graph, elaborated on in chapter 4, shows the KEI for different levels of per capita income.

This report is organized as follows: The second chapter provides a theoretical framework for examining the rationale for public participation in the funding of private industrial R&D and commercialization of innovative ideas. We begin with a brief description of how innovation and knowledge affect growth (endogenous growth theory) and therefore poverty reduction. We discuss in detail several market failures that may justify government intervention: the partial

Figure 3. Relationship between GDP per capita and KEI



appropriability of knowledge creation and information asymmetries leading to funding gaps at early stages of commercialization. We discuss how these market failures apply to developing countries, particularly highlighting the risk of "government failures" in attempting to resolve market failures. We conclude that although two market failures, partial appropriability (spillovers) and information asymmetries (funding gap), provide a well-grounded economic rationale for government support of innovation, the risk of government failures needs to be taken into account, as explained in chapter 3.

Accepting that there is a rationale for government intervention, we discuss in chapter 3 the most effective and least-distortive instruments for public support for commercial innovation. This chapter is based mainly on the analysis of different support mechanisms in OECD countries and its applicability to the ECA countries. As a start, we identify three key principles for the design of any support system:

1. *Attention to the institutional environment*: Especially in ECA countries, the institutional design should aim to immunize, as much as possible, the funding allocation from interference by political actors, corruption, and other state or specific interests capture.
2. *Additionality of funds*: Government interventions need to be carefully designed to promote private risk taking instead of rent seeking and to stimulate markets for private risk capital, so as not to crowd out private investment and other funding sources.
3. *Neutrality of intervention*: The government should not decide ex ante which technological sectors, firms, or projects to support, but rather should respond to the demands coming from the market.

We then discuss the different instruments used in OECD countries (grants, loans, tax incentives, procurement preferences). We describe in detail the most appropriate instruments for transition economies: grants (minigrants and matching grants) for early-stage R&D and commercialization and venture capital leverage at a later stage, as well as the role of business support services to complement these instruments. We discuss the need for, and possibilities of, adapting these instruments to the conditions prevalent in many countries, also in ECA (e.g., state capture, corruption, and weak courts). In this context, the role of the World Bank advice on the selection of funding instruments is quite timely, because many ECA countries plan to adopt funding programs designed in OECD countries without proper attention to the transferability of those instruments to transition countries (e.g., R&D tax benefits complicate prevailing weak tax enforcement). The study concludes that the utilization of instruments such as matching grants and venture capital—with as much private sector participation in risk sharing and selection as possible—will be needed in ECA countries to ensure transparency and commercial viability and mitigate the risks of government failure. In situations in which the government is actively involved in selection, such as early-stage grants, the selection process needs to be carefully designed to include outside expertise. Business support services are important complementary instruments to support financial instruments, such as grants and venture capital, but have a weak track record on a stand-alone basis.

Following the theoretical discussion of the rationale and instruments for public support for innovation, we turn in chapter 4 to a specific empirical analysis of the requisite institutional framework for that type of intervention. We present a classification of countries according to knowledge indicators that might help determine the readiness of a country to start an innovation support program. A word of caution is important at this stage. The core of this study is not to assess ECA countries in regard to their readiness to start innovation support programs or to determine which reforms in their national innovation systems are most urgent. That assessment needs an in-depth analysis on a country-by-country basis and is well beyond the scope of this study. In this sense, the World Bank has collaborated in preparing knowledge economy assessments (KEAs) in a number of ECA countries—Russia, Poland, the Slovak Republic, Latvia, Lithuania, and Turkey. The classification of countries according to knowledge indicators serves mainly two purposes:

1. To elaborate on the main complementary elements and to identify bottlenecks that a country should be aware of in designing innovation support programs (although the list might not be comprehensive—again it will depend on country).
2. To show the wide differences in ECA countries. Some countries just might not be ready to engage in designing and implementing such policy instruments and might be better advised to follow a different route to acquire and absorb knowledge.

The institutional requisites have been selected on the basis of empirical work in the literature (described in chapter 4), which identifies the determinants of the national innovation capacity. To assess ECA countries we use the knowledge assessment methodology (KAM) developed by the World Bank Institute[3], although many other institutions developed similar indicators (the EU, United Nations Industrial Development Organization [UNIDO], United Nations Development Programme [UNDP], World Economic Forum [WEF]). This instrument assesses the readiness of the national innovation system (NIS) in each country and compares it with other countries.

We provide in chapter 4 a grouping of countries which is intended to be a guide for countries considering whether to invest public capital in the specific financial instruments to support innovation or to invest in building the institutional requisites for an innovation system but, again, it does not replace an in-depth KEA. In particular, countries can use this analysis to identify and prioritize interventions targeted

[3] The KAM can be found in www.worldbank.org/wbi

at specific *bottlenecks* and to identify particular *institutional strengths* that might improve the potential for success in enhancing their innovation system. It might well be that a country has a fairly high education level and a fairly well developed information infrastructure but its economic incentives regime is so weak that it presents a severe bottleneck to the commercialization of such research. In that case, the country might consider aggressively addressing the bottleneck before engaging in public financial interventions in innovation.

Chapter 2. Economic Rationale of Support for Commercial Innovation

Ever since the path-breaking research of Robert Solow (1956), economists have known that secular growth is due mostly to technological change, rather than to factor accumulation. Indeed, a vast array of subsequent empirical research during a half century has shown conclusively that at least half of the growth in per capita income, in virtually every country studied, is associated with the growth of total factor productivity (TFP) rather than other, more traditional, factors. However, attaching the label of technological change to the famous "residual" (i.e., TFP growth) begs the question of what it contains exactly, and perhaps, more important, how it evolves over time, and the nature of the economic forces that determine its course and pace.

Indeed, one of the frustrating aspects of the early phase of economic thinking about these matters was that the growth of TFP (arguably the single most important economic phenomenon) appeared to economists as an impenetrable "black box" and seemed to occur outside the realm of economic forces. A long and very fruitful research agenda pioneered by Griliches, Jorgenson, Denison, Rosenberg, and their associates sought to open this 'black box' to understand its contents. However, it was only with the extensive development of endogenous growth theory in the late 1980s (Romer 1986, 1990; Lucas 1988; Grossman and Helpman 1991, etc.) that the economic profession came to accept the view that innovation, spillovers, and R&D were indeed the key factors driving self-sustained, long-term economic growth and, moreover, that these factors were generated from within the economic system, responding to economic incentives.[4]

Recent literature examines the interplay between competition and innovation and their impact on growth (Aghion et al. 2002). Although Schumpeterian growth models predict that only firms with market power would have the resources and incentives to innovate, these empirical findings suggest that, contrary to the Schumpeterian assumption, in the more developed economies, among the incumbent firms closer to the "technology frontier," competition does encourage innovation. In a further article Aghion, Carlin, and Schaffer (2002) look particularly at the relationship between competition, innovation, and growth in transition economies: by using different methodologies and the BEEPS survey, they show that competitive pressures raise innovation in both new and incumbent firms, subject to hard-budget constraints for incumbent firms and availability of financing for new firms. In a more recent article, Aghion and Howitt (2005) discuss Europe in comparison with the United States and argue that since Europe has recently come closer to the world technology frontier, it would benefit from a competition and labor market policy that not only emphasizes competition among incumbent firms, but also stresses the importance of entry, exit, and mobility. For this report, it is important to note that the closer firms in ECA countries move to the technology frontier, the more

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[4] Work on education and technological change by Nelson and Phelps (1966) mentioned that technological progress was key to growth and highlighted the difference (for growth) between human capital stock and accumulation. However, it was only in the late 1980s that those views were widely shared.

competitive pressures and market structures will play a role in the innovation capability of a country. The companion report (ECAKE II will) elaborate on the impact of competition and innovation, particularly innovation financing.

This conceptual framework molds our analysis: on the one hand, the view of the centrality of innovation and knowledge creation in the growth process and, on the other hand, the understanding that these are economic factors that may be shaped and influenced by properly designed economic policies. Building on that view, a recent paper by the World Bank (Chen and Dahlman 2004) seeks to decompose "knowledge" into a wide array of indicators and assess their contribution to growth. By using an array of indicators, each of which represents an aspect of knowledge, as independent variables in cross-section regressions that span 92 countries for the period 1960 to 2000, the paper shows that knowledge is a significant determinant of long-term economic growth. It finds that an increase of 20 percent in the average years of a population's schooling tends to increase the average annual economic growth by 0.15 percentage point. In regard to innovation, it finds that a 1 percent increase in the annual number of U.S. Patent and Trademark Office (USPTO) patents granted is associated with an increase of 0.9 percentage points in annual economic growth. Last, Chen and Dahlman find that when the ICT infrastructure, as measured by the number of phones per 1,000 persons, is increased by 20 percent, annual economic growth tends to increase by 0.11 percentage points.

One corollary of the developments just sketched was the emergence of a soundly based and carefully articulated economic rationale for public support of R&D and innovation, which is by now widely accepted among academic economists and practitioners. The basic argument for public support of R&D is that innovation is a critical factor for growth (and hence inter alia for poverty alleviation), but a well-functioning market economy cannot generate by itself the optimal levels of R&D. There are two main sources of market failure with respect to R&D[5]: (1) partial appropriability (due to spillovers), which does not allow inventors to capture all the benefits of their invention, and (2) information asymmetries, for example, the difference between the information that an inventor looking for financing has about an invention and the information that the potential financier has, which leads to a "funding gap." These failures inhibit private firms from investing enough in innovation and R&D, thus depriving the economy of one of the key levers for sustained growth.[6]

2.1 Partial Appropriability (spillovers)

A basic feature of knowledge creation is that the returns from investments in it are not fully *appropriable* by the original investor. Knowledge has significant public good attributes, that is, once created it can be used repeatedly by multiple actors at no or very low extra costs. Firms

5 For a full list of rationales for state interventions in fostering knowledge creation see the flagship study of the World Bank's Latin American and Caribbean Studies, De Ferranti et al. (2003). They list other important aspects of knowledge creation that prevent markets from generating the optimal level of knowledge: (1) the long-term and risky nature of R&D investments, (2) lumpiness of innovation, and (3) coordination failures. See Baumol, 2002, for a description of the features of the free market economy (market structure, productive entrepreneurship and rule of law, markets for technology trading and reasons why R&D expenditure might be efficient despite substantial externalities on innovation) that explain its effectiveness in promoting innovation and growth.

6 Clearly though, it is not enough to spell out such an economic rationale: for it to lead to policy, it must be weighed against the *costs* of government intervention, namely, the well-known problems of "industrial policy," capture and corruption, which constitute the so-called government failures. We shall discuss those later on.

making investments in knowledge creation capture only a portion of the benefits created. They do not receive compensation for the "spillovers" that their innovative efforts generate, that is, for the positive externalities of their actions on other firms and agents. Further, new technologies confer benefits to the purchasers of new products (consumers and producers alike) that often exceed any increase in the selling price that can be sustained. These nonappropriable benefits are also referred to as *spillovers* to consumers and are of particular importance in the context of "general purpose technologies" (as described further in section 2.3). Both types of spillovers, namely, the purely technological externalities and the excess benefits to buyers, imply that the social returns from innovations may be far larger than the private returns (Jaffe 1998).

As a result of this gap, innovators operating in a market economy will invest in R&D less than the socially optimal amount; the extent of underinvestment depends of course on the extent to which social returns exceed private returns, and that may vary widely across fields, technologies, stages along the innovation cycle, and so on. Empirical studies have shown that typically the social rates of return of R&D expenditures are very large, often several times larger than private ones (Klette, Moen, and Griliches 1999). Moreover, these studies show that the returns from R&D exceed by a wide margin the returns from other types of investments, in particular, from investment in physical capital. This implies that a government role in increasing the amount of resources devoted to R&D at the economywide level can have significant social benefits.

Spillovers may occur in many different ways, one of them being the mobility of R&D personnel. The process of innovation and its commercialization in an enterprise builds the human capital of its employees. Employees acquire R&D skills and an understanding of technologies and markets that are partly general, that is, they go beyond the specific knowledge embodied in the innovation and protected by intellectual property rights (IPR). Employees that move from one firm to another carry with them this human (or innovation) capital, which may benefit their new employers beyond the increment in wages that the mobile employees may receive. If mobility takes the form of migration, then the origin countries may be unwittingly "subsidizing" the destination countries through these spillovers; thus the mobility of inventors is an important transmission mechanism for spillovers, and hence a channel that should be closely monitored because it may have both positive and negative effects on any given country.[7]

Openness to trade and FDI increase the probability of receiving spillovers that originate elsewhere. As Coe and Helpman (1995) have shown, large economies tend to benefit the most from international spillover flows mediated by trade. Countries can increase their productivity by importing goods (especially capital equipment) from foreign, more advanced technologies (Coe, Helpman, and Hoffmaister 1997). Another potential source of technology spillover is FDI, although investors frequently "keep their knowledge at home" (Blomstrom and Kokko 1999). That is beginning to change (e.g., R&D is moving to India), although the international principals still maintain control of the innovations via patents registered abroad. The impact

[7] The spillovers-based argument clearly holds for large, mostly closed economies: being closed there is no risk of spillovers slipping out, and being large there is a high probability that at least some other local economic agents will benefit. In small open economies, spillovers may spill *out* of the country and benefit external firms and consumers rather than the local economy. Any policy designed to promote R&D should aim not only at increasing total R&D, but also at increasing total R&D in a way that incentivizes *local* spillovers rather than external leakages, develops absorptive capacity, and ultimately affects the productivity of a wide range of sectors in the local economy.

of FDI is indirect, via "spillover effects,"[8] owing to the presence of multinationals—first, because they create linkages with domestic firms and, second, because their presence spurs domestic producers to invest in new technology to compete with the foreign-owned firms. For example, in the Czech manufacturing sector during the 1995–98 period, the indirect effect of R&D via the development of the absorptive capacity was found to be far more important than the direct effect of innovative R&D in increasing productivity growth of the firm; it was also found that R&D and intraindustry spillovers from FDI go hand in hand. (Kinoshita 2000). In Poland, so far, spillover effects leading to technology improvements in firms are observed only in a few industries, such as the auto industry, in which foreign R&D is high.[9] To be able to capture these international spillovers, the country needs to develop "absorptive capacity" (see Cohen and Levinthal 1989), which entails, inter alia, investing in local indigenous education and innovation, which will be the subject of Part II of this study.

Another result of partial appropriability is "coordination failure." Often, technical advances in a given field require complementary advances by numerous distinct parties. Any one party may find that it is not worthwhile to develop one component of the system unless it can be sure that others will develop complementary components. If these parties do not have a mechanism to coordinate their investments, it is possible that no investment will occur. Government support may tip the balance such that multiple actors will invest in R&D independently. Innovation instruments can also be designed specifically to remedy coordination failures in innovation by encouraging "consortia" of universities/research institutes and firms or by promoting technology "clusters." We will discuss encouraging consortia in chapter 3.

2.2 Information Asymmetries and the "Funding Gap"

A second source of market failure related to the creation of knowledge has to do with asymmetric information between inventors and external agents (e.g., investors such as banks). Innovative activities entail by necessity a fundamental information asymmetry, certainly ex ante, that is, at the stage at which the inventor formulates the idea and seeks funds to develop it. It can be assumed that inventors have sufficient knowledge of the technology and of the details of the planned innovation, of their true abilities to carry it out, and of the efforts they are willing to put into developing the innovation. However, there will always be a significant gap between what the inventor knows and what an external agent can gauge, even if the information on those crucial matters is well documented.

In particular, there will be significant information asymmetries in that respect between the inventor and mainstream financial intermediaries, such as banks and institutional investors, who lack the capacity to verify the specific technical information and claims of the entrepreneur. Potential investors will therefore be skeptical of the likely returns on investments in developing new technologies. Entrepreneurs

8 Spillover effects (from neighboring countries or industries) arise when production affects the economic activity of other local firms or their employees. Positive spillover effects occur through the supply of new information, new technologies, managerial practices, and so on. Thus the "social" gain is larger than the profit or productivity gain made by the "source" company.

9 This is consistent with Kinoshita's (2000) finding concerning Czech enterprises' data—in oligopolistic sectors, such as electrical machinery and radio and television, there is a significant rate of spillover as a result of having a large foreign presence. Also, R&D investment has a higher rate of return in these sectors. However, less oligopolistic sectors, such as food and nonmetallic minerals, show no evidence of spillovers despite the large presence of foreign investors in these sectors.

who could offer attractive returns may have no credible way of conveying such potential to risk-averse investors.

The information asymmetry makes it very hard for a creditor or equity investor to predict the returns from a potential investment in innovative ventures, which implies that such funding is not likely to be forthcoming. In the absence of demonstrated cash flows or other collateral, a typical start-up company or individual innovative entrepreneur will not have access to traditional sources of finance—this is the so-called "funding gap". At the most basic level, the "funding gap" implies that entrepreneurs face stiff constraints in the funding of innovations and therefore will not invest (or will invest too little) in innovative projects that may have high social returns.

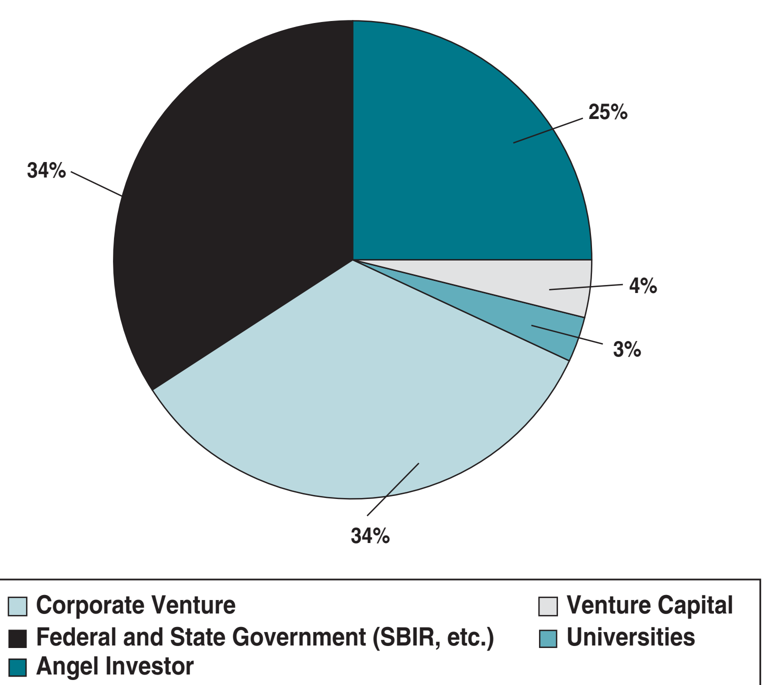
This "funding gap" has been studied in most detail in the United States, but the findings have direct implications for the ECA region as well. Figure 4 shows an estimated breakdown of actual funding sources for early stage technological development (ESTD) in the United States (see Auerswald and Branscomb 2003). ESTD is the most problematic phase in the innovation process and is defined as the link between invention and innovation, when a new product and market are identified. In this stage, product specifications appropriate to the identified market are demonstrated. Production processes begin to be developed, allowing estimates of production costs. At the end of this stage the entrepreneurial venture has articulated a business case."

Figure 4 emphasizes the importance of internal financing by enterprises, government funding, and "angel investors" in the ESTD stage. But most important, it emphasizes the virtual absence of more mainstream intermediaries such as banks, private equity, and other institutional investors. Although the percentages are for the United States only, the figure illustrates that, typically, even in one of the most advanced and innovative economies, early-stage finance of innovative projects is undertaken directly by firms, if they have the resources, or by very specialized institutions, with a significant role played by the government.

Not surprisingly, internal funds account for the biggest share of ESTD financing in the United States because that is the most straightforward way of overcoming information asymmetries. Established enterprises know the track record of their own inventors/employees and, typically, have a better understanding of the market and the commercial potential of internally proposed innovations than do outside agents. Enterprises use the cash flows generated by established operations to finance innovation or source external funds on the basis of their balance sheet strength.

"Angel investors" are another important source of ESTD funding in the United States and to some extent in Europe. The term "angel investor" refers to successful entrepreneurs that look for new opportunities to invest private

Figure 4. ESTD Funding in the United States



funds (earned from their own previous innovations) and are willing to invest in ESTD projects in technological fields that they understand well (having "been there and done that"). Studies of the behavior of "angel investors" frequently find that they are often heavily involved in the commercial decision making and that this "business support" function can be as important as the financing. Managerial advice and commercial control over the ESTD entrepreneur are typical characteristics of the "angel investor" and venture capital funding models, as well as, of course, in internal funding models.

Given the short history of capitalist accumulation and profit-generating enterprises in ECA, internal financing by enterprises and "angel investors" is rare in the region and does not provide a viable basis for promoting innovation. The absence of "angel investors" is problematic not only from a funding perspective, but also given their role as sources of managerial expertise, as information brokers, and as access points to formal and informal networks of entrepreneurs and innovators. The role of government is therefore different in ECA countries than in OECD countries. The lack of "angels" and internal financing is acute, and the capacity of government agencies to fill their place is extremely limited. The Finnish case study in box 2 and the discussion in chapter 3 provide possible options for interventions that compensate for the absence of local "angel investors" by promoting international "angel investor" networks and building public information marketplaces and networks.

ESTD requires patient and high-risk tolerant investment capital to fund early, prerevenue stages of research, development, and commercialization. Yet filling the "funding gap" requires specialized investors with the skills to evaluate and directly manage the risks of ESTD ("angel investors" or innovative managers in firms that are willing to invest retained earnings accumulated in other activities in the highly risky innovative projects) or governments with a broader public policy objective of capturing some of the spillovers associated with ESTD. In the absence of positive internal cash flows and "angel investors", even if appropriability is adequate to yield a reasonable profit expectation, it may be impossible to secure the capital necessary to develop a new technology. Typically, in developing countries, the information asymmetry and "funding gap" problem is much more acute than in developed economies.

2.3 The Impact of General Purpose Technologies (GPTs)

Technological change contributes to growth wherever it happens, but there are certain technological advances that have played a critical role over the long term in fostering growth in the economy as a whole. Indeed, in any era there are a handful of (or even a single) "general purpose technologies" (GPTs) that drive growth by spreading over the different sectors of the economy and prompting them to innovate further (see Bresnahan and Trajtenberg 1995 and Helpman and Trajtenberg 1996). Progress in the adopting sectors feeds back, in turn, into the GPT sector, providing incentives for further advances in the GPT itself, thus setting up a positive, self-sustained virtuous cycle.

During the past two decades innovation has commonly been associated with the tremendous technological advances that have taken place in what is generally referred to as "high tech" and in particular in Information and Communication Technologies (ICT). Indeed, the advent of the personal computer and of the Internet, cell phones, and the digitization of words, voice, and image in a wide array of existing and newly created media and, above all, the inexorable march of "Moore's Law" have revolutionized the way we produce, communicate and consume virtually everything. The preeminent GPT of our era is undoubtedly ICT, and as such it is enabling and fostering economic growth in developed countries as well as in many transition and developing countries.

As a result of the wide-reaching impact of ICT, many developing countries focus their innovation support specifically on developing an ICT sector. This approach misinterprets, however, the role and impact of GPTs on innovation. The way a GPT fosters economywide growth is not simply and not mainly by innovation taking place only in the GPT itself; rather, economywide growth occurs when a wide and ever-expanding range of *other* sectors adopt the advancing GPT and, as a consequence, improve their own technology. The best example is the revolution in retailing brought about by WalMart via the massive adoption of ICT-based methods, which made a sizable contribution to the productivity growth of the U.S. service sector and the economy during the second half of the 1990s. Indeed, the GPT sector itself is bound to be small relative to the economy as a whole (e.g., think of the steam engine–producing sector or the electricity sector), and however fast it innovates and grows in itself, it can never pull the whole economy on its own. In that sense, the often-used analogy of the GPT as a "locomotive" is wrong and misleading. Moreover, if the rest of the economy fails to widely adopt the GPT or fails to make complementary innovations and investments in the adopting sectors, economywide growth will just not materialize. That touches on the possibility of the emergence of a "dual economy," an economy in which one or several sectors are highly innovative and dynamic but are mostly disconnected from the rest of the economy. The result is that only those parts of the economy connected to the innovative sector or sectors ("enclaves") benefit and that spillovers to the rest of the economy are lacking, which could lead to increasing socioeconomic inequality.

The dual economy picture could be problematic not only from an equity viewpoint; it may also affect the future growth potential of the economy by restricting the pool of skilled labor and otherwise creating frictions and tensions that are detrimental to growth. In India and China the impact of "enclave" innovation on the rest of the country remains to be seen: some argue that the benefits of such innovation, mostly exporting to foreign markets, are being reaped mostly by a small share of the population and regions engaged in these industries as well as foreign customers. Yet, the increase in exports surely improves the current account and the fiscal situation, thus allowing expansion of services for those who are poor: building schools and hospitals, fighting diseases, and so forth. Moreover, the skills acquired by the entrepreneurs or employees of the innovative companies increase the human capital of the country of origin even if the new product is exported and the inventing start-up is acquired by a multinational corporate investor.

A key issue then in countries that are not at the frontier of the GPT ("secondary countries") is how to allocate R&D and other innovative inputs so as to leverage the growth potential of the prevalent GPT. Just trying to jump onto the bandwagon of ICT innovation per se is far from enough and may not necessarily be the most effective strategy. A more effective strategy will be to encourage ever-expanding segments of the economy to adopt ICT in ways that increase their own productivity. These types of complementary actions (i.e., adoption of ICT, local innovations in traditional sectors, etc.) may appear to be less overtly "innovative" (and therefore may not be deemed as worthy of public support) but will eventually constitute the key to economywide growth. Intensification of ICT adoption, in particular, in services and traditional manufacturing sectors, requires a conducive business climate that combines open borders to trade with liberalized product and labor markets, robust financial systems, developed regulatory framework, and sufficient quality of human capital.

Nevertheless, it can be argued that in some more advanced middle-income countries, developing the legal and institutional framework (e.g., protection of IPR) so as to enhance the development of a local ICT industry, joining forces with ICT multinationals, and otherwise encouraging the ICT-producing sectors may play an important role in the process of economic development and economywide innovation for two reasons. First, an indigenous ICT sector allows for the concomitant development of local technological skills, managerial expertise, and world-class standards in ICT. Second, local ICT strategies require the opening up of the economy, which itself brings in inflows of capital, expanding trade, and so on. The spillovers related to a thriving local ICT sector may play a crucial role in prompting the rest of the economy to innovate and open up.

Thus, growth-oriented innovation policies have to proceed from a far wider perspective than just promoting the ICT sector per se. Indeed, the guiding conceptual framework should be that of GPT, which emphasizes the spread of (in our era) ICTs throughout the economy, and the "innovational complementarities" that ought to materialize for economywide growth to take place. The development of the ICT sector may be in some cases an effective stepping stone, but by no means the final destination. In fact, the recalcitrant problem may lie in eliciting adoption and innovation, not in ICT producers but in those that could benefit from its use (Jorgenson and Vu 2005; Piatkowski and van Ark 2005).

2.4 Exports-versus Local Markets–Oriented Innovation

The issues of "high tech" versus the rest of the economy and of exports- versus local market–oriented innovations are connected, as touched on in the previous discussion. For developing countries, especially, the role of exports- versus local market–oriented innovations deserves further scrutiny in evaluating a rationale for innovation support. In the era of globalization, there are widely held perceptions that there is no such thing as "local needs" or "local markets," particularly not in innovative technologies. This view holds that virtually all relevant markets are global, and hence local innovators should aim at serving global demand rather than local niches. It cannot be denied that the ICT sector is preeminently global, both in inputs and outputs. Furthermore, the extent of global specialization and cost arbitrage is increasing over time, leading to further productivity gains and faster innovation. For many countries, linking with this vast, enormously complex and extremely dynamic ICT machine can be a worthy policy goal. That approach, however, does not preclude supporting locally oriented innovation, which can be desirable and even critical for growth.

Globalization does not imply homogeneous demands to be served by uniform products and services. There is increased recognition of the inherent heterogeneity of preferences (and of "needs," even if this notion is ill defined in textbook economics) in specific markets and of the vast opportunities to increase both consumer surplus and profits by catering to this heterogeneity. In fact, advances in ICT and in the Internet, in particular, are often heralded as providing the means for such mass customization, that is, for tailoring products and services to the specific preferences of individuals, without sacrificing scale economies.

If this heterogeneity trend holds true for markets in (advanced) countries, it surely holds across markets, across countries, and across the development divide. The needs to be served in developing countries differ from those of developed countries in a wide array of markets, and in some areas may be radically different. Applying a single strategy for R&D and innovation that focuses on plugging into the global network of ICT to supply the demand emanating mostly from developed countries neglects a huge market opportunity. There are vast areas of economic activity in which innovation is needed to serve local needs and local demand, in which "local" may mean a large fraction of the developing world population. A few examples can illustrate that point:

In the area of health care, the incidence of diseases in less developed countries differs significantly from the Western world, with the prime example being the prevalence of tropical diseases (e.g., malaria, parasites, yellow fever). Given the dearth of access to medical care and even to elementary medicines, the largest market opportunities in developing countries are innovative ways of delivering simple, cheap, easily administered preventive medicine. Innovation in sophisticated technologies (e.g., MRIs, stents, “orphan” drugs for rare diseases) are virtually irrelevant for those countries, and in some cases may have unintended consequences (such as the widespread use of ultrasound in India to select male newborns).

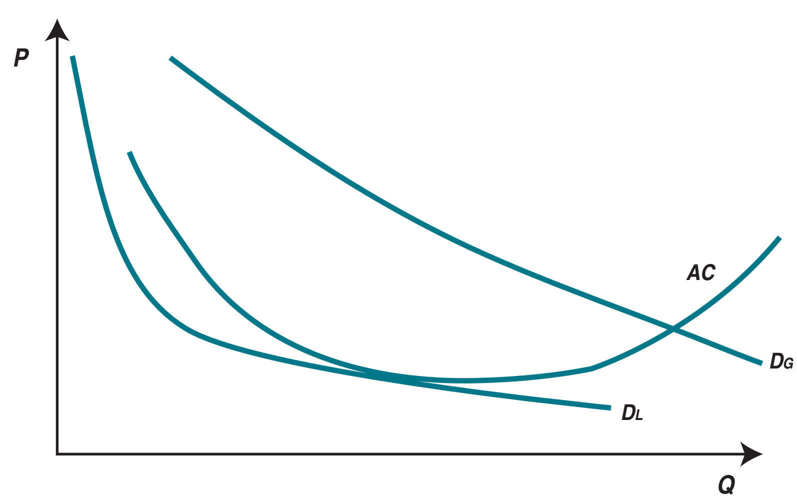
In the ICT sector and, in particular, in software, developing country markets rarely need what is typically viewed in advanced economies as innovation, such as adding more features to already highly complex and cluttered software packages. Instead, innovations are needed to simplify operations and ensure “sturdiness” and backward compatibility, so that barely literate workers could use software, computers, and computer-based tools in a reliable fashion, and use older versions as well. Likewise, local innovations could improve and reduce the costs of satellite-based broadband to deliver Internet services to farmers in isolated villages or develop search engines tailored to their prime needs, for example, having real-time information on prices of crops and on agricultural inputs.

It could be argued that if it were profitable to engage in innovations oriented toward local needs, then market forces would lead to it, and therefore there is no need to intervene in that respect. Figure 5 illustrates why that may not be the case:

DG denotes the demand from high-income countries (the “global” demand); *DL* is the local demand; and *AC*, whose shape is driven by a fixed cost of innovating (e.g., R&D), is the average cost curve facing local entrepreneurs. Absent intervention, the local entrepreneur will surely develop an innovation to serve the global demand, because doing so would result in positive profits, whereas as it stands serving the local market would not cover the fixed cost.

Is it optimal then to leave it at that? Not necessarily. A small R&D subsidy may tip the balance and make it profitable to innovate for the local market, and the local surplus generated may be significantly larger than the subsidy. Recall that the “global” consumer surplus (under the *DG* demand curve) is irrelevant from the standpoint of the local economy, only the profits count, whereas if serving the local demand *both consumer and producer surplus* should count equally. In particular, the social gains of serving the local market in regard to consumer surplus may be very large, as is likely to be the case in the area of medical care (e.g., developing a malaria vaccine). Moreover, local spillovers may be in some cases more significant and more widespread if innovating for the local market, if only because of demonstration effects, but that of course remains to be established empirically.

Figure 5. Exports–versus Local Markets–Oriented Innovations



Source: Trajtenberg 2005

Chapter 3. Instruments to Support Commercial Innovation

At the most basic level, an effective government policy should create an institutional base for innovation by improving the business environment, establishing effective IPR regimes, and enhancing the quality of academic and research institutions to generate the specific R&D projects that attract private investment by firms and investors. Beyond those general policies, most OECD governments have also intervened at the firm level to stimulate private funding of R&D on the basis of the arguments of market failures and the capital gap for funding innovative technology-oriented firms. In general, those types of interventions have taken two forms: (1) direct government support for firms' R&D investment, typically at the early stage of the R&D cycle, to determine commercial viability through procurement preferences, tax incentives, direct grants, or loans and (2) intervention in the market, through direct government funding or incentives for private venture capital funding, for financing innovative technology-oriented firms that are engaging in commercialization of R&D.

In countries such as the United States, Finland, Ireland, and Korea, policy packages of these types of government interventions are widely credited with stimulating private R&D investment and helping to support the technology-oriented firms responsible for high levels of innovation and growth in these economies. Many developing countries and most ECA countries have reacted to that seeming success and rushed ahead with the adoption of support programs, on the basis of their visits to OECD countries, without proper attention to the suitability of particular instruments to developing and transition countries.

Using the experience of interventions in OECD countries, we will first discuss the basic principles of instrument design and how these can be applied to ECA countries. We will review the basic type of financial instruments used in OECD countries, including grants, loans, tax incentives, and procurement preferences, and discuss their applicability to ECA countries. We will then describe in detail the recommended instruments for the ECA region, including R&D grants (minigrants, matching grants) and venture capital. Some additional aspects of instrument implementation, including complementary business support services, coordination efforts, and sequencing, will be discussed. It is important to differentiate between financial support instruments, such as matching grants or tax incentives, which are the main topic of this study, and nonfinancial support instruments, such as business support services. Both are government subsidies to private entrepreneurs, but although the nonfinancial instruments combine subsidization with the public provision of the subsidized service (e.g., government owned and run incubator), a financial subsidy allows the entrepreneur to spend the subsidy on buying the business services (e.g., from the incubator) or to invest the subsidy in, for instance, equipment (e.g., a prototype) or working capital. But clearly, both types of instruments are complementary, reinforcing each other. Although in this study we deal primarily with financial instruments to support innovation, a more in-depth analysis of nonfinancial instruments such as incubators and the provision of business support services, including the question of public versus private provision of these services,[10] will be undertaken in a future study (ECAKE II).

3.1 Basic Principles of Instrument Design

OECD countries have been experimenting for decades with several instruments in support of commercial innovation. On the basis of a review of this experience, a number of principles have emerged as key factors for effective program design. An overarching principle for program design is the *institutional environment*, especially governance and the tendency toward state capture. Given the institutional and governance situation and the identification of corruption as one of the main constraints to the business environment in many ECA countries, it is of the utmost importance to protect projects from misappropriation by the state. Another important principle is *additionality*: any instrument needs to, as much as possible, avoid crowding out, while promoting private investment and risk sharing. The second, related principle is *neutrality*: to minimize distortions, governments should avoid sector and company targeting ("picking winners").

3.1.1 Institutional Environment: Corruption and State Capture

The design of new instruments needs to account for the existing institutional environment. Many ECA countries, especially the new EU member states and accession candidates, already operate variations of innovation support schemes. The analysis of the institutional setup needs to consider the benefits and potential for effective restructuring of existing instruments vis-à-vis the advantages of creating new institutions and instruments from scratch.

To avoid government capture and failure, instruments should be designed to be as neutral and transparent as possible. Most critically, the decision-making (selection) processes about funding allocations need to ensure that the quality of selection is driven by true innovative and commercial potential. The continued presence in many ECA countries of corruption and capture of governmental processes by interest groups places a heavy burden on the design of successful policy instruments. The various grants and venture capital funding proposed under the project are likely to attract rent-seeking behavior, which could result in inefficient funding allocations if the institutional design cannot immunize the funding allocation from interference by political actors and other interest groups.

The design of instruments is crucially dependent on the capacity of public servants to administer them and insulate their decision-making promises from capture and rent seeking. As the Finnish case study in box 2 below shows, some of the most successful innovation support systems in the world rely heavily on the analytical and managerial skills of public servants to take good economic decisions. Although Finland is successful with this setup, it is questionable whether the model can be implemented as such in many ECA countries. Weak public service institutions might result in a lack of capacity to make informed and economically beneficial decisions.

The instrument design in ECA therefore needs to enhance the decision-making processes with sufficient checks and balances through a wide representation of private sector, academia, civil society, and foreign expertise to protect the decision-making process from rent-seeking behavior and capture by interest groups. An optimal instrument design should include the following key elements:

- The administration and funding decisions are located in an independent institution

[10] This question is similar to the debate about public versus private schools in the United States, in which the vouchers could be used to subsidize schooling without necessarily using public schools.

with a clear mandate and control mechanism, separating it from other public policy goals.
- The funding decision is made by an independent investment committee. To enhance transparency it is advisable to staff the investment committee with technical experts and foreign experts that are less likely to be subject to political influence. A potential problem is the question of confidentiality and fear of industrial espionage.
- The investment policy and decision processes are instituted and supervised by a supervisory board consisting of representatives of different government institutions and international advisors.
- Technical assessments of the project proposals are based on external peer reviews involving international experts where possible.
- All project proposals and decisions are recorded, tracked, and made publicly available to enhance transparency. E-government procurement technologies should be considered to aid the process.

3.1.2 Additionality and Crowding Out

The most important design question to be examined in this chapter is whether government support programs create new investment in R&D or whether they simply crowd out private investment, which is substituted by government funding. Most impact assessments of these types of programs in OECD countries are based on aggregated statistics such as the volume of financial flows, as well as anecdotal and intuitive evaluation of the relationships between policies and the subsequent economic performance of an economic sector.

Empirical evaluations using counterfactual data sets are few: Lerner (1999) studies recipients of the U.S. government's long-running Small Business Innovation Research (SBIR) R&D grant program. When comparing program awardees and a matched sample of firms that did not receive awards during a 10-year postwar period, Lerner finds that firms receiving grants grow significantly faster than the others after receipt of the grant. His results are ambiguous in suggesting that the effect may relate more to "quality certification" by the government, enabling the firm to raise funds from private sources. Indeed, his findings suggest distortions in the award process; companies receiving multiple grants showed no increase in performance. Trajtenberg's (2000) review of a number of studies of Israel's R&D grant programs also suggests that there is evidence, although limited, of a positive relationship between the grant programs and productivity in R&D-intensive industries.

Wallsten (2000) found that the SBIR program crowds out the firm's own research spending approximately dollar-for-dollar, reversing the finding of Lerner (1999) for this same program. Branstetter and Sakakibara (2000) found that Japanese funding of research consortia increased the R&D of the participating firms. Lach (2000) found that research support of commercial firms in Israel increased the firms' total R&D expenditure by $1.41 for every dollar of public research expenditure. Ali-Yrkkö (2004 and 2005) showed that the increase of public funding in Finland did not lead to a crowding out of private R&D funding.

Therefore, government interventions need to be carefully designed so that they do not crowd out private investment and funding sources. Although financial market failures can be identified, especially in the early stages of innovation, the smaller the distance of the innovative process from the market and the higher the probability of market success, the higher the probability of financing from mainstream financial intermediaries. It can be argued that the important principle of matching may prevent or at least mitigate crowding out. Projects closer to commercial application should be funded by venture capital or other private sources.

As much as possible, therefore, interventions should be designed to promote private risk taking and stimulate the private risk capital market. A number of design issues can be taken into account:

- *Risk sharing:* The high uncertainty about technological and commercial success in the ESTD phase not only deters mainstream financial institutions, it also represents a risk for the innovator. Often, the inherent uncertainty of success is the key obstacle in providing incentives to potential entrepreneurs to invest their own money, accommodate the opportunity costs of leaving a secure job, and last, but not least important, take commercial risks by borrowing money.
- *Preservation of incentives:* However, the design of the instruments also needs to preserve the incentives for entrepreneurs to invest their intellectual resources and time and effort in the pursuit of success. Concessionary funding is prone to "moral hazard" problems.
- *Commercial orientation:* Criteria for funding decisions need to clearly distinguish between projects that are technologically interesting and the targeted group of projects that are technologically innovative and have potential for commercial success. Commercial success potential must be a criterion for project selection.
- *Instruments tailored to address specific bottlenecks:* The choice of instrument varies according to the different stages of the innovation chain. As discussed in chapter 4, in some ECA countries the most effective set of interventions will be combinations of financing instruments and measures to enhance innovative capacity and the reforms to the business environment. The optimal level and degree of subsidy should be lower, the closer the intervention target is to functioning market mechanisms.

3.1.3 "Industrial Policy" and Neutrality

Neutrality of government programs supporting innovation (such as matching grants) means that the government does not decide ex ante which technological areas, firms, or projects to support, but rather responds to the demands coming from the market. Under that approach, the government sets universal criteria for submission and eligibility (e.g., technological and commercial viability, proven business record). The entrepreneurs (i.e., the would-be innovators) submit project proposals for support, and the agency in charge supports those that best fit the criteria.

More generally, neutrality means that the program should not try to steer the grants (or any other such instrument) in any predetermined direction, but rather should try to deploy them in such a way as to maximize spillovers or social returns. The success of R&D support programs in Finland and in Israel is in large measure attributed to the fact that in both cases the policies implemented were largely neutral in that sense. There were still instances of targeting, but the thrust of the policies remains neutral. Today, Finland has established specific sector programs; however, the emergence and selection of these specific sector programs are driven by an ex post recognition of clusters that have emerged in a neutral and competitive policy environment.

The main critique of the merits of neutrality in this type of intervention is that, in the first place, the rationale given above for intervention is the presence of spillovers—that is, a gap between the private and social rates of return. The difference between the social and private rates of return may be more than a factor of 3 to 4 (Jones et al. 1998). Yet, this gap may not be constant across projects. Suppose we have two projects with identical private rates of return, but one has a social rate of return marginally higher than the private return, and the other has a social rate of return higher by a factor of 10 than the private rate of return. The market will be indifferent between the two although from

Box 1 Taiwan's Experience with Targeted Research Grants

Historically, a number of Asian countries (Taiwan, Japan, Korea) have actively supported commercial R&D through grants and low-interest loans in highly targeted technology sectors. In Taiwan, for example, the Industrial Technology Research Institute (ITRI) acts as a public sector applied research center, participating and managing R&D and technology transfer in high-tech industries. ITRI conducts research directly on new technological developments in the international arena and then transfers its research to the private sector for commercial development. More recently, the government has offered direct grants and subsidies to finance private R&D in high-tech sectors ("Industrial Policy in East Asia: In Search for Lessons", background paper prepared for the *World Development Report 2005: A Better Investment Climate for Everyone*). Most of this R&D support, however, has been absorbed by large companies and research consortiums as part of state subsidies for large-scale industrial policies. Often the subsidies were tied to FDI initiatives and technology transfer.

The approach of large and direct R&D subsidy tied into foreign technology partners undoubtedly created clusters of successful industrial activity in certain technology sectors in these countries. However, the long-term impact on the innovation system remains questionable. Noland and Pack (2003) argue (based on Wang 1998) that the impact of Taiwan's interventions has been modest: "Rather than the government's sectoral policy and preferential treatment of the strategic industries, it was the government's creation of a favorable climate and environment that contributed the most to the blossoming of Taiwan's information industry."

a social perspective, the one that offers such a high social rate of return is preferable. If all this information is available, neutrality is not the best policy. Some countries in East Asia have taken a mixed approach—adopting project and firm neutrality while targeting certain sectors or industries in their approach (see box 1).[11] However, selecting projects based on their "social return" is in most countries impractical because it requires huge amounts of information about the parameters of the social benefit of each project. Moreover, because such parameters are necessarily subjective, selection based on the social benefit of each project opens a "Pandora's box" of capture and corruption possibilities. Given the limited institutional capacity, it is unlikely that many governments in ECA countries would be able to estimate the social rates of return and select projects with the highest social benefit. We can therefore, as a second-best option, opt for neutrality. The threat of capture by vested interests (e.g., old firms or organizations for whose services there is no demand but who are trying to survive from state aid for innovation) and corruption lead us to recommend neutrality as a principle of intervention. Only after a track record of excellence has been established, with several years of experience (as has happened in Israel and Finland) could the principle of neutrality be modified—but only toward sectors/industries, not toward individual

[11] The role that government intervention played in the success of several East Asian economies has been questioned recently (Pack and Saggi 2005). It is argued that such targeted interventions are likely to fail, even more so taking recent developments into account (the liberalization of trade and finance flows as well as stricter rules internationally, e.g., at the World Trade Organization).

firms or projects. Moreover, neutrality does not imply lack of choice criteria: the authority in charge of administering the program will choose among competing projects, using certain criteria. The question is what criteria guide the choices and what the information requirements of such criteria are (e.g., the authority administering the program could choose those projects that maximize spillovers, although information requirements may make this criterion difficult to implement and open the door for unwanted influence).

3.2 Basic Types of Instruments

3.2.1 Grants versus Loans

With that in mind, it is useful to evaluate the two most basic types of instruments for government intervention to promote investments in innovation and R&D: direct subsidies (grants) and instruments with mandatory repayment (loans). In the next section we will review indirect support instruments such as procurement preferences and tax incentives. These types of instruments can be applied to different levels of activity—whether to companies or investors—and to achieve different program objectives.

One form of subsidies is grants, which typically require some share of matching investments by the grant recipients. Grants have two clear advantages over loans for the promotion of innovation. First, providing funds through matching grants reduces the entrepreneur's risks, which is typically the most important constraint in providing incentives to innovators to pursue commercial applications. In the case of technological or commercial failure, the loss to entrepreneurs is limited to their own matching investment, and they do not have to pay back the grant.

Second, R&D and innovation activities require high up-front investments that may generate positive cash flow of an uncertain level at some point in the future. Grant instruments (like the equity provided by private risk capital investors) can support this investment profile by providing the needed up-front investment without crippling the company or project with mandatory payments before the positive cash flow can support them. Many of the most successful grant programs are designed specifically to mimic the positive cash flows with royalty payments on successful programs.

Instruments with mandatory repayments such as commercial loans or even loans with interest rate subsidies provide neither the crucial risk-reducing feature nor the cushion of support for the cash flow. Mandatory repayments may starve a potentially successful project of internal financing to invest in later stages of development and commercialization. In the case of technological or commercial failure entrepreneurs not only lose their own investment, but they also have to repay the loan in full. The implications of this at the level of the entrepreneur are very significant. An entrepreneur is very unlikely to consider engaging in already risky innovative activities when this risk is compounded by the high prospect of business failure from loan foreclosure, potentially leading to bankruptcy.

The mandatory payment structure of loans makes them unsuitable instruments for ESTD projects with uncertain cash flows and unknown ex ante prospects of success. Still, loans can play a role at later stages of the innovation process in which the risk to the entrepreneur declines with a greater probability of success and reduced distance to market. When looking at best-practice examples implemented globally, it is important to look at the economics of the instrument employed. A variety of instruments can be found that are nominally classified as loans; however, they contain provisions that forgive the loan repayment in case of project failure or convert the loan into an equity participation, thereby reducing the ex ante risks and disincentives to the entrepreneur and effectively assuming the economic advantages of a grant mechanism combined with a "tax on success."

3.2.2 Procurement Preferences and Tax Incentives

It is useful to evaluate a number of other instruments that have been used internationally to promote investment innovation and R&D. Rather than directly allocate government funding for projects, these instruments attempt to indirectly stimulate investments through procurement preferences and tax incentives. Because they act indirectly, however, they require efficiency in response to the preferences and incentives on the part of both public and private actors to achieve the required response. They are therefore a more complex policy lever. In the ECA region, with weaker institutional contexts, they are likely to be difficult to implement effectively.

Tax incentives have been widely used, especially in Europe, for a general encouragement of R&D investment across a wide range of firms. Broadly, tax incentives encourage investors or companies to invest in R&D or new companies through tax credits or lower tax rates. Tax incentives can come in several forms: (1) up-front tax credits for investments, (2) reductions in capital gains taxes or tax rates on investments, and (3) tax credits to offset losses from investments in small and medium-sized enterprises (SMEs) or equity funds. Tax incentives are in principle neutral—they do apply to all qualifying firms equally and therefore would uphold one of the key principles in instrument design. Moreover, in the United States, a study by Hall and Van Reenen (1999) suggests that a dollar in tax credit for R&D stimulates a dollar in additional R&D.

Tax incentives, however, have a number of weaknesses that make them less applicable to the ECA region. First, tax benefits would help existing enterprises that can use profits from related products to take advantage of the credits or offsets. However, tax incentives do not help start-ups that have not yet accumulated sufficient profits and therefore cannot offset tax liabilities. Innovative start-ups may have very low profits for a long time. Thus, tax benefits would provide no funding at the critical initial period when commercialization takes place.

Second, in countries with a weak tax enforcement system, tax incentives may promote distorting tax avoidance behavior rather than productive investment. There is a risk that companies will reclassify expenditures without justification by presenting regular expenses as R&D expenditures. Coping with such tax avoidance or evasion requires a highly sophisticated tax inspectorate, which is unavailable in most ECA countries. Lack of specificity and poor design of the tax code can also limit the impact of tax incentives because some firms are able to benefit from reduced taxes without having significantly altered their behavior.

Third, because tax incentives are indirect, the fiscal cost of the support is not fully apparent in the budget and thus hidden from policy makers, while financial support in direct programs is easily observable in the budget.

Fourth, tax incentives cannot be used like grants to promote the creation of networks and linkages between the private sector and universities and research institutes, which lie at the heart of this type of instrument.

Procurement preferences are a variation on a direct grant program in which a portion of existing government research budgets are earmarked for small innovative firms, as in the SBIR Program evaluated by Lerner in the United States (see box 2) . This type of program is most effective in large economies with significant government-sponsored, commercially oriented research budgets and transparent procurement processes, conditions that are unlikely to exist in most ECA countries.

3.3 Financial Instruments for ECA

As can be seen in figure 4 in chapter 2, about 60 percent of ESTD funding in the United States comes from “angel investors” or corporate ven-

Box 2 The U.S. Small Business Innovation Research (SBIR) Program

To support the commercialization of early-stage technology start-ups, the U.S. government established the Small Business Innovation Research (SBIR) program in 1982 (renewed in 1992 and 2001) to more directly affect the process of commercialization of government-backed research. The SBIR grants support research in scientific and engineering areas that will encourage the conversion of government-funded R&D into technological innovation and commercial application. The program is intended to fund projects that transform a research-based idea into a prototype, the type of research that many SMEs and venture capital companies are unable to support. Small businesses must meet certain eligibility criteria: they must be for-profit, American-owned, and independently operated; the principal researcher on the project must be employed by the company; and company size is limited to 500 employees.

Small businesses receive awards or grants in three phases. Phase I is the start-up phase, with awards of up to $100,000 for approximately 6 months to support exploration of the technical merit or feasibility of an idea or technology. Phase II awards of up to $750,000 support expanded R&D work that allows the developer to evaluate commercialization potential. Phase III moves the technology from the laboratory into the marketplace. No SBIR funds support this phase

Source: Wessner (2004)

ture (internal financing by corporations), and 34 percent comes from federal and state governments (SBIR, etc.). In ECA, as mentioned above, because of the low capital accumulation before 1990 and the shortage of entrepreneurial capacity in corporations, the funding gap presented in chapter 2 is more severe. Accumulation of retained earnings in Russian corporations has recently given rise to nascent corporate ventures. It is important that state intervention in this environment deal with the bottlenecks in all stages of the innovation chain from the generation of ideas to commercialization. It is important to stress here that the supply of ideas (the pipeline of projects) is endogenous: potential inventors and entrepreneurs need to be confident that if they create projects there will be funding available for them. Why else would they invest resources in innovation? Therefore, funding programs cannot wait until ideas appear by themselves, but rather all stages of the innovation chain need to be dealt with in parallel. Taking these design principles and possible instruments into account, there are three types of instruments that are most useful for the region: minigrants, matching grants, and early-stage venture capital support. Business support services are necessary to develop projects that would be acceptable for funding. However, it is important that business support services be viewed not as a stand-alone policy lever but a complementary support to the core instruments that provide financing for innovation and R&D. Finally, the design of such a program will also have to play a coordinating role in the number and types of instruments that a country puts in place to support commercial innovation. As will be shown in the next sections, there is a certain sequencing of instruments that matches the innovation process—researchers and entrepreneurs have to be aware that these instruments are available for the entire innovation process and that the support system has been designed in a comprehensive and coordinated manner. Not only will that ensure the availability of support for the entire process, but it will also help curtail

Box 3 TEKES—The Case of Finland

In 2004 most (82%) of the support funds administered by the Finnish agency TEKES were in the form of neutral grants. By 2004 TEKES provided 42 percent of all its funding through *technology programs*, totaling €171 million. In total, TEKES has been funding 26 technology programs focusing on a broad variety of technology sectors ranging from public health care technologies to nanotechnology and business and management technology. The economic rationale of the technology programs is to enhance R&D cooperation between different companies, public R&D institutes, and international actors and to transfer knowledge and skills among the participating entities. Internal evaluations of initial programs find positive returns to the promotion of R&D cooperation and coordination. However, the success of the programs relies equally heavily on the quality of public administration in identifying and deciding on relevant program areas. The decisions to launch specific technology programs are based on strategic decisions within TEKES. In interviews conducted by World Bank staff TEKES decision makers emphasized that TEKES relies heavily on information feedback mechanisms and coordination with local R&D institutions and industry in formulating the technology strategy. Although the process is not formalized, the cooperative model of public policy formulation in Finland fosters a bottom-up approach to developing the technology program priorities, thereby avoiding some of the risks of top-down industrial policies.

TEKES represents international best practice in the support of innovation through grants and other soft funding instruments. The diversified approach to different project stages, the maturity of companies, and the emphasis on grant funding for start-ups and projects with high technological and commercial risks are of direct relevance to the ECA region. However, the decision-making process, project selection, and formulation of programmatic priorities are heavily dependent on the quality and capacity of public servants, as well as the Finnish governance model with the virtual absence of corruption and capture and a transparent and cooperative approach to public policy formulation. The absence of most of the latter implies that the TEKES model cannot be transferred as is to many ECA countries. ECA governments should focus on adopting the funding instruments but complement the decision-making processes with independent, external control and oversight through peer reviews, foreign experts, and so forth. In regard to programmatic priorities, ECA governments should be encouraged to emphasize neutrality in the early stages of the development of funding programs and to focus on technology policies based only on ex post patterns occurring over time.

inefficient duplication of efforts by several agencies. (More on coordination in the discussion of the NIS in chapter 4.)

These three types of instruments address in particular weaknesses at different segments of the innovation value chain in the ECA region, with limited distortions and clear objectives. Minigrants provide small grants directly to support precompetitive R&D, and matching grants require companies to match the investment. Finally, government leverage of private venture capital support promotes the risk capital market, which will eventually become the long-term driver of innovation investment.

3.3.1 Minigrants

Minigrants are small grants designed to support the identification of commercially viable ideas and scientific work as well as encourage entrepreneurship among the scientific and SME community. The objective of a minigrant is to provide an initial financing grant to support entrepreneurs/SMEs in transforming basic ideas for innovative commercial activities into a business plan format that can be presented for consideration under a matching grants program and, if and when the project matures, to potential investors (angel or venture capital).

Minigrants are the first phase of funding and focus on the commercialization of a given innovation. The purpose of a minigrant program is twofold: (1) to stimulate the initiation of entrepreneurial activities in the field of innovation by providing small grants to help *potential* entrepreneurs take their existing ideas and determine whether these ideas can evolve into commercially viable ventures and (2) to help scientists and entrepreneurs who have limited experience in building successful companies obtain technical assistance and consultancy services that can help them conceptualize the business functions that would be needed to take their products to market.

Because many of the most innovative ideas evolve through the process of scientific research and because the focus and objectives of scientific research differ significantly from the processes involved in establishing and running a business, there is often a disconnect between accomplishments that are achieved in the laboratory and successful innovations emerging in the product and consumer marketplace. This disconnect is compounded in the ECA region, in which most countries have emerged just during the past 15 years from a centrally planned economic system and, as such, do not have a long-standing tradition of entrepreneurship. Consequently, the minigrants tool is designed to help stimulate the evolution of an entrepreneurial mind-set and provide an incentive for scientists to innovate by offering them access to a vehicle that can help them gain commercial success following their success in the lab.

An additional feature of minigrants that increases their overall value to an innovation finance program is that they maximize the likelihood of success of given innovators by matching them up with additional skills and resources to which they likely would not otherwise have had access. That is because most innovators in this context expend whatever limited resources they have in developing and building the technological value of their ideas, that is, working toward proving that their ideas are in fact technologically feasible. That results in a knowledge gap, whereby insufficient time is afforded to assessing and documenting the commercial feasibility of their ideas. Furthermore, given that many of these individuals are likely to be inexperienced in taking on the tasks needed to help assess commercial viability (i.e., market analysis, marketing plan, financial plan, etc.), giving them access to this expertise helps improve the quality of the analysis concerning the viability of their ideas.

A drawback of minigrants is the high degree of "business support services" required in the form of advice, knowledge, and technology transfer to achieve success at this stage of the innovation. Administering such a program, especially in which the capacity of the bureaucracy is low, will be challenging because of the need to involve technical and business support in both the selection process and the implementation of the grant.

In many ECA countries, the level of private business support services, such as consultants, training, business mentors, entrepreneurial networks, and even infrastructure services, is low. However, generally public provision of business support services has proved ineffective. There are a number of potential solutions to this challenge that we discuss below in the section on business support services (including incubators). It is worth noting here, however, that to be effective the financial instrument of minigrants must be combined with some way of providing business support .

A possible solution to the problem mentioned above would be to design a combined system of minigrants with "virtual incubators." Recipients would receive the money only in conjunction with subscription to services of a virtual incubator. That would ensure that they receive the appropriate advice and mentoring, plus it would reduce the moral hazard problem of such a system. Virtual incubators are incubators without a physical infrastructure, which prevents the incubator from developing into a real estate business, a result that occurs only too often. It also would put more emphasis on providing business support services. This solution does not come without problems (entrepreneurs having to provide their own location and infrastructure might be a problem in some ECA countries), but it is an option to consider.

3.3.2 Matching Grants

Although the more traditional approach to R&D support to firms has been through tax incentives or subsidized loans, since the 1980s there has been an increasing awareness among OECD countries of the benefits of matching grants in encouraging firms to share and manage risk. A number of historically successful grant programs, such as Australia's R&D Start Program and the U.S. SBIR Program, have an implicit matching component in that firms are expected to support a portion of the research budget. In countries such as Finland and Israel, more formal matching grant programs are helping to create a seedbed of precommercialization activities out of which the most promising innovations can be generated for follow-on investment by private sector investors, such as venture capital (VC) firms.

A matching grants program works by encouraging risk sharing with firms, and it orients the selection process toward R&D programs that are most likely to generate innovations that can be commercialized. Qualifying firms, or consortia from academic institutions, will submit grant applications for specific R&D projects that are reviewed by an independent research committee. If approved, the applicants receive a grant from 50 percent to 70 percent of the stated R&D budget for the project. Successful projects (i.e., those leading to sales) will be required to repay the grant, as a royalty from revenue, up to the dollar-linked amount of the grant. The sharing of risk with the firm alleviates, although it does not eliminate, the negative consequences of "picking the winners" by the public sector. The royalty scheme also orients the selection process toward picking projects mainly to achieve sales and profitability targets.

There are two critical aspects of a matching grant program that make it useful in the ECA context. First, firms are required to invest a dollar of their own funds for every dollar they receive as a grant. Proof of the private expenditure of a dollar is required before the government reimburses the entrepreneur for the dollar it invested. The importance of matching stems from the fact that its effect is to reduce the marginal cost of research to the firm. *A firm facing a downward sloping marginal research returns schedule will always increase total expenditure when the marginal cost falls, precluding the dollar-for-dollar crowding-out result.*

Second, the administration of matching grants must involve an independent and effective selection process whereby the projects most likely to generate commercial innovations are chosen. That factor is crucial. In the ECA region the selection mechanism will face the risk of excessive administrative burden and corruption. As much as possible, industry experts and private sector players who are familiar with commercialization of innovations should be involved in the selection. It is also important that the criteria for selecting projects and using grant proceeds are clearly laid out and that they are adequate to the country environment.

Another critical component of matching grants (as well as minigrants) is the potential they have to create and foster linkages between the private sector and universities and research institutes by favoring consortia. Cooperative schemes between the private and public sector have been at the heart of many programs in OECD countries. Given the dissociation between the private and public sector, it is important that these instruments be used to promote schemes between the two. Because the main aim of these instruments will be to promote commercial innovation, it is also important that the private sector be in the driver's seat of these consortia. This topic will be studied under ECAKE II.

3.3.3 Venture Capital Support

Although matching grants support ESTD, venture capital (VC) plays an important role in the commercialization phase of the innovation chain. VC targets projects that have passed the early stage; these projects may or may not have been supported by a grants program to reach the stage at which they are mature enough to be of interest to VC. It is important to note, as described in chapter 2, that typically purely commercial VC funds avoid the uncertainties connected with early-stage companies. To achieve the high commercial returns expected by their investors, they seek out companies that have successfully developed their innovation, proved its technical capability, and identified probable commercial applications and markets. At that stage, venture capital provides the funds to expand production and develop markets and the customer base and plays a critical role in supporting the later (and most visible) stages of commercialization.

Although VC plays a role in financing the commercialization of innovation and the expansion of innovative firms,[12] it does *not* provide, a solution to the market failure in ESTD. This observation is of great importance for policy formulation in ECA because of the misguided discussion by ECA governments about the virtues of VC in ESTD. Although there is certainly a shortage of VC provision in ECA, it is important to put the role of VC in context. VC does not address the market failure in ESTD, and yet the success of VC funds depends on having a "deal flow" of attractive companies coming out of the ESTD stage. *Therefore, any intervention supporting VC needs to be preceded or complemented by interventions addressing the early funding gap through matching grants or by other means.*

Therefore, for a VC instrument to work effectively, a pipeline or deal flow of companies with commercial potential is required. A VC program is therefore likely to work best in situations in which support for R&D through a grants program provides the critical funding at the earlier stages to advance companies to the level at which they can be supported by VC firms. Similarly, minigrants and matching grants programs are likely to work best in circumstances in which support for later stages of the innovation process is available. Entrepreneurs will be able to plan better, and their incentives for engaging in commercial R&D will be greater if they know that there are adequate support instruments available after the initial stages of the innovation process. VC measures should also be coupled with specific reforms to improve the conditions for developing a VC industry, including further revisions to the VC legislation and capital market reforms to increase the liquidity of the stock market. It is useful to note that

[12] Venture capitalists act as the first step of formal commercial financing for innovative, high-growth firms. They often play a similar role as angel investors in providing critical technical assistance and managerial support. Venture capitalists also support firms in accessing later rounds of financing, including initial public offerings VC.

the countries with some of the most robust VC industries (United States, Israel, Canada, Australia) have active programs at all stages of the innovation life cycle: from grants through VC support programs. For example, Australia has the R&D Start Program to provide grants for the commercialization of innovations by SMEs, which is complemented by its Innovation Funds Program to encourage VC investment in innovative SMEs.

It is also important to emphasize that VC cannot be relied on to provide all of the financing necessary for innovation. Only 1 in 200 SMEs in emerging markets (compared with 1 in 100 in the United States) is able to secure VC financing (Nastas 2005). In fact, large multinational corporate investors (e.g., Shell, General Electric, IBM, for example, in Russia), rather than VC investors, are often best suited to provide access to finance for innovation in middle-income countries. Multinational corporations (MNCs) can co-invest to form public–private funds locally, particularly to finance projects in sectors of the economy in which MNCs are interested in developing new start-ups to strengthen the supply chain. The latter may be of particular relevance for countries rich in natural resources, such as Russia, Kazakhstan, and Ukraine. Corporate venture will become an increasing source of ESTD financing if and when local corporations accumulate sufficient retained earnings to allow them to engage in risky ventures that may be only tangential to their core business. Ideally, such new ventures will be spun off to establish more flexible and entrepreneurial SME start-ups. This development depends critically on the availability of farsighted entrepreneurial owners in these private companies, either privatized or de novo companies.

The success of the most prominent venture capital funds in OECD countries relies, therefore, on three characteristics:

- *Investment expertise*: VC investment analysts are highly specialized, with a strong understanding of different technology fields and their markets. If a venture capital fund invests in a company, it typically gains high levels of control and influence over the management decisions of the company. The VC fund manager brings management and commercialization expertise to the company and exercises control to ensure commercial success.
- *Risk Profile*: VC investment strategies are formulated such that they can absorb a high number of failed investments. Typically, the VC fund aims to earn very high returns from 1 or 2 of 10 investments it makes, which compensates for the expected failure of the rest of the investments (cross-subsidization).
- *Deal Flow*: Venture capitalists rely on a supply of high-potential companies emerging from the earlier stages of business, technological, or innovation development. Therefore, VC works best in economies (such as the United States and Israel) in which the early stage of technological development is financed by internal funding, angel investors, and/or government-supported grant financing.

These three characteristics of VC constrain the possibility of government intervention. Misperceptions of the role of VC have led to a number of failed interventions in the risk capital markets.[13]

State-owned and state-managed VC in particular, have proved to be especially prone to failure. Government officials usually do not have the crucial technical expertise and risk-taking mind-set to support innovations at their commercialization stage. Thus, caution is advisable

[13] Because efforts to promote the emergence of a VC industry have failed in at least one reform-oriented country (Chile), a careful analysis of the reasons for this failure and any design problems that may have caused the failure is needed.

in the latest Russian government's initiative to establish "Private–Public Early Stage Regional VC Funds." As in fact is planned, the participation of the private sector is critical to the success of this program.

Typically, in many cases in which so-called VC funds managed by government entities are operating with commercial success, the risk profile does not display features of VC and the funds are not being invested in innovative ventures, but rather in small, more mature companies with less-risky product lines. Capture and rent seeking are prevalent and problematic because these types of fund set-ups are prone to be dominated by political interests (patronage).

However, there are a number of successful examples, in Taiwan and South Korea, in which government support for the development of a private VC industry has played a significant role in the development of a dynamic innovative sector (see box 4). In these cases, the government has "seeded" the VC industry through investing in privately managed funds.

In these public–private partnerships, governments mitigate some of the risk inherent in technology-oriented SME start-ups, and the venture capitalist provides commercial and managerial expertise. In time, funds graduate from using government support to avoid the restrictions placed on the fund by government. This type of instrument can take many forms:

- *Direct cofinancing*: By participating in a privately managed VC fund, the government lends credibility to the fund and acts as a catalyst for other investors to participate. This works well if the VC industry is experienced and there are attractive opportunities. Israel's Yozma Fund is an example of this approach. In 1992 the Israeli government provided U.S.$100 million divided among 10 private funds. Each fund manager raised a matching amount of private funding. The funds made investments of U.S.$300,000 to U.S.$750,000 in hundreds of companies. By 1997 the government felt that it had achieved its goals and sold the Yozma Fund through privatization.
- *Leveraged returns:* In this scheme the government, either by subscribing for ordinary equity shares or providing grants, co-invests with private investors but takes only a small part of the return, thus "leveraging" the upside potential for private investors. The Australian Innovation Investment Fund Program, for example, provides up to two-thirds of the capital for the VC funds but takes only 10 percent of the return with the remaining 90 percent allocated to the private investors and management. In exchange, fund managers are required to invest a portion of their fund in SMEs and early-stage companies. Israel's Yozma Program and the U.S. Small Business Investment Company (SBIC) Program have variations on this basic approach. These programs have proved very successful in countries in which there are opportunities to achieve very high returns.
- *Guarantees.* Guarantees against losses have been successfully used to promote investments in VC funds but tend to be most useful for countries with financial systems capable of sophisticated risk evaluation. By guaranteeing a certain return to investors and/or taking a subordinated position in the distribution of the funds' profits, the government protects investors against major losses of principal (downside risks are capped). Although guarantee programs can mitigate risk and attract commercial capital, they sometimes distort investment decisions. Facing limited losses, venture capitalists tend to be less rigorous in assessing the downside of deals.

In the case of the ECA region, VC leveraging may be the most effective approach. VC in the ECA region is still very limited. Therefore, the government may need to provide incentives

Box 4 Government Support for VC Funds in Korea, Taiwan, India and Chile

The Korean government has a long history of support for the VC industry through co-investment with private investors in VC funds (starting in the 70s and 80s with the Korea Technology Advancing Corporation and the Financial Assistance to New Technology Businesses Act in 1986. The government has been and continues to be the largest supporters of VC funds in Korea, contributing over 30 percent of the capital in new VC funds in 2004. The Korean strategy for promoting VC firms includes multiple instruments—tax incentives; participation as a limited partner; credit guarantee program (less successful); and establishment of a bank, later privatized, specialized in R&D loans. Both the establishment of VC firms and the investment resources in the VC pool increased dramatically after 1997, after the adoption of the act on Special Measures for the Promotion of Venture Businesses. The government co-investment approach is viewed by many as a critical catalyst to the development of the VC market (Baygan 2003 and Koh 2005).

The Taiwan government has also actively supported the VC industry by using tax incentives, including through tax credits or lower tax rates, to encourage investors to invest in equity funds. Taiwan allowed investors in qualified VC funds a credit of 20 percent of their investment to offset tax liabilities, proportionate to actual investments by the VC companies. Taiwan's tax incentive was very effective in encouraging domestic investors, especially large companies, to invest in VC funds, resulting in the establishment of a number of local VC funds. Eliminating the tax incentive, however, has had a very negative effect on the VC industry in Taiwan, with an immediate decline in funding through VC. Companies now prefer to invest directly rather than through VC funds.

The Indian experience in supporting VC through government was the least successful of the four presented here. The government program was initiated with the assistance of the World Bank, based on guidelines issued by the government of India in 1988. Government regulations that were adverse to the development of the VC industry (geographical as well as instrumental limitations were imposed) and the lack of managerial skills ensured that the first VC firms achieved very low returns on their investments. A second phase saw a greater participation of the private sector (foreign, local and, more important, the IT Diaspora). Their managerial expertise brought some successes, but these were to a large extent hindered by continuing government regulations adverse to VC development (e.g., nonneutrality of portfolio, adverse selection). The private Indian VC industry emerged out of the boom in the IT industry *despite,* rather than because of, the government's involvement (Dossani and Kenney 2002). The latter positive developments have been aided both by a better-defined role in the past few years for the government of India, which has been very active in gradually removing both the regulatory and the legal bottlenecks, and by the fact that previous efforts, although less successful, provided a good training and learning ground for all people involved.

Chile tried to replicate the Israeli Yozma Program through the CORFO "Capital de Riesgo Program". The Chile program has had mixed results, mainly owing to low uptake by firms (World Bank "Chile New Economy Study" [2004]). The fact that the CORFO Program was not successful, although its design was consistent with international best practice, points to the need to assess country-specific conditions, both on the supply side and on the demand side.

for private investors beyond merely cofinancing VC funds. However, guarantee programs are more complex to implement, and ECA governments are unlikely to have the capacity to effectively evaluate the guarantee risk associated with the funds.

3.4 The Role of Business Support Services

Even if researchers or inventors have the capacity to innovate, they may lack the skills, knowledge, and business acumen to develop a project that would be acceptable for funding, not to mention the ability to engage in the business planning and implementation necessary to commercialize their innovations. In that case, the deal flow and utilization of the instruments may be constrained by the lack of project/business development capacity.

Many OECD and developing country governments implement business support services, especially incubators, as an instrument to promote the commercialization of innovation. Their rationale is that innovators and nascent entrepreneurs cannot be expected to manage all parts of the commercialization process—from launch strategy to financial planning, to IPR, to basic logistics. By providing logistical support and technical assistance, incubators are meant to help entrepreneurs transition from a supportive institutional environment of universities or large companies to the more challenging environment of a new company or R&D project.

Incubator programs have not received high marks for effectiveness, either in their success in promoting businesses or in their cost-effectiveness. This is in part because many incubator programs have developed poor reputations as they devolved from the high goals of business support to the provision of real estate and office support services. But incubators and technical assistance programs in OECD and developing countries alike tend to suffer from poor utilization and poor track records in creating successful companies. Though there has been remarkably little analysis or impact assessment of these types of programs, the reasons for the perceived lack of success include the following:

- *Necessity for specialized skills and knowledge.* The technical advice or market knowledge required by inventors and entrepreneurs is often highly specialized, whereas most technical assistance programs are designed to reach a range of business needs and therefore are general in nature. The type of business advice needed, however, is from seasoned, experienced businesspeople who are unlikely to be consultants to these types of programs. Therefore, the skills and knowledge required by an entrepreneur in a specific context rarely match the technical assistance provided by a program.
- *Government allocation of resources.* These types of programs tend to be highly subsidized by government and designed and managed by government agencies (supply driven)—without necessarily taking into account inventors' needs. As noted above, government officials are ill-suited to evaluating the paradigm of inventors or entrepreneurs and effectively allocating resources to support them.
- *Incentives for entrepreneurs.* It can be argued that part of the seasoning process of becoming an entrepreneur is overcoming the challenges of commercializing an innovation and setting up a company. The entrepreneurs who are most likely to be successful, therefore, do not have a need for "incubation" because they have the wherewithal to mobilize needed resources. Therefore, there is a self-selection process whereby weaker candidates access incubation services and are unable to graduate from those services.

Most of the existing business incubators and industrial parks in transition countries, including Russia, are little more than custodial care centers and, in the worst case, tax havens. A recent study argued that "elements of infrastructure such as technological parks and innovation and technology centers (ITC) are considered by managers of small companies more as nice premises, with subsidized rents, rather than structures enabling to promote small enterprises renting these premises" (Gaidar et al 2005). They are primarily controlled work premises designed to help start-up firms survive in the midst of a hostile environment. There is a logic to some form of infrastructure support in hostile environments in which land is difficult to rent, utility and communication connections are difficult to organize, and petty harassment (or worse) from bureaucratic inspectors is an unfortunate but common fact of life. But these real estate services should not be confused with the proactive value-added support and the tools, information, education, contacts, advice, and resources critical to success in the ESTD of a business.

Given these historic problems in incubator programs and government provision of support services, it is necessary to critically evaluate direct subsidies for these types of programs and to be more creative in developing solutions to the real challenge of delivering effective managerial and technical business support to ESTD companies.

It can be argued that the most successful models for incubation and business support services for new companies are the "angel investors" and early-stage VC funds that operate primarily in the U.S. market. Typically, these "angel investors" are seasoned businesspeople with experience in the industry who provide business advice and contacts for specialized skills and knowledge. Because they are investors in the business, they resolve the failures noted above by having the incentive to do rigorous due diligence on the capabilities of the entrepreneur, to critically evaluate the needs of the business and direct it toward necessary resources, and to remain involved in the company, "hand holding", over an extended period of time.

Unfortunately, "angel investors" are not prevalent in the ECA region. Nonetheless, a number of best practices can be taken from the model and applied to the provisioning of business support services:

- *Business support services linked with investment activities.* Business support services should be a paired component of an investment (such as a matching grant or VC investment). The entrepreneur is therefore screened as part of the investment selection process, and the investment capital helps the company execute its business plan.
- *Private allocation of support services.* Rather than having government set up ponderous technical assistance schemes, entrepreneurs articulate and determine the type of assistance they need as part of their application for a grant or VC. A portion of the investment budget is allocated specifically for business support services.
- *Private provision of technical skills and knowledge.* Entrepreneurs are empowered to seek out the skills and knowledge they need from private consultants—it is therefore a demand-driven supply of business services.
- *Seasoned business expertise*. As much as possible, the successful businesspeople in a country or region should be involved in the design and selection process of innovation programs. Even though they are unlikely to become intimately involved in the selected businesses, their advice and perspectives can be diffused throughout the program.

Let us stress that under this flexible approach, *business* support services are viewed not as a stand-alone policy lever but as a complementary support to the core instruments that provide financing for innovation and R&D. Business support services should be supplied in a demand-driven way, with financial assistance for business support services being offered *to* *firms*—who in turn will use the financial support to purchase business support services.

Clearly, however, government support for knowledge and technology transfer and business support services remains a challenging topic. It is further limited by the lack of a critical evaluation of programs and the proliferation of programs. ECAKE II will provide a more in-depth analysis of knowledge and technology transfer in the context of a discussion of absorption of innovation.

3.5 Monitoring and Evaluation

An effective monitoring and evaluation (M&E) framework should be a component of the deployment of policy instruments mentioned in this chapter targeted at the enhancement of innovation. M&E should provide information about the program's progress on three levels: (1) the project level in regard to the success of individual projects; (2) the program level in regard to the uptake of funding and overall portfolio performance trends; and (3) the economy level in regard to changes in the technological capabilities, productivity, and growth and in regard to the role of the program in stimulating those changes. Jaffe (2002) explores the possibility of producing more compelling empirical evaluations by having the grant agencies anticipate the need for such evaluation and build certain features into the grant process to facilitate later evaluation. The proposed design of the grant-making process that may facilitate ex post evaluation is discussed below.

An M&E framework for innovation policies must be flexible enough to take into account the organic nature and unpredictability of innovation policies. There is likely to be a significant amount of uncertainty about key variables (e.g., pipeline of project). There may be time lags because the policies change the incentives related to innovation activity. The dynamic nature of the political and business environment will also affect the uptake and performance of the program. Innovation-support programs must therefore be designed with sufficient flexibility to allow their mechanisms and tools to continue to evolve with changing conditions.

The role of the M&E system is to identify how a program is performing relative to its objectives to allow correction or cancellation of the program midcourse, for example, as a result of low uptake (pipeline lower than expected). Specifically, an M&E system should (1) follow up on whether the program is overfunded and unnecessarily tying up resources and (2) evaluate the overall success of the program on an ongoing basis to help determine when and if the program should be discontinued or restructured. Problems with the program may stem from a lack of demand for resources or a lack of appropriate output resulting from the investments made and, in some cases, from the sufficient evolution of other funding vehicles, thereby making the existing program no longer necessary.

To fulfill that role, M&E vehicles must effectively provide data about the program's progress on the three levels mentioned above—project, program, and economy.

M&E at the Project Level

The M&E framework should provide feedback on whether the tools being deployed are making a significant impact on the projects being financed in regard to increasing their individual likelihood of success and their access to follow-on financing.

At the project level, therefore, projects must be evaluated in regard to their success on two dimensions: technological success and commercial success. This process begins with ensuring that projects submitted for evaluation for funding clearly state, and distinguish between, the technological and commercial objectives. These objectives should be approved by the evaluation committee/authority and should be amended in conjunction with the applicant where necessary. In doing so, each project begins with specific, measurable, time-bound benchmarks that can be evaluated to assess the overall success of the project.

Although measuring how a project performs relative to its benchmarks makes it possible to determine whether or not the project has been a success, it does not effectively convey whether the program itself has had a significant contribution to the success or whether the program merely identified which projects were most likely to succeed. In other words, were these projects successful because the tools made available in support of innovation facilitated this success, or were these projects successful because the selection process identified the best projects, with these projects likely to produce a successful outcome independent of the support provided by the program itself?

Jaffe's "regression discontinuity design" (Jaffe 2002) can be a very effective tool in helping to answer that question. The regression discontinuity design is an econometric tool that focuses on evaluating projects at two stages: the selection stage and the assessment stage. The tool requires that projects be ranked in relation to their likelihood of success at the selection stage (a process that needs to take place in any event to enable the selection of projects for funding) and at the assessment stage, to include not only those projects that were selected for funding, but also those projects that were not selected for funding. Essentially, the evaluation team will keep track of projects that were not selected for funding (this can be done by making it a requirement at the application stage) and apply the regression discontinuity design to assess to what extent the provision of funding and innovation support contributed to the increased success of the selected projects.

M&E at the Program Level

Project-level impact evaluation, however, will not address the overall goal of the program in regard to directly stimulating private investment in innovation. Many R&D grants programs, technical assistance programs, and VC programs have suffered from poor utilization of funding because the program was too early in the life cycle of innovation, or because of poor program design in regard to the attractiveness of the financing package, or because of poor implementation in regard to the government delivery vehicle.

An M&E tool, therefore, should aim specifically to monitor the use of funding and the underlying factors driving use. In that regard, the program should take into account an expected time lag associated with changing incentive structures in the economy. Low uptake during the early years of the program should be expected and even encouraged. Above all, pressure to invest in lower-quality projects during this early phase should be avoided because early failures are much more likely to negatively affect market perception of investments in innovation than is slow ramp up.

At the same time, underuse of funding must at some point be evaluated to determine whether to release funding for other uses. In that regard, the program design in relation to the attractiveness of the financing package to the private sector, as well as the implementation vehicle, should be evaluated to determine whether they are creating bottlenecks in the program. Surveys of program firms/clients and nonclients can provide input on whether and how the program is fulfilling its objectives. For example, the selection and disbursement process should also be evaluated in regard to its efficiency, effectiveness, and burden on the applicant. Overutilization of funding can also be evaluated similarly as to whether the incentive structure is so attractive that it leads to crowding out of private investment and whether the selection process is consistent with the objectives.

M&E at the Economy Level

Although the project and program evaluations are important measures, they do not address the more difficult determination of whether the overall program was beneficial for the economy.

Fundamentally, the most important evaluation of the program's overall success is determining whether implementing the program itself is helping to generate greater returns in relation to increasing the productivity and growth prospects of the local economy. Clearly identifying the causal connection between the specific program and the changes in the economy requires a long time span: ex post evaluation will have to take place when a sufficient number of years have elapsed since the beginning of the program.

M&E at the economy level is complex because the evaluation must show not only whether productivity and growth have increased, but also whether the program had an impact on that increase. Because, as argued in chapter 2, publicly funded R&D should be targeted at the generation of spillovers, it is important to focus not only on the commercial or technological successes under the program, but also on whether the program helped to generate increased R&D beyond the sum of its projects and to contribute to innovation at the economy level. The knowledge economy index (KEI) (see description in chapter 4) is likely to provide some of the best indicators of changes in the knowledge economy. These indicators will need to be observed over a period of time to note significant changes. Obviously, it will be difficult to identify to what extent changes at the economy level are due to the program rather than to other variables.

3.6 Conclusions

This chapter has dissected the variety of instruments that have been used in OECD countries to understand the principles underlying effective design, the rationale for the basic types of instrument, and the applicability to ECA countries. On the basis of this analysis, we have recommended three specific instruments for interventions: minigrants, matching grants, and VC leverage. These three instruments potentially address key pressure points along the innovation and commercialization continuum—minigrants for early-stage research, matching grants for precommercialization-stage development, and VC leverage for commercialization and scaling up.

The availability of government assistance along these pressure points may, in some circumstances, constitute such a lever and may feed back into the system by providing incentives to other projects in the pipeline. At other stages of development, or under other macroconditions, there may be different levers to act on. This may be disconcerting, but it is of the essence of the phenomenon that we are trying to influence: extremely dynamic and fluid.

However, setting up one or more programs may not be sufficient to trigger the entrepreneurial response. Consider for example the case of Finland, which has also implemented extensive R&D support programs for more than three decades and is widely regarded as a prominent success in developing a thriving high-tech sector. Yet, a recent report on the Finnish innovation systems complains that there is still a noticeable shortage of innovative entrepreneurship (see Georghiou et al. 2003). Even more striking is the case of Chile, in which a World Bank project focused the support of innovation on the promotion and funding of VC. However, the well-funded VC program did not have a sufficient pipeline to invest in, and the project was not successful in raising R&D and innovation levels in the Chilean economy.

The difference between necessary and sufficient conditions is of the utmost importance here: the establishment of a direct support program for R&D is in many cases a necessary condition for innovation, but it is by no means a sufficient one. It may (also) have significant signaling value, showing serious commitment on the part of the government to promote innovation and R&D over the long run and, hence, making it worthwhile for the entrepreneurs to engage in innovation activities. But it may also fail if the requisite institutional conditions are not in place. The next chapter turns to such a discussion.

Chapter 4. ECA's Institutional Framework for Public Support of Commercial Innovation

In chapter 2 we outlined the rationale for public interventions in creating new knowledge—namely, the public-good character of knowledge—as well as the intrinsic information asymmetries that hinder the funding of innovation. In principle, these arguments do not refer to specific economic circumstances and hence could be applied equally to any country, at any stage of development. Yet, any attempt to draw specific policy recommendations from such arguments should pay close attention to policies and institutions that mediate the impact of innovation and R&D on economic growth.

In this chapter we acknowledge that market failure per se is a necessary but not *sufficient* condition for the success of the support instruments described in chapter 3. Government support aimed at increasing the total amount of resources devoted to R&D, by offering for example R&D subsidies, is predicated on the assumption that there are inventors, entrepreneurs, and companies with valuable innovative projects that are effectively constrained by prohibitively high costs of financing those projects.[14] The assumption is that if the government were only to use policy levers to lower those costs through some subsidies, the entrepreneurs would be forthcoming and the projects undertaken. In developed economies with strong interfaces between science, advanced technology, and commercial R&D; with abundant human capital; and with institutional and legal settings that encourage entrepreneurship, such an assumption is for the most part well grounded. In many transition and developing economies, in which any number of these factors may be lacking, the availability of worthy innovative projects waiting to be supported cannot be taken for granted.

Although it is not a precondition per se that a country already be producing a steady flow of innovations and companies before a government intervenes, there is nonetheless a minimum level—a threshold of macroeconomic stability, infrastructure, human capital, investment climate quality, and trade openness—that represents a prerequisite for starting any intervention in the innovation context. Moreover, the government's capacity to manage such an innovation policy depends on the interaction of these factors in the institutional framework, the so-called national innovation system (NIS). The NIS must be gradually put in place so that at the very least there is the human and institutional potential to generate innovative ideas and the investment climate to allow companies to act on and commercialize those ideas.

In this chapter we use the NIS framework and knowledge assessment methodology (KAM) developed by the World Bank Institute to assess ECA countries' readiness to apply innovation support instruments. This exercise is not meant to provide an absolute standard to dictate to

[14] Of course, these entrepreneurs are not to be associated necessarily with new ventures (start-ups), but could well be (and in most cases will actually be) established firms willing to undertake new R&D projects.

governments whether or not they can implement innovation support instruments. Rather, it is meant to provide a useful guide to governments in deciding on whether to allocate public support for specific innovation interventions, rather than investing in the requisite institutions that support innovation.

This chapter will first describe the NIS framework and our empirical methodology in assessing the "readiness" of ECA countries. It will then provide detail on specific indicators for ECA countries before classifying them in the following categories:

1. Countries that are "ready" for implementing innovation support instruments.
2. Countries without properly functioning innovation systems (e.g., low-quality ICT, no intellectual property rights, low level of human capital).
3. Countries that lack one or more of the elements of an NIS but that should start putting in place the institutions required to implement the instruments identified in chapter 3.

As noted above, this categorization should serve only as a broad guide to governments in thinking about their innovation policies. Furthermore, rather than being a definitive indicator, it should point the direction toward a detailed study of the NIS system and the appropriateness of applying the specific instruments to support innovation. Nonetheless, the categorization provides a clear message to governments that they should "look before they leap" and critically evaluate the returns on investments in innovation instruments given their existing NIS systems. Given EU's Lisbon Agenda and the current vogue for innovation instruments designed for OECD economies (particularly VC funds), this message is especially pertinent for ECA countries at this time.

4.1 The National Innovation System (NIS)

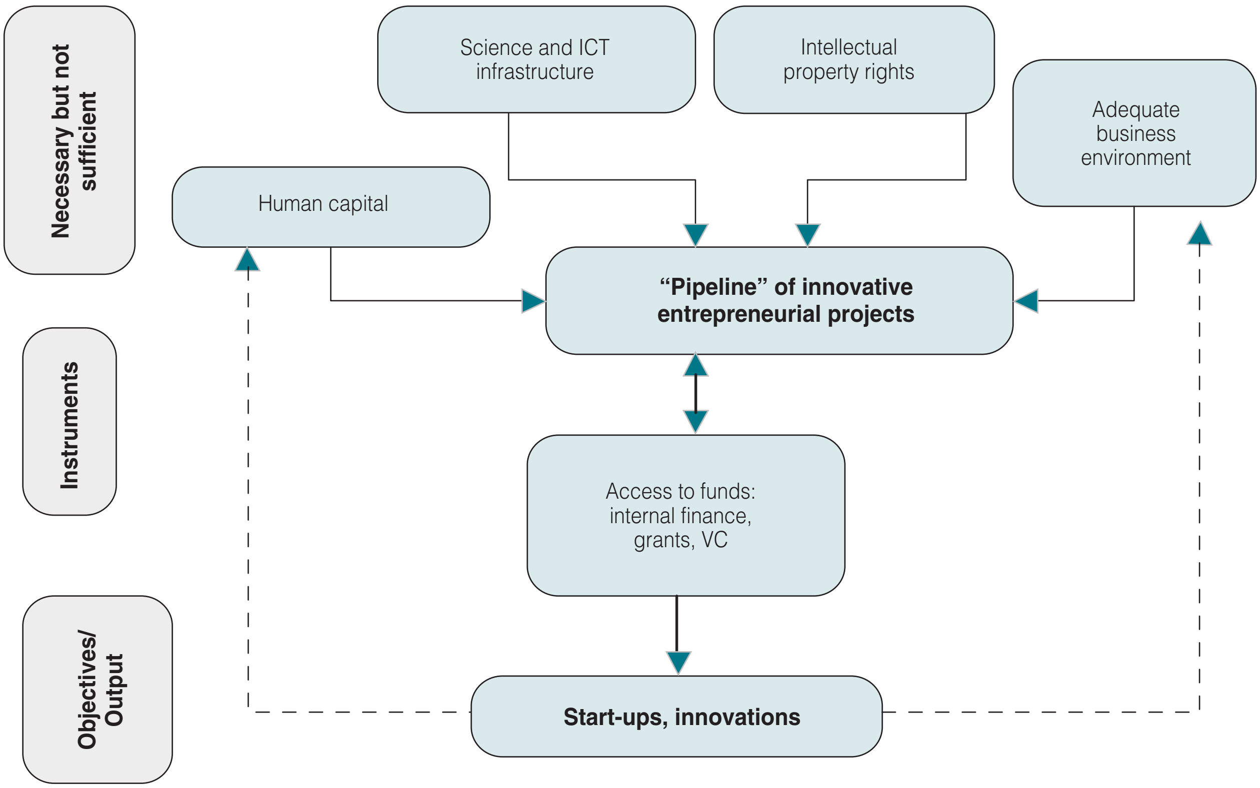
What is the NIS? The realization that individual measures to support R&D are ineffective when poorly coordinated has led to an extensive literature on the concept of a holistic national innovation system (the concept is elaborated in Nelson 1993; OECD 1998 and 2001; Lundvall et al. 2002). The NIS is a system in which those who generate new knowledge are efficiently connected to those who can benefit from its use. This connection is established through a set of instruments, institutional settings, and infrastructure that accelerate knowledge flows and enable innovation. For the system to work efficiently the "links" form effective networks that help overcome market failures caused by coordination and information problems, as discussed in chapter 2.

Specifically, the NIS needs to have the following:

1. *Institutions* such as universities/research institutes that are linked to each other and to a strong private sector, centers of technological innovation, and so forth.
2. *Instruments* such as a public-financing process to elicit the largest possible private sector R&D investment response, fiscal and financial incentives, and so forth.
3. *Incentives* such as a proper intellectual property rights regime and strong competition in product and input markets, as well as the proper linkages among the latter.

Notwithstanding the national scope of the innovation system, a critical element of its success is the ability to take advantage of the stock of knowledge abroad and to absorb and diffuse it locally. This system, including the availability of human capital, science and ICT infrastructure, intellectual property rights (IPR), and a business-friendly environment, is illustrated schematically in figure 6.

Figure 6. National Innovation System



A component of the NIS is the innovation production function, a concept building on Romer's endogenous growth model (1990) (see literature review in chapter 2), which articulates the economic foundations for a sustainable rate of technological progress (A) by introducing an "ideas" sector to the economy. It is assumed that growth follows the national ideas production function:

$$\dot{A}_t = \delta H_{A,t}^{\lambda} A_t^{\phi} \quad (1)$$

According to this structure, the production of new "ideas" is a function of the number of ideas workers (H_A) and the stock of ideas available to these researchers (A_t), making the rate of technological change endogenous in two distinct ways. First, the share of the economy devoted to the ideas sector is a function of the R&D labor market (which determines H_A); allocation of resources to the ideas sector depends on R&D productivity and the private economic return to new ideas. Second, the productivity of new ideas generation is sensitive to the stock of ideas discovered and accumulated from the past.

The literature proposes two approaches to estimating the effects of knowledge and its determinants on growth. One approach is to estimate the effects of the various inputs, including human capital and R&D, directly on growth. Such an approach is followed in Lederman and Maloney (2003) and in Chen and Dahlman (2004). Another approach is to look for a proxy for "ideas" or knowledge: the most prevalent relatively usable and universal measure is the registration of patents in the USPTO and recently in the EU patent office. This approach is followed by Jaffe and Trajtenberg (2002); Furman, Porter, and Stern (2002); and Bosch, Lederman, and Maloney (2005). We will use the second approach to argue that variables that have been found to have a large and significant effect on patents are, to the extent that patents proxy innovation, determinants of innovation and therefore should be used in our analysis of the components of the institutional support for innovation. Clearly, patents are only an imperfect proxy for innovation, given that much innovation takes place without patenting—especially at the lower end of the innovation spectrum. Process innovations normally fall outside the domain of patents and, more important for ECA countries, patenting will normally take place in the countries in which the inventors have commercial interests—local patenting or even EU patents could be more relevant for ECA countries than U.S. patents. In addition, the high costs of applying (and maintaining) a patent may deter many inventors from filing for protection. However, given the extended use of USPTO data in the literature, we will accept the use of patents to proxy for innovation but not without noting the caveats mentioned above.

For example, we look at the evidence from Furman, Porter, and Stern (2002), who estimate an expanded form of equation 1, and find that in addition to the level of inputs used in innovation (R&D resources and human capital), other factors that have an impact include the business environment (proxied by openness to trade and tax breaks), the IPR regime, and the knowledge stock in each country. They also find that the type of industrial organization in the country and its interplay with research institutions (e.g., universities) can also play an important role.

Bosch, Lederman, and Maloney (2005) analyze the elasticity of innovation (proxied by U.S. patents) with respect to inputs (proxied by R&D). They find a very strong relationship in developed countries, but a somewhat weaker one in developing countries. They argue that this difference is due to the different ways in which the national innovation systems function. Some of the variables that they find to have an important bearing on the ability of countries to innovate are education and security of intellectual property rights as well as the quality of the research institutions and the role of the private sector in the system. The implications of their findings are far reaching for countries trying to climb the technology ladder—increasing R&D funds alone will not do the job, the countries will also have to take into account other determinants in their national innovation systems.

Having introduced the concepts of the production function for "ideas" and the role of the NIS and its main components, we now discuss the relationship between the two empirically. We continue using the same framework (the NIS) and try to quantify these concepts to clarify the situation in the ECA countries.

4.2 Key Factors in the Knowledge Economy

As discussed above, recent research allows us to identify which factors affect the innovation capability of a country. That will help us to evaluate whether specific countries should consider innovation interventions and to determine how they should sequence the interventions. It is useful to categorize the key factors that come into play to make it possible for innovative entrepreneurs to emerge in sufficient numbers, and to have a reasonable chance of success. The literature identifies the following key areas, or "pillars," of the knowledge economy[15]:

- Economic incentives and institutional regime
- Education (tertiary in particular)
- Innovation system
- Information infrastructure

[15] According to the Knowledge for Development website of the World Bank, the term Knowledge Economy has been coined to reflect this increased importance of knowledge. A knowledge economy is one where organizations and people acquire, create, disseminate, and use knowledge more effectively for greater economic and social development.

4.2.1 Economic Incentives and Institutional Regime

Typical business environment factors, such as regulatory and taxation burdens on small business, will more generally affect the "deal flow" of businesses capable of absorbing or matching government-supported investments in R&D. The business environment in which potential innovative entrepreneurs operate is crucial for their chance of success in transforming ideas into viable enterprises and commercializing innovations.16 As demonstrated by various investment climate assessments conducted in ECA by the World Bank Doing Business Series, the business environment may present barriers that affect all businesses, but particularly technology-oriented SMEs. The number of procedures and high costs associated with business incorporation, unfavorable tax and labor regulations, the high level of social contributions, and the low efficiency of the bureaucracy and of the judicial infrastructure are major obstacles for innovative entrepreneurs.

The extent to which the economy is open to international trade (with profound implications in regard to the competitive pressures exerted on local markets); the opportunities for expanding in global markets; the access to foreign inputs, capital, technologies, and so forth; as well as the macroeconomic stability of the country will also determine whether businesses are able (and willing) to invest and benefit from existing knowledge.

At a more micro level, the business environment has to do with the structure of specific markets and, in particular, with the extent to which these are competitive. Indeed, the effect of competition on innovation has recently received renewed attention in the context of development: the WDR (World Development Report) 2005 presents the results of an analysis of 27 ECA countries with ICA (Investment Climate Assessment) and BEEPS (Business Environment and Enterprise Performance Survey) II data, which show that the tendency to develop or upgrade new products or use new technologies is higher under stronger competitive pressures. Aghion and Howitt 2005, found that competitive pressures raise innovation in both new and incumbent firms. Entry, exit, and mobility, and not just competition among incumbent firms, are therefore important if risk taking for innovation is to be enhanced to create a business culture that rewards success handsomely but does not stigmatize failure.

It is particularly useful in this context to evaluate the role of SMEs in the process of innovation. The role of SMEs in spearheading innovation may be similar to their role in the initial years of the transition (Mitra and Selowsky 2002). In the early 1990s Polish SMEs, for example, started by taking advantage of remaining price distortions; once they accumulated enough capital they switched to manufacturing taking advantage of pent-up demand and shortages that existed in the postsocialist economies. Yet, there is evidence that these SMEs, although having thus far exhibited significant signs of entrepreneurship, do not know how to start innovating. They realize that the EU accession poses a challenge for their future business and are looking for strategies to restructure once again (Piatkowski 2004).[17]

Goldberg, Radulovic, and Schaffer (2005) find that the effects of ownership on TFP in a sample of 27,000 firms from 50 countries are positive, large, and significant: "The results for new entrants, however, are unambiguous: new private firms in Serbia, like those in the rest of the world, are more productive, more profitable,

[16] The development of SMEs, measured for example by the increase in the number and sales volume (relative to GDP) of active SMEs, is one possible index of the entrepreneurial capacity in a given country, which is a prerequisite for innovation.

[17] For example, Polish farmers have invested a great deal in adjusting to the hygiene requirement of the EU.

and growing more rapidly than state/socially-owned firms." The institutional setting in the country (rule of law, corruption, legal system, etc.) will also have a strong bearing on the ability and willingness of the private sector to invest in R&D and innovation. Special attention in this section should be given to a particular institutional setting: intellectual property rights.

Ideas and inventions are only the first stage: the business environment must encourage entrepreneurial activity in the form of new and existing companies with the resources and skills that allow for a reasonable chance of commercializing the innovation. The degree of protection that intellectual property rights receive allows companies to legitimately own or acquire and profit from specific knowledge, and the degree of protection will specifically affect the likelihood of commercialization of knowledge generated from the knowledge economy.

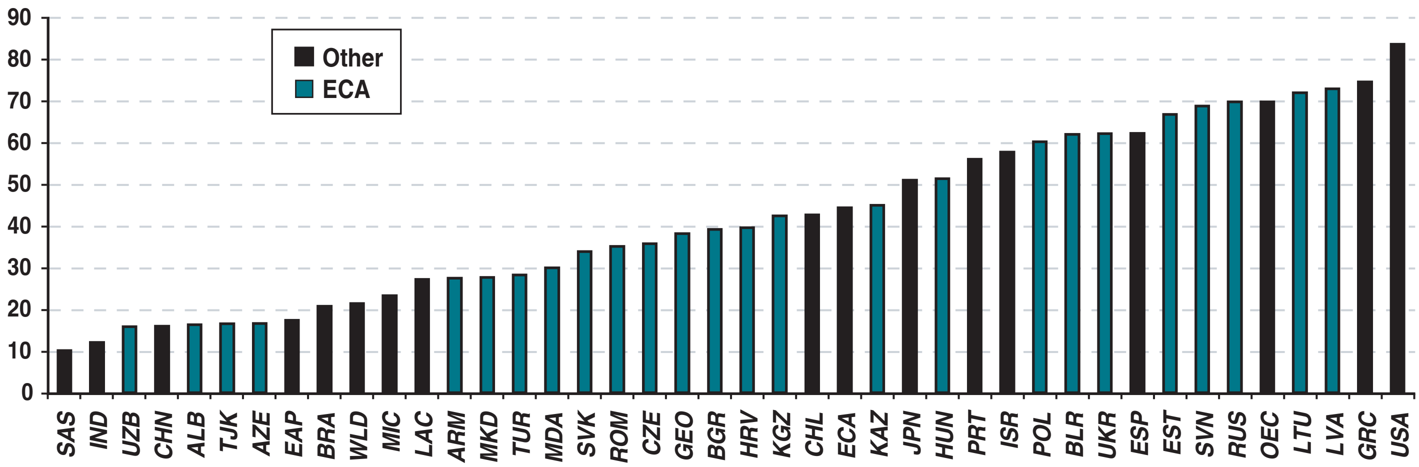
Intellectual property rights (IPR) developed in many countries as a response to the market failure that the public-good character of knowledge represents. By granting, for a predetermined period of time, monopoly rights to the knowledge creators, IPR allow creators to recover the costs of creating the knowledge, and in this way solving the problem of the "partial appropriability" of knowledge. Empirical analysis (Mansfield 1994, 1995; Smarzy_ska 2005) of the relationship of FDI, training, and licensing with IPR has shown their importance in developing the innovation potential of the ECA countries. In broad terms, the conclusion of this line of research was that IPR regimes that fail to provide effective patent protection are a drag on investment in innovative activity. These researchers found that in four technology-intensive industries—pharmaceuticals, chemicals, and the machine and electrical equipment industries—potential investors are very sensitive to IPR regimes.

However, IPR also imply costs (lost rents, costs of enforcing IPR, monopoly prices, etc.) that have to be taken into account when designing an IPR regime. These have to be weighted against the benefits of IPR (and, more important, the costs of an inappropriate IPR regime). Inventors, entrepreneurs, and investors will react to government signals on the IPR issue. They need to be sure that they will be able to capture the benefits of their investment in R&D. In regard to the IPR regime that ECA countries would want to follow, much will be determined by the *acquis communitaire* for the EU-8 and those in accession talks. Other ECA countries will have more leverage. Regardless of their EU accession status, countries will still be able to tailor much of their IPR regime to their needs and a proper understanding of its working—the way it incentivizes knowledge creation by assigning ownership of knowledge is important. Similarly, IPR might be an adequate protection instrument for certain forms of codified knowledge—while they are not for others (trade secrets, process innovations). It is important that countries find ways to promote those other types of knowledge also.

4.2.2 Education

A creative knowledge economy is reflected in the human capital of engineers, scientists, and entrepreneurs that are technically and creatively capable of engaging in knowledge creation and invention. A country rich in human capital will also be more able to absorb and disseminate knowledge and new technologies, enabling it to benefit more from sources of technology diffusion such as FDI or trade. These abundant scientific and technological skills intertwined with entrepreneurial capabilities are clearly the primordial ingredient for innovation to emerge. Education at all levels, of course, is one of the crucial levers for policy action. Basic education is necessary to increase people's capacity to learn, but university, technical, and business training, especially in the engineering and scientific areas, can most directly affect the innovation potential. Historically, ECA countries have benefited from

Figure 7. School enrollment (tertiary education), 2002



Source: World Development Indicators

high levels of investment in education, which enables them to tap into a pool of highly skilled individuals. Figure 7 illustrates that fact by comparing ECA countries with a number of other countries and regional averages in regard to their school enrollment in tertiary education.

Figure 8 shows that when tertiary education is plotted against GDP per capita for a worldwide sample, many ECA countries show a higher level of human capital than would be expected by their GDP per capita. Abbreviation explanations to this and other figures can be found in annex F.

Human capital, or education, has an important part to play in the relationship between innovation and growth. High levels of education as available in ECA are an advantage, but that does not translate automatically to innovation successes and even less so to commercial innovation if adequate incentives structures and institutions are not in place. The historical dissociation between the private sector and universities and research institutions has prevented the private sector from benefiting in full from such high levels of human capital. The education system as well as the surrounding institutions and structures have to be reformed to reverse that trend.

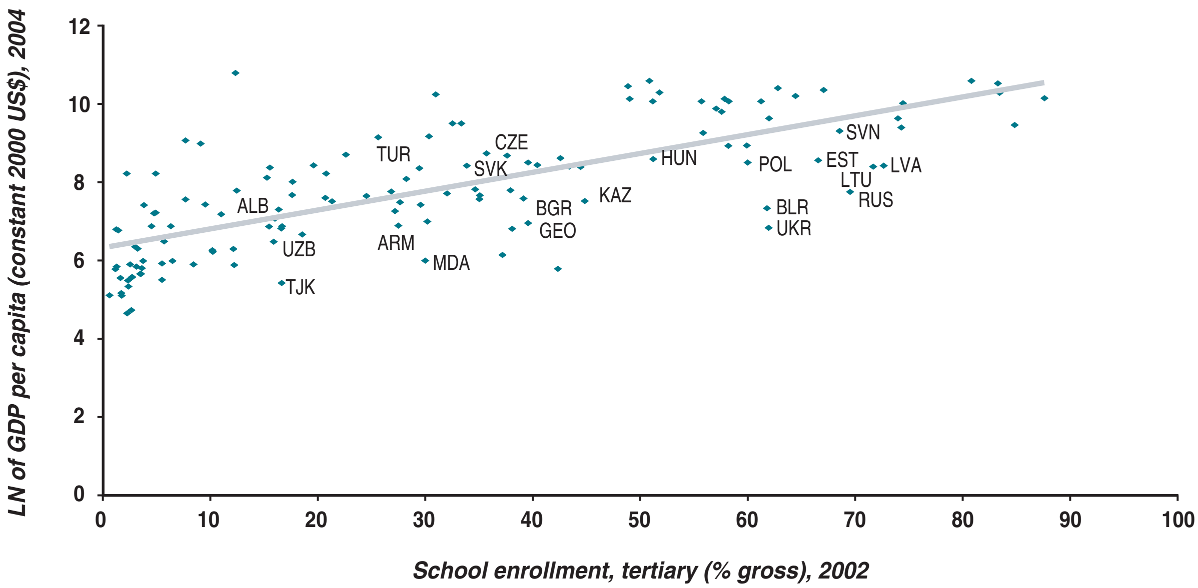
4.2.3 Effective Innovation System

Human capital needs to operate in an institutional setting that supports creative endeavors. Indeed, the institutional setting of research may profoundly affect the supply of "scientific entrepreneurs." Heavily research focused science institutions without links to industry can severely limit the commercial applicability of R&D.

The innovation system refers to the institutional setting (rules, linkages, governance) that determines the way in which countries create and disseminate knowledge (domestically or, more important for developing countries, from abroad). It determines the way in which universities, government, research institutes, and the private sector liaise with each other. In addition to the existence of effective communication channels and coordination mechanisms, the innovation system has to provide the right set of incentives for all players involved.

One of the most prevalent indicators of investment in innovation is the ratio of R&D to GDP. This has long been used as a key measure of inputs into the innovation system by enterprises and governments. Many ECA clients are driven in this respect by the Lisbon Agenda (in particular, the EU-8 and the accession coun-

Figure 8. GDP per capita in relation to schooling



Source: World Development Indicators

tries), which set a target of achieving a 3 percent R&D-to-GDP ratio by 2010. Currently, however, all ECA countries are significantly below that benchmark (see figure 1 in chapter 1) and, as mentioned in chapter 1, the average for the region is significantly lower, at 0.9 percent of GDP. Of the 28 ECA countries, only 6 countries had an R&D-to-GDP ratio of 1 percent or more. That highlights the differing paths that ECA countries underwent during the transition, in which countries that reformed earlier, deeply, and consistently have advanced beyond the others on all fronts, including those pertaining to the knowledge economy.

Another important measure of knowledge inputs available to the economy is the number of researchers per one million people in the population. The ECA region has a long-standing and rich tradition of building up a strong science and technology sector, dating back to Soviet times. A significant investment was made by the state in the former Soviet Union to support research and development across a number of different industries, ranging from aerospace to defense, chemical, and machine building.

As mentioned in chapter 1, researchers remain in relative abundance in the ECA region, with an average of nearly 2,000 R&D researchers per million (see figure 2 in chapter 1). Some common characteristics of the problems encountered in the R&D systems of many countries inherited from the Soviet era are the reliance (almost exclusively) on government support, which has resulted in concentrating on basic rather than applied research, and the lack of cooperation between research institutes and the private sector, calling into question the financial viability of innovations undertaken. In addition, this reliance has also meant that given budgetary constraints suffered in most ECA countries during the past 15 years and the need to prioritize, many R&D innovation systems have seen small and decreasing budget allocations. That has resulted in many institutes losing their best people and facing a lack of resources for investment and R&D.

In light of the above, and bearing in mind that this is a generalization, we could say about innovation systems in ECA countries that the two basic motives of research are hardly served by the system: new knowledge does not diffuse as it should through teaching, and it does not respond to market signals. A vast restructuring of the existing system is necessary to free the human capital that could become innovative entrepreneurs and to make sure that more is generated by the reformed system.

4.2.4 Information Infrastructure

An appropriate scientific and information and communications technology (ICT) infrastructure is a key element of the knowledge economy. Innovating in most sectors, especially in technically advanced sectors, requires an infrastructure comprising testing equipment, fast communications, and scientific consulting that substantially increases productivity. In the economy as a whole, the information infrastructure can be measured by the availability of reliable computers, phones, and other communication media. The World Bank includes in its definition of ICT both the hardware and the software to facilitate communication.

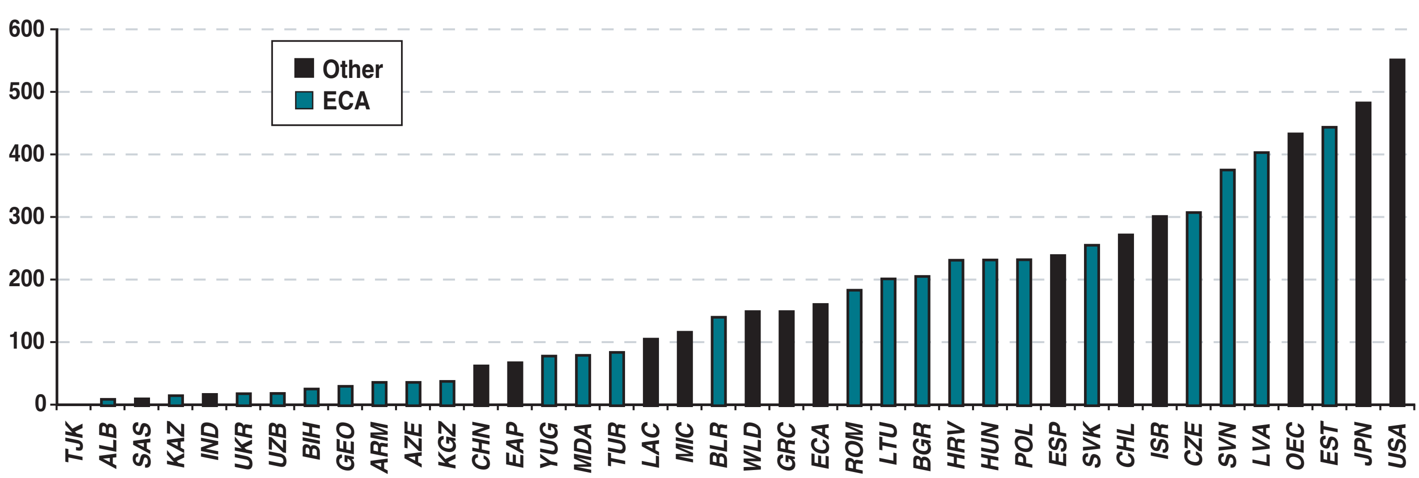
There is an increasing trend to view a country's ICT infrastructure as a key to economic growth and sustainable development. This has been empirically tested, and various studies have found that ICT production and, more important, use has led to economic growth (Pilat and Lee 2001; Van Ark and Piatkowski 2004; Schreyer 2000). In addition, governments are also turning to a heavier use of ICT to improve and expedite the delivery of services (e-government). A proxy for the use of ICT infrastructure in a country could be the Internet penetration rate. Figure 9 shows Internet use in ECA and a few benchmark countries.

Several countries (some of the EU-8 countries) have Internet penetration rates that are higher than in the benchmark countries. This can also be taken as a signal of the readiness and the effort that some of these countries are putting in place to become knowledge economies.

4.3 Knowledge Assessment Methodology (KAM)

We now use the knowledge assessment methodology (KAM) developed by the World Bank Institute's Knowledge for Development (K4D) Program to group countries in ECA according to the KAM indicators and assess which countries in ECA are ready for public support of commercial innovation. There are an increasing

Figure 9. Internet Usage per 1,000 (2003)



Source: World Development Indicators

number of indexes developed for similar purposes that could have been used instead of the KAM indicators. The EU has developed a similar methodology called the European Innovation Scoreboard to assess and compare the innovation performance of its member countries. UNDP, UNIDO, the United Nations Conference on Trade and Development (UNCTAD), and WEF have all constructed indexes that assess the innovation capacity of a country. A brief description of these indexes is included in annex B. For our purposes, the KEI is preferred because our focus is on commercialization and the KEI has more information on economic incentives and the investment climate. In addition, the KEI has data for most countries in ECA, whereas some of the other indexes do not cover all ECA countries. For comparability's sake, we have added five benchmark countries—three of the less-developed EU15 countries (Spain, Portugal, and Greece) and two small open economies that have been successful in climbing the technology ladder (Finland and Israel).

The KEI summarizes the performance of a country in relation to the four pillars of the NIS. It produces a composite index that combines 12 variables (3 for each pillar). The KEI is available for all ECA countries except for Azerbaijan, Macedonia, and Turkmenistan. The countries, variables used, as well as scores in the KEI and pillar indicators are shown in annex A and figure A1.

We also attempt grouping according to a "median country" approach rather than according to average KEI: we find that the KEI of half of the ECA countries is higher than Ukraine's and the KEI of the other half is lower. The median is to a certain extent a more appropriate measure than the average because it is less sensitive to extreme scores than is the average. The median analysis also allows us to visualize the groupings based on the concrete example of the median country (Ukraine). This analysis does not change our rankings: countries with the most (least) developed NIS, have the highest (lowest) KEI scores. Yet, it does allow us to ask interesting questions about the countries in the middle of the distribution (around the threshold). Is Ukraine, as the threshold country, ready for the instruments we are proposing? If so, are the countries just above and below it equally ready? In fact, the World Bank is already engaged in a knowledge economy project in Romania, which is just above Ukraine in the ranking. We present this analysis in annex E.

In computing the average KEI for a country, we weigh the indicators equally. Obviously, that practice is debatable: Is education as important as Internet use as an indication of the innovative capacity of a country or the quality of its NIS? In annex C we look at the impact of the weights. First, we compare the rankings of the ECA countries according to the aggregate KEI with the rankings according to the separate four indicators: incentives, education, innovation, and ICT. Although there are some differences in the rankings, the ranking according to the KEI is not very dissimilar to the ranking according to the four individual pillars. Second, we change the weighting of the individual pillars, attributing a weight of 50 percent to each pillar at a time and the other three sharing the remaining 50 percent equally. Although scores change using different weightings, the rankings of the countries remain fairly consistent, which means that the use of equal weights does not distort the results significantly.[18]

In determining whether to engage in innovation interventions, it will be useful to review the scores in the individual pillar indexes to identify and prioritize interventions targeted at specific *bottlenecks* and to identify particular

[18] A recent exercise by the European Commission on the use of different indicators (Sajeva et al. 2005) to assess the innovation capacity of its member countries (including the new countries) showed that using different weighting methodologies, when the indicators were properly chosen, did not significantly change the ranking and scores that countries achieved.

institutional strengths that might enhance the potential for success. [19] It might well be that a country has a fairly high education level and a fairly well developed information infrastructure but its economic incentives regime is so weak that it presents a severe bottleneck to the commercialization of research. In that case, the country might consider aggressively addressing the bottleneck before engaging in innovation interventions.[20] The KEI indicator tool when combined with a review of bottlenecks and institutional strengths, allows countries around the threshold level to critically evaluate whether they are ready to consider innovation interventions and how best to implement them.[21] For example, a weak economic incentives regime might represent a bottleneck for government intervention even though the other three scores—education, innovation and ICT—are higher and thus the KEI is relatively high. Thus countries with an imperfect economic incentives regime (such as Russia) might need to take a closer look at the elements that form this weak pillar, comparing their performance with that of other countries. Tables D3 through D7 in the annex present the scores for each of the four pillars.

4.4 Results of the Analysis: Categorizing ECA Countries

In Figure 10, we plot the (natural logarithm of) GDP per capita (GDP per capita in 2004 based on actual exchange rates) against the KEI. In this graph we can identify a relationship between innovation and per capita GDP. We can group together countries that have similar KEI scores for a similar development level (GDP per capita). For example, Turkey, with a GDP per capita similar to that of Lithuania or the Slovak Republic, seems to be in a different grouping because of its much lower KEI score.

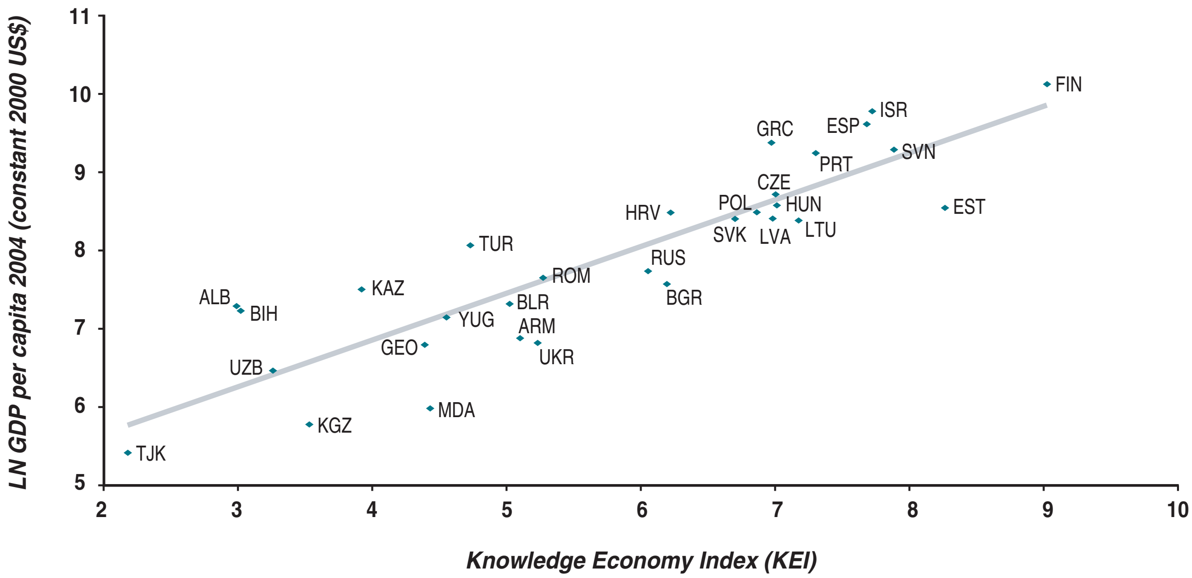
The KEI scores in Figure 10 show that eight ECA countries (Estonia, Slovenia, Czech Republic, Latvia, Lithuania, Hungary, Poland, and the Slovak Republic) have a KEI above, say, 6.5. Assuming a threshold of 6.5 on the KEI score (on a scale of 1 to 10), we hypothesize that countries above this threshold are more likely to have an incipient NIS that is sufficient to start an innovation support program. Interestingly, few of the countries mentioned above do score higher than some of the EU15 benchmark countries, Portugal, Spain, and Greece (see table A1 in the annex). We check whether or not any of the individual pillars represents a bottleneck in this group. Based on Table 1, we find that none of the scores for the four pillars are lower

[19] We have included a table that illustrates the bottlenecks in the KEI and pillar indicators (table D1 in the annex). It provides an empirical support for the discussion here. It should be noted, however, that the bottleneck evaluation needs to be driven by an understanding of the specific context of the country and the types of innovation instruments that the country will be applying. It is therefore inherently a qualitative and policy design–oriented analysis.

[20] This approach is analogous to the “growth diagnostics” that Hausmann, Rodrik, and Velasco (2005) advise as a tool for identifying growth strategies for countries. They argue that “the key step is to develop a better understanding of how the binding constraints on economic activity differ from setting to setting. This understanding can then be used to derive policy priorities in a way that uses efficiently the scarce political capital of reformers.” The key words in this statement are both “binding constraints,” meaning that there might be a policy area that is halting progress as a whole (in our case the bottleneck), and “priorities.” Given scarce resources (and political capital), it might not be feasible to argue for reform in all areas, so that priorities have to be identified.

[21] Table D2 in the annex highlights the weakest pillar indicator for those countries that have KEI scores low enough that they may want to consider addressing necessary reforms in their NIS as they introduce these types of instruments. In addition, we highlight cases that do not necessarily show low KEI or pillar scores but in which the country appears to score significantly worse in comparison with the other ECA countries (e.g., Croatia and Romania in education).

Figure 10. Relationship between GDP per capita and KEI



Source: World Development Indicators

than, say, 5 in any of the pillars. Thus none of these pillars seem to be a binding constraint *in this group of countries*.

Countries with lower KEI scores, (e.g. below 6.5 and above 4) are included in the second grouping: Croatia, Russia, Bulgaria, Serbia, Romania, Belarus, Armenia, Ukraine, Turkey, and Moldova. However, these countries might face problems in one or more of the pillars of the knowledge economy creating a bottleneck for government intervention in support of innovation. For example, Turkey scores low in education and Serbia scores low on the Economic Incentives Regime. Belarus with a score of 1.4 in the economic incentives regime (third from the bottom in the whole group) might consider targeting a reform of its economic incentives regime rather than the design of an innovation finance program because given the severe limitations of its business environment, innovations are likely to fail to commercialize despite Belarus' relatively high level of education. Countries may also want to look at the composition of the individual pillars (tables D3-D7 in the annex).

For example, in the innovation system pillar, Armenia appears to have a problem particularly on total expenditure on R&D and the collaboration between universities and the private sector. This approach of looking at more information under the different pillars of the NIS is a further step in the bottleneck analysis, but it by no means precludes a more in-depth country-by-country analysis.

Lastly, there is a third group of countries with fairly low KEI scores. If we set a threshold of 4, below which countries are assumed to have a NIS that is not conducive to commercial innovation, most CIS (Commonwealth of Independent States) and several Balkan countries would fall in this third group, showing serious shortcomings in one or several of the pillars. Countries with a KEI score below 4 should likely, for the time being, concentrate on reforming other areas of their NIS, and only after significant advances have been made in that sphere should they consider public support programs to foster commercial innovation. That does not preclude countries with a dysfunctional NIS from fos-

Table 1 Comparison of Rankings of Countries according to KEI and the Four NIS Pillars

Country	KEI	Rank KEI	Econ. Inc. Regime	Rank Econ	Innovation	Rank Inn	Education	Rank Edu	Inf. Infrast.	Rank Inf. Inf.
Albania	2.99	29	2.66	23	1.65	28	4.81	28	2.82	27
Armenia	5.10	19	4.90	15	5.72	20	6.00	22	3.77	24
Belarus	5.02	20	1.40	29	5.83	18	7.64	11	5.20	19
Bosnia and Herzegovina	3.02	28	2.62	24	1.02	30	4.00	30	4.45	21
Bulgaria	6.19	15	6.05	12	5.94	17	6.73	17	6.03	15
Croatia	6.22	14	4.31	18	7.12	7	6.55	19	6.91	12
Czech Republic	7.00	9	6.01	13	6.92	10	7.10	15	7.96	5
Estonia	8.26	2	8.77	1	7.29	6	8.14	5	8.83	2
Finland	9.02	1	8.44	2	9.73	1	9.21	1	8.71	3
Georgia	4.39	24	1.75	26	6.07	16	6.43	21	3.30	25
Greece	6.97	11	6.75	7	6.73	11	7.61	12	6.77	13
Hungary	7.01	8	6.42	10	7.00	9	7.65	10	6.98	11
Israel	7.72	4	6.70	8	8.37	2	6.93	16	8.90	1
Kazakhstan	3.92	25	1.47	28	4.07	25	7.11	14	3.05	26
Kyrgyz Rep.	3.53	26	3.09	20	1.79	27	6.53	20	2.70	28
Latvia	6.98	10	6.65	9	6.12	15	8.11	6	7.02	9
Lithuania	7.17	7	6.91	6	6.46	13	8.32	3	7.01	10
Moldova	4.43	23	3.91	19	4.43	24	5.40	26	3.97	23
Poland	6.86	12	6.36	11	6.15	14	8.32	4	6.60	14
Portugal	7.30	6	7.35	3	7.07	8	7.37	13	7.42	8
Romania	5.27	17	4.37	17	5.20	21	5.60	25	5.93	16
Russia	6.05	16	3.01	21	7.47	5	7.85	9	5.88	17
Serbia and Montenegro	4.55	22	2.15	25	5.17	22	5.93	23	4.94	20
Slovak Republic	6.70	13	5.96	14	6.70	12	6.65	18	7.47	7
Slovenia	7.88	3	7.01	5	7.91	3	8.58	2	8.00	4
Spain	7.68	5	7.30	4	7.65	4	8.10	7	7.68	6
Tajikistan	2.18	30	1.71	27	1.22	29	5.36	27	0.43	30
Turkey	4.73	21	4.50	16	4.89	23	4.19	29	5.35	18
Ukraine	5.23	18	2.83	22	5.82	19	7.98	8	4.31	22
Uzbekistan	3.26	27	1.40	30	3.77	26	5.64	24	2.23	29

tering innovation and R&D, also within their private sectors. A whole array of public interventions are suitable—but the particular nature of the instruments we are proposing and the objectives they have make their implementation more difficult and therefore not suitable for certain economic and policy environments. Aubert (2005) provides a rich discussion on the types of innovation systems available in countries at different development levels.

In sum, it should be stressed that countries with low to average KEI scores are most in need of detailed and critical analysis of their NIS before embarking on innovation interventions. Following the bottleneck analysis in this report, a more detailed analysis conducted by the World Bank as a knowledge economy assessment (KEA) can help decide whether to invest public funds in innovation interventions or allocate those funds and efforts, at least initially, toward strengthening the institutional framework of the NIS. That approach can also help countries address some of the bottlenecks as part of program design.

4.5 Conclusion

A country should not decide whether or not to engage in financing a public support program for innovation on the basis of this KEI indicator analysis. A more in-depth analysis of the country and its circumstances is advisable. The analysis above shows the following:

1. ECA countries differ widely in their national innovation capacity, economic incentive regime, and ICT, but less so in education.
2. Sequencing is critical. Some countries might be better advised to invest first in the necessary reforms of other NIS components before—or in some special cases, in parallel with—engaging in a public support program for innovations.
3. On the basis of an analysis of their NIS, countries should invest in solving bottlenecks that hamper innovation (tables D1 and D2 in the annex might serve as a first indication of where the problem areas may lie).

Government funds are scarce and should be used where returns are greatest. If a country lacks the institutional framework described in this chapter and the innovation infrastructure or if it lacks the appropriate set of economic policies, incentives, and institutions, funds used in supporting R&D and innovation might be wasted or will bring lower returns than investments in other areas (such as improving human capital or the economic and business environment).

Chapter 5. Conclusion

This study aims to provide ECA policy makers with policy options to increase and maintain productivity and growth by creating an environment conducive to innovation. The countries in the ECA region, including those that are already members of the European Union or are on its doorstep, will increasingly be competing with countries that have a comparative advantage in innovation, as well as with countries with very low wages that specialize in low value added manufacturing.

Investing in knowledge should not stem only from the threat of competition, but also from the opportunities this investment provides. The tradition of learning and research in socialist economies, although with weak linkages to commercial applications, provides a basis for hope that basic research and commercial innovation could be restructured, revised, and built "on the shoulders" of the past, making a transition to an economy based on knowledge, innovation and technology creation easier than in other countries in which such foundations do not exist.

The current report (part I of the ECA Knowledge Economy Study—ECAKE I) focuses on the rationale, instruments (primarily financial instruments, such as matching grants and VC), and institutional requisites for effective public support for commercial innovation. The follow-up study, ECAKE II, will cover issues dealing with absorption and diffusion of knowledge.

We have to re-emphasize at this late stage that the focus of this study is not to assess ECA countries in relation to their readiness to start innovation support programs or which reforms in their national innovation systems are most urgent. Some discussion on this is presented in chapter 4, but merely for the purpose of identifying key policy areas that also have to be addressed and to stress the heterogeneity in the region that will certainly call for a differentiated approach. NIS diagnosis in ECA countries as well as the design of policy instruments to support innovation will certainly need an in-depth analysis on a country-by-country basis.

As mentioned in chapter 4, the region has a fairly high human capital stock and well-developed research institutions. However, there is an obvious mismatch between the research being undertaken in the region and private sector needs. Spending on applied research that has higher commercial potential is very low when compared with the world's most developed countries. The financial instruments recommended in this study aim at addressing these problems by encouraging private R&D in companies and by incentivizing collaboration by cofunding "consortia" of firms and universities/research institutes to implement innovative projects.

The study provides a theoretical framework for examining the rationale for public participation in funding of private industrial R&D and commercialization of innovative ideas. This is based on the fact that knowledge has a public-good character with positive externalities (social rents being higher than private rents), and therefore the amount of knowledge created by the private sector will be suboptimal (from a social point of view) without public intervention.

Failing the possibility of internalizing excess rents (e.g., via intellectual property rights), government intervention could increase the amount of knowledge created toward a "socially optimal" amount. Issues concerning asymmetric information (inherent in knowledge creation) also mean that funding levels for knowledge creation will be below what would be socially desirable. Clearly, government intervention might be a necessary, but by no means sufficient, condition for innovation. There is the danger that government interventions badly designed or badly implemented could make things even worse than they are.

Given the justification for government intervention, we discussed the most effective and least-distortive instruments for public support for commercial innovation. We analyzed different support mechanisms in OECD countries and their applicability to the ECA region as well as key principles for the design of any support system. After a careful review of the policy instruments used in OECD countries, this study suggests three types of instruments to support innovation: (1) minigrants, (2) matching grants, and (3) VC support.

According to a country's characteristics, certain types of instruments might be better suited than others, and this type of continuum of instruments may not hold. A further instrument, largely discredited but that should still be taken into account, is the provision of business services—partly in the form of incubators. The fact that these instruments are largely discredited may stem from their current design, and a more careful design as well as anchoring them as part of a public support program for innovation would ensure better performance.

In this study we have also stressed that a country's national innovation capacity will depend on a certain number of requisites. This set of requisites (human capital, information infrastructure, the innovation system, as well as the economic incentives regime), further elaborated in the revised literature, forms different pillars that allow a country to articulate its transition into a knowledge economy and use its resources efficiently in the absorption and creation of new knowledge. In the fourth chapter we compared the KEI with a set of different indicators that have been developed to assess a country's innovation capability.

Although we find some differences in the way our sample of countries score with the different indicators, there is consistency in which countries are shown to be at the top of the S&T (Science and Technology) ladder as well as those shown to be at the bottom, with the picture becoming somewhat blurred in the middle section. That is hardly surprising, given that the different indicators emphasize different aspects of the S&T realm. Rather than dwelling on the differences in these indicators, the important aspect of this exercise is to demonstrate the importance of other aspects of the NIS, for example, the importance of an adequate economic incentives regime, hardly recognized in the literature, and the heterogeneity among ECA countries.

This heterogeneity will certainly imply the need for a differentiated approach to this problem. In that light it is important to highlight the concept of bottlenecks in the NIS. Whilst some countries have already developed most elements in their NIS and would therefore certainly benefit from public financial support for commercial innovation, some countries are less ready for these types of intervention and might be better off concentrating their efforts on reforms that improve the institutional requisites for these types of intervention.

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Table A1 KEI Scores

	Country	KEI	Econ. Incentive Regime	Innovation	Education	Information Infrastructure
Group I	Tajikistan	2.18	1.71	1.22	5.36	0.43
	Albania	2.99	2.66	1.65	4.81	2.82
	Bosnia and Herzegovina	3.02	2.62	1.02	4.00	4.45
	Uzbekistan	3.26	1.40	3.77	5.64	2.23
	Kyrgyz Republic	3.53	3.09	1.79	6.53	2.70
	Kazakhstan	3.92	1.47	4.07	7.11	3.05
Group II	Georgia	4.39	1.75	6.07	6.43	3.30
	Moldova	4.43	3.91	4.43	5.40	3.97
	Serbia and Montenegro	4.55	2.15	5.17	5.93	4.94
	Turkey	4.73	4.50	4.89	4.19	5.35
	Belarus	5.02	1.40	5.83	7.64	5.20
	Armenia	5.10	4.90	5.72	6.00	3.77
	Ukraine	5.23	2.83	5.82	7.98	4.31
	Romania	5.27	4.37	5.20	5.60	5.93
	World	5.63	4.80	7.15	4.26	6.33
Group III	Europe and Central Asia	6.02	4.62	6.52	6.67	6.27
	Russia	6.05	3.01	7.47	7.85	5.88
	Bulgaria	6.19	6.05	5.94	6.73	6.03
	Croatia	6.22	4.31	7.12	6.55	6.91
	Slovak Republic	6.70	5.96	6.70	6.65	7.47
	Poland	6.86	6.36	6.15	8.32	6.60
	Greece	6.97	6.75	6.73	7.61	6.77
	Latvia	6.98	6.65	6.12	8.11	7.02
	Czech Republic	7.00	6.01	6.92	7.10	7.96
	Hungary	7.01	6.42	7.00	7.65	6.98
	Lithuania	7.17	6.91	6.46	8.32	7.01
	Portugal	7.30	7.35	7.07	7.37	7.42
	Spain	7.68	7.30	7.65	8.10	7.68
	Israel	7.72	6.70	8.37	6.93	8.90
	Slovenia	7.88	7.01	7.91	8.58	8.00
	Estonia	8.26	8.77	7.29	8.14	8.83
	Western Europe	8.27	7.58	8.77	8.14	8.57
	Finland	9.02	8.44	9.73	9.21	8.71

Variables used in the KEI:

Economic incentive and institutional regime
- Tariff and nontariff barriers
- Regulatory quality
- Rule of law

Education and human resources
- Adult literacy rate (15% and above)
- Secondary enrollment
- Tertiary enrollment

Innovation system
- Researchers in R&D, per million population
- Patent applications granted by the USPTO, per million population
- Scientific and technical journal articles, per million population

Information infrastructure
- Telephones per 1,000 persons (telephone mainlines + mobile phones)
- Computers per 1,000 persons
- Internet users per 1,000 persons

Annex B: Comparison S&T Indicators

In addition to the KAM used in this study, an increasing number of indexes are used to assess a country's readiness for the knowledge economy.

Among the most widely cited indexes that try to assess the innovative capacity of a country we can find the Technology Achievement Index from UNDP, the Competitive Industrial Performance Index from UNIDO, the National Innovative Capacity Index from WEF, and the Innovation Capability Index from UNCTAD. In a recent paper (still in draft form) by Soubbotina (2005), a comparison and assessment of these indexes are attempted. The different indexes put the emphasis on different aspects of the S&T realm—some, such as UNIDO's, put the emphasis on outcome indicators, whereas others, such as UNCTAD's, place more emphasis on inputs into R&D. The rankings are therefore not always the same, and countries such as Singapore with low inputs and high outputs rank relatively high on UNIDO's and lower on UNCTAD's. Table B1 shows a comparison of the scores (although not directly comparable) and rankings produced by these indexes for our sample of countries.

The EU has developed a similar methodology called the European Innovation Scoreboard to assess and compare the innovation performance of its member countries. The EU has constructed a composite index (the Summary Innovation Index [SII]), which includes a number of variables similar to that of the KAM. Importantly, the ranking of countries according to the SII in 2005 produced results very similar to that of the KAM (for the countries included). Table B2 shows the scores of the KAM and the SII for a number of countries and compares the rankings they produce, which are fairly similar.

The comparison across indexes is made more difficult by the fact that some of the indexes do not have any data for more than half of our sample of countries. The economic incentives included in the KEI are reflected in a lower score, in comparison with other indexes, for countries such as Belarus, Georgia, or Ukraine. UNIDO's index emphasizes outcome indicators (or revealed technological capacity), as shown in the high rankings of countries such as Portugal, Hungary, and Turkey, whereas UNCTAD's index—ICI—puts more emphasis on the inputs into innovation (underlying technological capacity) and therefore shows higher rankings for countries with well-functioning education systems. However, that somehow failed to translate the higher education into innovation—especially in Russia but also Ukraine and Belarus.

Table B1 Comparison of KEI with Other S&T Indicators

Country	KEI	Rank. KEI	TAI	Rank. TAI	CIP	Rank CIP	ICI	Rank. ICI	NICI	Rank. NICI
Finland	9.02	1	0.744	1	6	1	0.977	1	35.96	1
Estonia	8.26	2	n.a.	n.a.	n.a.	n.a.	0.775	6	28.42	4
Slovenia	7.88	3	0.458	6	24	5	0.801	4	28.16	6
Israel	7.72	4	0.514	2	22	4	0.804	3	32.64	2
Spain	7.68	5	0.481	3	20	3	0.819	2	29.77	3
Portugal	7.30	6	0.419	9	19	2	0.746	7	26.90	10
Lithuania	7.17	7	n.a.	n.a.	n.a.	n.a.	0.742	8	27.08	8
Hungary	7.01	8	0.464	5	31	7	0.725	11	26.00	13
Czech Rep.	7.00	9	0.465	4	26	6	0.690	15	27.27	7
Latvia	6.98	10	n.a.	n.a.	n.a.	n.a.	0.705	12	28.17	5
Greece	6.97	11	0.437	8	33	8	0.737	9	27.01	9
Poland	6.86	12	0.407	11	36	9	0.732	10	26.87	11
Slovak Rep.	6.70	13	0.447	7	n.a.	n.a.	0.626	17	26.12	12
Croatia	6.22	14	0.391	12	n.a.	n.a.	n.a.	n.a.	25.23	15
Bulgaria	6.19	15	0.411	10	n.a.	n.a.	0.665	16	23.62	17
Russia	6.05	16	n.a.	n.a.	40	11	0.788	5	25.59	14
Romania	5.27	17	0.371	13	47	12	0.554	20	22.97	19
Ukraine	5.23	18	n.a.	n.a.	n.a.	n.a.	0.705	13	24.51	16
Armenia	5.10	19	n.a.	n.a.	n.a.	n.a.	0.526	21	n.a.	n.a.
Belarus	5.02	20	n.a.	n.a.	n.a.	n.a.	0.697	14	n.a.	n.a.
Turkey	4.73	21	n.a.	n.a.	39	10	0.390	25	23.23	18
S & M	4.55	22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Moldova	4.43	23	n.a.	n.a.	n.a.	n.a.	0.413	24	n.a.	n.a.
Georgia	4.39	24	n.a.	n.a.	n.a.	n.a.	0.593	18	n.a.	n.a.
Kazakhstan	3.92	25	n.a.	n.a.	n.a.	n.a.	0.525	22	n.a.	n.a.
Kyrgyz Rep.	3.53	26	n.a.	n.a.	n.a.	n.a.	0.500	23	n.a.	n.a.
Uzbekistan	3.26	27	n.a.	n.a.	n.a.	n.a.	0.564	19	n.a.	n.a.
B & H	3.02	28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Albania	2.99	29	n.a.	n.a.	62	13	n.a.	n.a.	n.a.	n.a.
Tajikistan	2.18	30	n.a.	n.a.	n.a.	n.a.	0.362	26	n.a.	n.a.

Note: TAI = Technology Achievement Index, from UNDP; CIP = Competitive Industrial Performance, from UNIDO; ICI = Innovation Capability Index, from UNCTAD; NICI = National Innovation Capacity Index, from WEF.

Table B2 Comparison between the KAM and SII 2005

Country	SII Score	Ranking	KEI Score	Ranking
Sweden	0.72	1	9.17	1
Switzerland	0.71	2	8.75	5
Finland	0.68	3	9.02	2
Denmark	0.60	4	9.00	3
United States	0.60	5	8.50	9
Germany	0.58	6	8.33	10
Austria	0.51	7	8.08	13
Belgium	0.50	8	8.25	12
United Kingdom	0.48	9	8.72	6
Netherlands	0.48	10	8.62	7
France	0.46	11	7.98	16
Iceland	0.45	12	8.83	4
Luxemburg	0.44	13	8.08	14
Ireland	0.42	14	8.05	15
Norway	0.40	15	8.56	8
Italy	0.36	16	7.48	19
Estonia	0.32	17	8.26	11
Slovenia	0.32	18	7.88	17
Hungary	0.31	19	7.01	22
Spain	0.30	20	7.68	18
Portugal	0.28	21	7.30	20
Cyprus	0.28	22	6.66	28
Lithuania	0.27	23	7.17	21
Czech Republic	0.26	24	7.00	23
Bulgaria	0.24	25	6.19	29
Poland	0.23	26	6.86	26
Greece	0.21	27	6.97	25
Slovak Republic	0.21	28	6.70	27
Latvia	0.20	29	6.98	24
Romania	0.16	30	5.27	30
Turkey	0.06	31	4.73	31

Annex C: Sensitivity Analysis of the KEI

Figures A2 through A5 in annex A illustrate how countries score in the different knowledge economy pillars. Although in general, countries score similarly in all four pillars (or at least they would appear to group equally in the KEI as well as in the four pillar indicators), there are important exceptions. Table C1 illustrates that fact by including the scores and rankings of our sample of countries for all four pillars (along with the KEI).

A quick look at some of the countries shows the differences in the rankings. Belarus is ranked 11th on education, although it is one of the worst ranked in the economic incentives regime. Israel, with a fairly high KEI score, is ranked 2nd in its innovation system and 1st in information infrastructure, but only 16th in education. Russia, for example, which has a medium score in the KEI, has one of the highest scores for the innovation system and a fairly high score in education (similar situation with Ukraine in education). A different weighting (giving education and the innovation system a higher weight than the economic incentives regime) would probably make Russia look very different and ready to engage in a program to finance innovation with public funds. Similarly, a country such as Belarus, with a dismal economic situation, would score very high if more weight were given to education. Countries such as Turkey or Armenia, with fairly low innovation systems and human capital levels, have a much more conducive economic regime, which means that a weighting that gives more emphasis to the country's economic situation might show fairly different results. To illustrate those effects, we undertook a sensitivity analysis changing the weights and giving a stronger weight to one indicator at a time.

In table C2 and figures A6 through A9 in annex A, we present the results of this exercise, in turn attributing a weight of 50 percent to one pillar with the other three pillars sharing the remaining 50 percent equally. We can see that Russia scores fairly high on innovation, and its ranking rises significantly when more weight is given to this indicator; similarly, Belarus's score drops when the economic regime is given more weight. Another interesting case is Ukraine (education and innovation system). Although obviously scores do change, there is sufficient consistency in the rankings and scores of the countries to warrant the use of an equal weighting of the pillar indicators.

Table C1 Comparison of Rankings of Countries according to KEI and the Four NIS Pillars

Country	KEI	Rank KEI	Econ. Incentive Regime	Rank Econ	Inno-vation	Rank Inn	Educa-tion	Rank Educ	Information Infrastructure	Rank Inf
Albania	2.99	29	2.66	23	1.65	28	4.81	28	2.82	27
Armenia	5.10	19	4.90	15	5.72	20	6.00	22	3.77	24
Belarus	5.02	20	1.40	29	5.83	18	7.64	11	5.20	19
B & H	3.02	28	2.62	24	1.02	30	4.00	30	4.45	21
Bulgaria	6.19	15	6.05	12	5.94	17	6.73	17	6.03	15
Croatia	6.22	14	4.31	18	7.12	7	6.55	19	6.91	12
Czech Rep.	7.00	9	6.01	13	6.92	10	7.10	15	7.96	5
Estonia	8.26	2	8.77	1	7.29	6	8.14	5	8.83	2
Finland	9.02	1	8.44	2	9.73	1	9.21	1	8.71	3
Georgia	4.39	24	1.75	26	6.07	16	6.43	21	3.30	25
Greece	6.97	11	6.75	7	6.73	11	7.61	12	6.77	13
Hungary	7.01	8	6.42	10	7.00	9	7.65	10	6.98	11
Israel	7.72	4	6.70	8	8.37	2	6.93	16	8.90	1
Kazakhstan	3.92	25	1.47	28	4.07	25	7.11	14	3.05	26
Kyrgyz Rep.	3.53	26	3.09	20	1.79	27	6.53	20	2.70	28
Latvia	6.98	10	6.65	9	6.12	15	8.11	6	7.02	9
Lithuania	7.17	7	6.91	6	6.46	13	8.32	3	7.01	10
Moldova	4.43	23	3.91	19	4.43	24	5.40	26	3.97	23
Poland	6.86	12	6.36	11	6.15	14	8.32	4	6.60	14
Portugal	7.30	6	7.35	3	7.07	8	7.37	13	7.42	8
Romania	5.27	17	4.37	17	5.20	21	5.60	25	5.93	16
Russia	6.05	16	3.01	21	7.47	5	7.85	9	5.88	17
S & M	4.55	22	2.15	25	5.17	22	5.93	23	4.94	20
Slovak Rep.	6.70	13	5.96	14	6.70	12	6.65	18	7.47	7
Slovenia	7.88	3	7.01	5	7.91	3	8.58	2	8.00	4
Spain	7.68	5	7.30	4	7.65	4	8.10	7	7.68	6
Tajikistan	2.18	30	1.71	27	1.22	29	5.36	27	0.43	30
Turkey	4.73	21	4.50	16	4.89	23	4.19	29	5.35	18
Ukraine	5.23	18	2.83	22	5.82	19	7.98	8	4.31	22
Uzbekistan	3.26	27	1.40	30	3.77	26	5.64	24	2.23	29

Table C2 Comparison of KEI Scores with Different Weightings

Country	KEI	KEI Econ	KEI Inn	KEI Educ	KEI Inf
Albania	2.99	2.88	2.54	3.59	2.93
Armenia	5.10	5.03	5.31	5.40	4.66
Belarus	5.02	3.81	5.29	5.89	5.08
Bosnia and Herzegovina	3.02	2.89	2.36	3.35	3.50
Bulgaria	6.19	6.14	6.11	6.37	6.14
Croatia	6.22	5.59	6.52	6.33	6.45
Czech Republic	7.00	6.67	6.97	7.03	7.32
Estonia	8.26	8.43	7.94	8.22	8.45
Finland	9.02	8.83	9.26	9.09	8.92
Georgia	4.39	3.51	4.95	5.07	4.03
Greece	6.97	6.89	6.89	7.18	6.90
Hungary	7.01	6.82	7.01	7.23	7.00
Israel	7.72	7.38	7.94	7.46	8.12
Kazakhstan	3.92	3.11	3.97	4.99	3.63
Kyrgyz Rep.	3.53	3.38	2.95	4.53	3.25
Latvia	6.98	6.87	6.69	7.35	6.99
Lithuania	7.17	7.09	6.94	7.56	7.12
Moldova	4.43	4.26	4.43	4.75	4.28
Poland	6.86	6.69	6.62	7.35	6.77
Portugal	7.30	7.32	7.23	7.33	7.34
Romania	5.27	4.97	5.25	5.38	5.49
Russia	6.05	5.04	6.53	6.65	6.00
Serbia and Montenegro	4.55	3.75	4.76	5.01	4.68
Slovak Republic	6.70	6.45	6.67	6.68	6.95
Slovenia	7.88	7.59	7.89	8.11	7.92
Spain	7.68	7.56	7.67	7.82	7.68
Tajikistan	2.18	2.02	1.86	3.24	1.60
Turkey	4.73	4.66	4.79	4.55	4.94
Ukraine	5.23	4.43	5.43	6.15	4.93
Uzbekistan	3.26	2.64	3.43	4.05	2.92

Note:
KEI = equal weighting of all pillars, KEI = 0.25*Econ + 0.25*Educ + 0.25*Inn + 0.25*Inf,
KEI Econ = 0.5*Econ + 1/6*Educ + 1/6*Inn + 1/6*Inf,
KEI Educ = 0.5*Educ + 1/6*Econ + 1/6*Inn + 1/6*Inf,
KEI Inn = 0.5*Inn + 1/6*Econ + 1/6*Educ + 1/6*Inf,
KEI Inf = 0.5*Inf + 1/6*Econ + 1/6*Educ + 1/6*Inn

Annex D: Analysis of Bottlenecks

Table D1 Bottlenecks in the NIS according to Pillar Indicators

Country	KEI	Econ. Incentive Regime	Innovation	Education	Information Infrastructure
Tajikistan	2.18	1.71	1.22	5.36	0.43
Albania	2.99	2.66	1.65	4.81	2.82
Bosnia and Herzegovina	3.02	2.62	1.02	4.00	4.45
Uzbekistan	3.26	1.40	3.77	5.64	2.23
Kyrgyz Rep.	3.53	3.09	1.79	6.53	2.70
Kazakhstan	3.92	1.47	4.07	7.11	3.05
Georgia	4.39	1.75	6.07	6.43	3.30
Moldova	4.43	3.91	4.43	5.40	3.97
Serbia and Montenegro	4.55	2.15	5.17	5.93	4.94
Turkey	4.73	4.50	4.89	4.19	5.35
Belarus	5.02	1.40	5.83	7.64	5.20
Armenia	5.10	4.90	5.72	6.00	3.77
Ukraine	5.23	2.83	5.82	7.98	4.31
Romania	5.27	4.37	5.20	5.60	5.93
Russia	6.05	3.01	7.47	7.85	5.88
Bulgaria	6.19	6.05	5.94	6.73	6.03
Croatia	6.22	4.31	7.12	6.55	6.91
Slovak Republic	6.70	5.96	6.70	6.65	7.47
Poland	6.86	6.36	6.15	8.32	6.60
Greece	6.97	6.75	6.73	7.61	6.77
Latvia	6.98	6.65	6.12	8.11	7.02
Czech Republic	7.00	6.01	6.92	7.10	7.96
Hungary	7.01	6.42	7.00	7.65	6.98
Lithuania	7.17	6.91	6.46	8.32	7.01
Portugal	7.30	7.35	7.07	7.37	7.42
Spain	7.68	7.30	7.65	8.10	7.68
Israel	7.72	6.70	8.37	6.93	8.90
Slovenia	7.88	7.01	7.91	8.58	8.00
Estonia	8.26	8.77	7.29	8.14	8.83
Finland	9.02	8.44	9.73	9.21	8.71

Note: In this table bottlenecks are defined as individual pillar scores below 2.5 (or ¼ of the maximum score of 10). Alternative approaches using the deviation from the ECA mean in the individual pillars as a measure of these bottlenecks offer very similar results.

Table D2 Main Problem Areas in Relation to the KEI

Country	KEI	ECON	ECONj-ECONav	DevECON	INN	INNj-INNav	DevINN	EDU	EDUj-EDUav	DevEDU	INF	INFj-INFav	DevINF
TJK	2.18	1.71	–2.54	–116%	1.22	–4.05	–186%	5.36	–1.30	–60%	0.43	–4.82	–221%
ALB	2.99	2.66	–1.59	–53%	1.65	–3.62	–121%	4.81	–1.85	–62%	2.82	–2.43	–81%
BIH	3.02	2.62	–1.63	–54%	1.02	–4.25	–141%	4.00	–2.66	–88%	4.45	–0.80	–26%
UZB	3.26	1.40	–2.85	–87%	3.77	–1.50	–46%	5.64	–1.02	–31%	2.23	–3.02	–93%
KGZ	3.53	3.09	–1.16	–33%	1.79	–3.48	–99%	6.53	–0.13	–4%	2.70	–2.55	–72%
KAZ	3.92	1.47	–2.78	–71%	4.07	–1.20	–31%	7.11	0.45	11%	3.05	–2.20	–56%
GEO	4.39	1.75	–2.50	–57%	6.07	0.80	18%	6.43	–0.23	–5%	3.30	–1.95	–44%
MDA	4.43	3.91	–0.34	–8%	4.43	–0.84	–19%	5.40	–1.26	–29%	3.97	–1.28	–29%
YUG	4.55	2.15	-2.10	-46%	5.17	-0.10	–2%	5.93	–0.73	–16%	4.94	–0.31	–7%
TUR	4.73	4.50	0.25	5%	4.89	–0.38	–8%	4.19	–2.47	–52%	5.35	0.10	2%
BLR	5.02	1.40	–2.85	–57%	5.83	0.56	11%	7.64	0.98	19%	5.20	–0.05	–1%
ARM	5.10	4.90	0.65	13%	5.72	0.45	9%	6.00	–0.66	–13%	3.77	–1.48	–29%
UKR	5.23	2.83	–1.42	–27%	5.82	0.55	11%	7.98	1.32	25%	4.31	–0.94	–18%
ROM	5.27	4.37	0.12	2%	5.20	–0.07	–1%	5.60	–1.06	–20%	5.93	0.68	13%
RUS	6.05	3.01	–1.24	–20%	7.47	2.20	36%	7.85	1.19	20%	5.88	0.63	10%
BGR	6.19	6.05	1.80	29%	5.94	0.67	11%	6.73	0.07	1%	6.03	0.78	13%
HRV	6.22	4.31	0.06	1%	7.12	1.85	30%	6.55	–0.11	–2%	6.91	1.66	27%
SVK	6.70	5.96	1.71	26%	6.70	1.43	21%	6.65	–0.01	0%	7.47	2.22	33%
POL	6.86	6.36	2.11	31%	6.15	0.88	13%	8.32	1.66	24%	6.60	1.35	20%
LVA	6.98	6.65	2.40	34%	6.12	0.85	12%	8.11	1.45	21%	7.02	1.77	25%
CZE	7.00	6.01	1.76	25%	6.92	1.65	24%	7.10	0.44	6%	7.96	2.71	39%
HUN	7.01	6.42	2.17	31%	7.00	1.73	25%	7.65	0.99	14%	6.98	1.73	25%
LTU	7.17	6.91	2.66	37%	6.46	1.19	17%	8.32	1.66	23%	7.01	1.76	25%
SVN	7.88	7.01	2.76	35%	7.91	2.64	34%	8.58	1.92	24%	8.00	2.75	35%
EST	8.26	8.77	4.52	55%	7.29	2.02	24%	8.14	1.48	18%	8.83	3.58	43%

Note: ECONj = score of the economic incentives pillar for country j; ECONAv = ECA average for the economic incentives pillar; DevECON = measure of the deviation in the pillar score relative to the KEI score (Econ-EconAv)/KEI

Table D3 Bottleneck Analysis—Economic Incentives Regime Indicators

	TNTB	IPR	BANK	INTR	COMP	CR/GDP	REGQ	RULELAW	GOVEFF	CORR
Albania	1.59	0.45	3.00	5.38	1.00	1.04	4.38	2.03	3.67	2.66
Armenia	6.03	0.55	2.09	1.15	0.18	0.48	5.00	3.67	3.83	3.44
Belarus	3.57	n/a	n/a	7.40	n/a	1.76	0.16	0.47	1.09	1.17
B & H	3.57	0.36	2.82	4.04	2.18	6.00	1.95	2.34	2.89	3.36
Bulgaria	6.03	1.91	3.91	4.33	1.55	5.52	6.56	5.55	4.92	5.47
Croatia	1.59	4.00	5.36	2.60	3.82	6.80	5.70	5.62	5.86	5.70
Czech Rep.	3.57	5.45	3.27	6.35	6.55	4.88	7.50	6.95	6.64	6.33
Estonia	9.52	6.82	7.64	8.37	8.18	5.84	8.98	7.81	7.66	7.81
Finland	6.03	9.09	8.36	8.56	8.45	7.12	9.61	9.69	9.53	9.92
Georgia	1.59	0.82	3.27	0.48	2.18	1.04	2.03	1.64	1.80	1.17
Greece	6.03	6.36	6.09	7.21	5.73	7.28	7.03	7.19	6.95	6.95
Hungary	3.57	6.36	5.55	7.98	7.64	6.16	8.12	7.58	6.80	7.11
Israel	6.03	8.09	6.82	7.88	9.18	8.08	6.80	7.27	7.58	7.58
Kazakhstan	1.59	4.00	3.91	n/a	3.18	4.00	1.48	1.33	2.58	0.55
Kyrgyz Rep.	3.57	0.82	0.18	0.77	2.18	0.4	4.61	1.09	1.56	1.09
Latvia	6.03	4.55	5.55	7.4	3.82	5.92	7.66	6.25	6.48	6.09
Lithuania	6.03	3.36	6.09	6.73	6.55	3.68	8.05	6.64	6.88	6.56
Moldova	6.03	1.91	4.27	4.33	0.09	3.04	2.81	2.89	1.95	1.72
Poland	6.03	5.36	3.27	7.98	5.73	3.76	6.64	6.41	6.02	5.86
Portugal	6.03	7.73	7.64	n/a	6.00	9.36	7.89	8.12	7.42	8.12
Romania	3.57	3.09	3.27	n/a	2.64	1.20	4.61	4.92	4.77	4.77
Russia	3.57	0.82	1.00	3.37	3.45	3.52	2.73	2.73	4.38	2.66
S & M	n/a	0.55	1.00	n/a	2.64	n/a	1.80	2.50	4.38	3.98
Slovak Rep.	3.57	6.00	7.27	5.96	5.27	4.56	7.97	6.33	6.72	6.64
Slovenia	6.03	7.18	4.91	6.25	5.27	6.08	7.11	7.89	7.81	7.97
Spain	6.03	7.18	7.82	9.71	7.64	8.96	7.81	8.05	8.36	8.44
Tajikistan	3.57	2.36	0.45	2.21	0.82	2.48	0.86	0.70	0.55	0.39
Turkey	3.57	3.36	0.27	n/a	6.55	2.32	4.45	5.47	5.31	4.92
Ukraine	3.57	1.91	1.36	2.79	3.45	3.6	3.12	1.80	2.34	1.41
Uzbekistan	3.57	n/a	n/a	n/a	n/a	n/a	0.08	0.55	0.70	0.16

Note: See table D7 for explanation of variables.

Table D4 Bottleneck Analysis—Innovation System

	FDI/ GDP	ROY	ROY/ POP	RESR&D	RESR&D /POP	R&D/ GDP	UNIPS	JOUR/ POP	PAT/ PAT	POP
Albania	3.85	3.20	4.37	n/a	n/a	n/a	0.09	3.31	0.00	0.00
Armenia	5.9	n/a	n/a	3.37	5.93	2.17	2.18	6.14	2.39	5.08
Belarus	1.88	2.82	2.62	6.28	6.51	4.70	n/a	6.38	3.63	4.61
B & H	4.79	n/a	n/a	n/a	n/a	n/a	2.91	2.05	0.00	0.00
Bulgaria	6.41	4.47	4.66	4.65	4.88	3.86	2.18	7.09	4.60	5.86
Croatia	6.84	5.92	7.18	4.07	6.63	6.51	4.36	7.40	5.31	7.34
Czech Rep.	7.86	6.21	6.8	5.93	5.23	7.23	7.55	7.87	6.90	7.66
Estonia	8.55	4.08	6.41	2.79	6.98	5.54	6.82	7.80	3.63	7.11
Finland	9.32	7.77	9.03	7.67	9.88	9.64	9.82	9.69	8.67	9.61
Georgia	7.18	3.40	3.98	5.47	7.09	2.89	1.18	4.72	4.60	6.41
Greece	1.62	6.89	7.38	5.70	5.12	4.82	4.91	8.03	5.66	7.03
Hungary	8.38	7.48	7.67	5.81	5.47	6.02	6.55	7.72	7.08	7.81
Israel	4.87	7.28	8.25	4.42	5.81	9.88	8.82	9.76	8.76	9.53
Kazakhstan	8.46	4.27	3.5	4.53	4.07	1.93	4.91	3.78	3.63	4.38
Kyrgyz Rep.	5.56	2.43	2.91	2.67	3.49	1.81	0.36	1.89	0.00	0.00
Latvia	7.44	3.69	5.34	2.91	5.58	3.73	4.36	6.61	3.63	6.17
Lithuania	5.38	4.17	5.63	3.84	6.28	5.18	5.55	6.85	4.16	6.25
Moldova	6.58	2.23	3.01	1.63	2.09	4.46	1.64	4.57	4.60	6.64
Poland	5.04	7.96	6.89	8.02	5.35	4.10	6.00	7.32	6.11	5.78
Portugal	8.97	6.70	7.09	6.51	6.40	5.90	7.09	7.56	5.93	7.27
Romania	3.16	5.53	5.15	6.74	4.53	3.13	1.64	5.67	5.31	5.39
Russia	2.39	7.86	5.53	9.53	8.37	7.11	6.00	7.17	7.61	6.88
S & M	n/a	n/a	n/a	5.35	5.00	n/a	4.91	6.22	2.39	4.30
Slovak Rep.	7.01	5.73	6.7	4.77	6.05	4.1	7.09	7.48	5.13	6.56
Slovenia	3.33	5.63	7.77	3.26	7.33	7.35	7.09	8.43	6.73	7.97
Spain	7.95	8.93	7.96	8.72	6.86	6.14	6.55	8.19	7.96	7.89
Tajikistan	2.91	1.17	1.36	n/a	n/a	n/a	2.18	2.44	n/a	0.00
Turkey	1.03	6.12	4.08	6.86	3.14	4.94	5.55	6.54	6.11	5.00
Ukraine	2.14	6.80	6.02	8.49	6.16	6.75	5.55	5.83	6.28	5.47
Uzbekistan	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3.86	2.39	3.67

Note: See table D7 for explanation of variables.

Table D5 Bottleneck Analysis—Education

	LIT	YEASCH	SECENR	TERENR	EDUCEXP/ GDP	8MATHS	QMATHED
Albania	7.09	n/a	4.30	3.04	n/a	n/a	4.55
Armenia	7.40	n/a	5.47	5.12	2.35	4.58	6.64
Belarus	7.87	n/a	6.41	8.64	8.17	n/a	n/a
B & H	5.20	n/a	3.36	3.44	n/a	n/a	5.27
Bulgaria	7.01	8.04	6.88	6.32	3.13	4.17	8.18
Croatia	6.77	4.46	6.25	6.64	5.13	n/a	6.64
Czech Rep.	8.19	8.26	7.34	5.76	4.52	7.29	9.45
Estonia	8.03	n/a	7.42	8.96	7.22	7.92	8.18
Finland	8.19	8.8	9.53	9.92	8.52	7.29	9.64
Georgia	8.19	n/a	4.69	6.40	0.61	n/a	4.55
Greece	6.38	6.63	7.27	9.20	3.83	n/a	6.82
Hungary	7.32	7.17	8.52	7.12	6.52	7.71	8.73
Israel	5.59	8.48	6.95	8.24	9.30	5.21	7.45
Kazakhstan	7.48	n/a	6.48	7.36	2.00	n/a	4.55
Kyrgyz Rep.	6.14	n/a	6.56	6.88	2.09	n/a	3.27
Latvia	8.03	n/a	7.03	9.28	7.22	6.46	5.73
Lithuania	7.72	n/a	8.20	9.04	7.91	5.83	8.18
Moldova	7.17	n/a	3.83	5.20	6.09	3.33	5.73
Poland	8.19	8.7	8.28	8.48	7.48	n/a	7.73
Portugal	5.12	3.7	9.22	7.76	7.91	n/a	2.64
Romania	6.30	8.37	5.23	5.28	2.70	3.96	9.09
Russia	7.56	8.91	6.64	9.36	2.09	6.46	7.73
S & M	n/a	n/a	5.86	6.00	2.70	4.38	7.45
Slovak Rep.	8.19	7.39	6.17	5.6	3.91	6.46	8.18
Slovenia	7.72	5.54	8.91	9.12	n/a	9.58	6.27
Spain	6.61	5.87	9.30	8.40	5.04	n/a	4.09
Tajikistan	7.24	n/a	5.31	3.52	1.39	n/a	0.73
Turkey	3.78	2.83	4.06	4.72	3.57	2.71	5.27
Ukraine	7.64	n/a	7.58	8.72	7.13	n/a	6.82
Uzbekistan	6.46	n/a	7.11	3.36	n/a	n/a	n/a

Note: See table D7 for explanation of variables.

Table D6 Bottleneck Analysis—Information Infrastructure

	TEL/POP	COMP/POP	INTER/POP	COMCOST	ICTEXP/GDP
Albania	4.77	1.58	2.11	3.42	n/a
Armenia	3.28	4.67	3.36	n/a	n/a
Belarus	4.45	n/a	5.94	4.21	n/a
Bosnia and Herzegovina	5.31	n/a	3.59	2.63	n/a
Bulgaria	6.64	4.42	7.03	6.97	2.03
Croatia	6.80	6.75	7.19	n/a	n/a
Czech Republic	8.52	7.25	8.12	7.76	n/a
Estonia	7.97	9.92	8.59	8.42	n/a
Finland	8.75	8.17	9.22	7.5	6.38
Georgia	3.59	3.50	2.81	8.55	n/a
Greece	9.06	5.17	6.09	8.82	2.61
Hungary	7.73	6.42	6.80	8.03	5.65
Israel	9.14	9.50	8.05	n/a	8.55
Kazakhstan	3.83	n/a	2.27	n/a	n/a
Kyrgyz Republic	2.34	2.33	3.44	0.00	n/a
Latvia	6.56	7.08	7.42	5.00	n/a
Lithuania	7.58	6.5	6.95	3.95	n/a
Moldova	4.06	2.83	5.00	4.34	n/a
Poland	6.48	6.83	6.48	5.92	2.75
Portugal	8.83	6.33	7.11	7.63	2.46
Romania	5.94	5.67	6.17	5.66	0.72
Russia	6.33	6.08	5.23	n/a	1.45
Serbia and Montenegro	6.09	3.42	5.31	4.87	n/a
Slovak Republic	6.95	7.5	7.97	8.03	3.77
Slovenia	7.81	7.92	8.28	9.08	n/a
Spain	8.36	7.33	7.34	n/a	1.88
Tajikistan	0.86	n/a	0.00	0.39	n/a
Turkey	6.17	4.08	5.78	4.74	7.54
Ukraine	5.55	3.00	4.38	n/a	7.1
Uzbekistan	1.80	n/a	2.66	n/a	n/a

Note: See table D7 for explanation of variables.

Table D7 Explanation of Variables

TNTB	Tariff and nontariff barriers
IPR	Intellectual property is well protected
BANK	Soundness of banks
INTR	Interest rate spread (lending rate minus deposit rate)
COMP	Local competition
CR/GDP	Domestic credit to private sector (% of GDP)
REGQ	Regulatory quality
RULELAW	Rule of law
GOVEFF	Government effectiveness
CORR	Control of corruption
FDI/GDP	Gross foreign direct investment as percent of GDP
ROY	Royalty and license fees payments ($ mil)
ROY/POP	Royalty and license fees payments/mil. pop.
RESR&D	Researchers in R&D
RESR&D/POP	Researchers in R&D/million
R&D/GDP	Total expenditure for R&D as percent of GDP
UNIPS	University–company research collaboration
JOUR/POP	Scientific and technical journal articles/mil pop.
PAT	Patent applications granted by the USPTO
PAT/POP	Patent applications granted by the USPTO/mil pop.
LIT	Adult literacy rate (15 percent and above)
YESCH	Average years of schooling
SECENR	Secondary enrollment
TERENR	Tertiary enrollment
EDUCEXP/GDP	Public spending on education as percent of GDP
8MATHS	8th grade achievement in mathematics
QMATHED	Quality of science and math education
TEL/POP	Telephones per 1,000 people
COMP/POP	Computers per 1,000 people
INTER/POP	Internet users per 10,000 people
COMCOST	International telecommunications, cost of call
ICTEXP/GDP	ICT expenditure as percent of GDP

Annex E: Analysis of Grouping Using the Median

Table E1 Comparison of ECA Average and ECA Median

Country	KEI	KEI—Median	KEI—ECA Average
Tajikistan	2.18	–3.05	–3.18
Albania	2.99	–2.24	–2.37
Bosnia and Herzegovina	3.02	–2.21	–2.34
Uzbekistan	3.26	–1.97	–2.10
Kyrgyz Rep.	3.53	–1.7	–1.83
Kazakhstan	3.92	–1.31	–1.44
Georgia	4.39	–0.84	–0.97
Moldova	4.43	–0.8	–0.93
Serbia and Montenegro	4.55	–0.68	–0.81
Turkey	4.73	–0.5	–0.63
Belarus	5.02	–0.21	–0.34
Armenia	5.10	–0.13	–0.26
Ukraine	5.23	0.00	–0.13
Romania	5.27	0.04	–0.09
Russia	6.05	0.82	0.69
Bulgaria	6.19	0.96	0.83
Croatia	6.22	0.99	0.86
Slovak Republic	6.70	1.47	1.34
Poland	6.86	1.63	1.50
Latvia	6.98	1.75	1.62
Czech Republic	7.00	1.77	1.64
Hungary	7.01	1.78	1.65
Lithuania	7.17	1.94	1.81
Slovenia	7.88	2.65	2.52
Estonia	8.26	3.03	2.90
ECA Median	5.23		
ECA Average	5.36		
Standard Deviation KEI-Median	0.89		

KEI Score below 1 standard deviation from median, NIS very undeveloped

KEI Score within 1 standard deviation from median, NIS in need of some reform

KEI Score above 1 standard deviation from median, NIS fairly developed

The median is to a certain extent a more appropriate measure than the average because it is less sensitive to extreme scores than is the average. We undertook a small exercise to assess whether the median would provide us with very different results than using the ECA average as a threshold. Table E1 shows the results of grouping the countries according to the difference between the individual scores and the median. We construct one group of countries around the median (1 standard deviation above and below the median, the middle group) and those above and below 1 standard deviation from the median. As we can see, both the previous methodology using individual pillar scores and this one result in a very similar group of countries.

Countries with the most (least) developed NIS, have the highest (lowest) KEI scores. Countries in the middle of the distribution pose a more interesting question. Is Ukraine, as the threshold country, ready for the instruments we are proposing? If so, are the countries just above and below it (Romania and Armenia, respectively) equally ready?

We would argue, that in the middle region, the devil is in the details, and we would have to look at the individual KEI pillar scores as well as individual characteristics of the country (such as size, commitment of the government, etc.) to make a more nuanced assessment. In fact, the World Bank is already engaged in a knowledge economy project in Romania and has undertaken knowledge economy advisory activities in both Poland and the Slovak Republic. It would appear that both methodologies identify as ready those countries in which in praxis governments and the World Bank are already working together to facilitate the countries' transition to a knowledge-based economy.

Annex F: Country Abbreviations

Abbreviation	Country
ALB	Albania
ARM	Armenia
AZE	Azerbaijan
BGR	Bulgaria
BIH	Bosnia and Herzegovina
BLR	Belarus
BRA	Brazil
CHL	Chile
CHN	China
CZE	Czech Republic
EAP	East Asia & Pacific
ECA	Europe & Central Asia
ESP	Spain
EST	Estonia
FIN	Finland
GEO	Georgia
GRC	Greece
HRV	Croatia
HUN	Hungary
IND	India
ISR	Israel
JPN	Japan

Abbreviation	Country
KAZ	Kazakhstan
KGZ	Kyrgyz Republic
LAC	Latin America & Caribbean
LTU	Lithuania
LVA	Latvia
MDA	Moldova
MIC	Middle income
MKD	Macedonia, FYR
OEC	High income: OECD
POL	Poland
PRT	Portugal
ROM	Romania
RUS	Russian Federation
SAS	South Asia
SVK	Slovak Republic
SVN	Slovenia
TJK	Tajikistan
TUR	Turkey
UKR	Ukraine
USA	United States
UZB	Uzbekistan
YUG	Serbia and Montenegro
WLD	World

Annex : Figures

Figure A1. Knowledge Economy Index

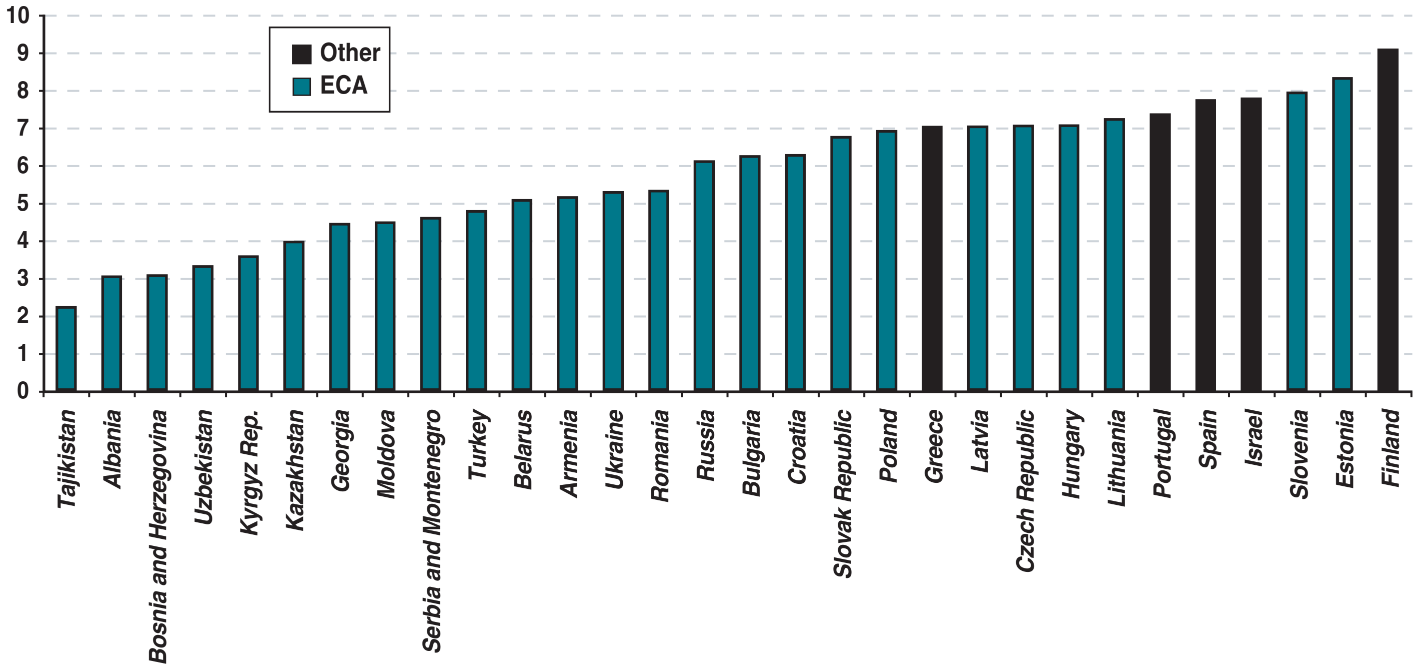

Figure A2. KE Pillar: Economic Incentives Regime

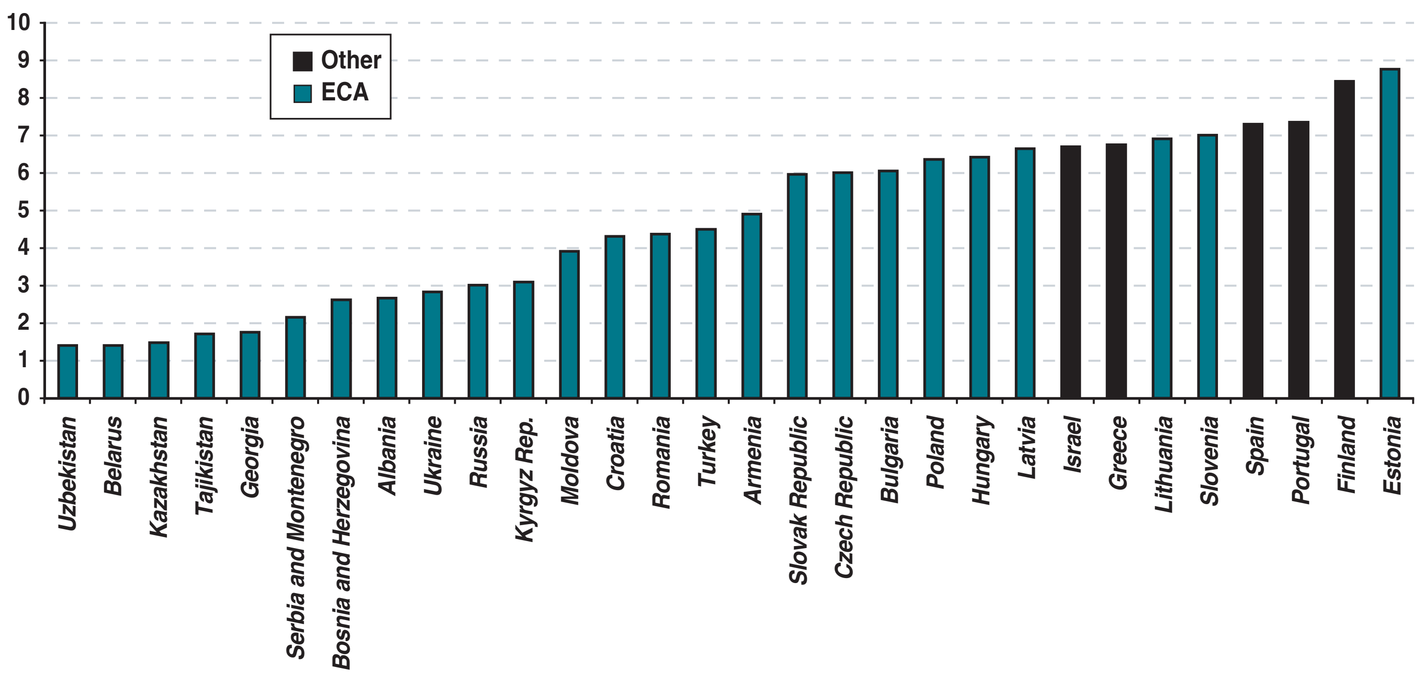

Figure A3. KE Pillar: Innovation

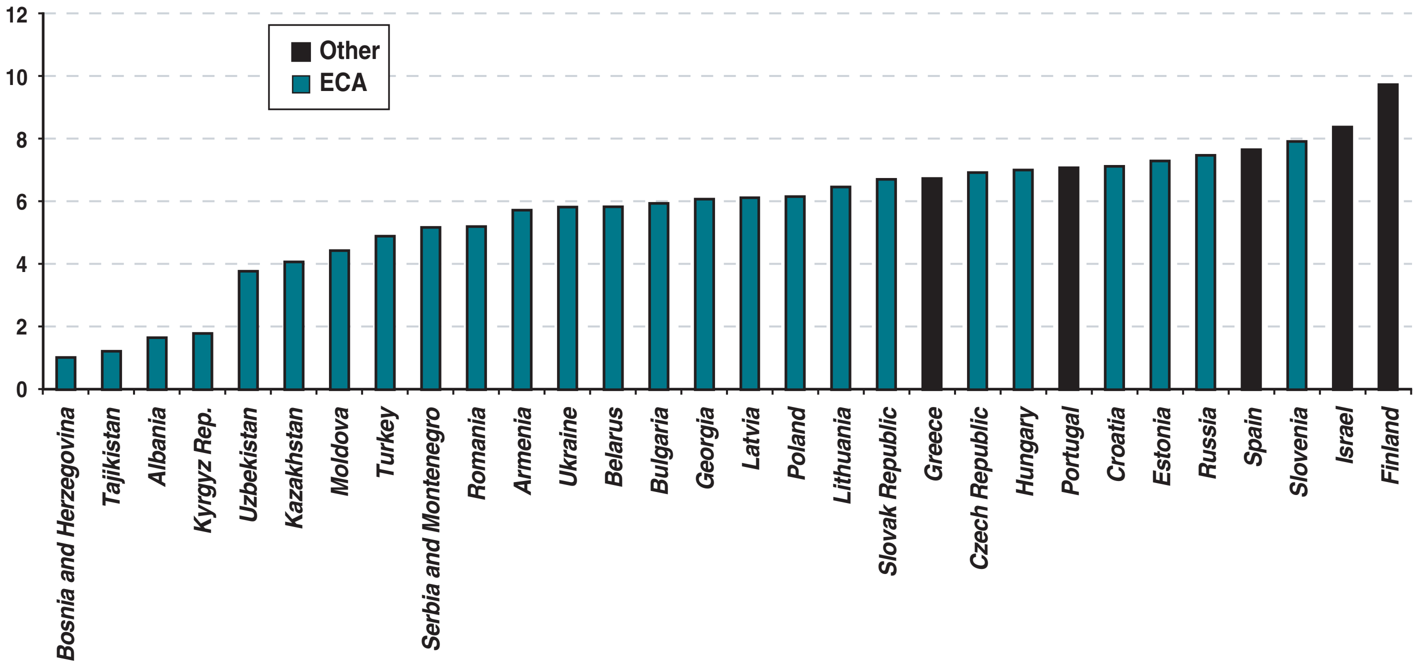

Figure A4. KE Pillar: Education

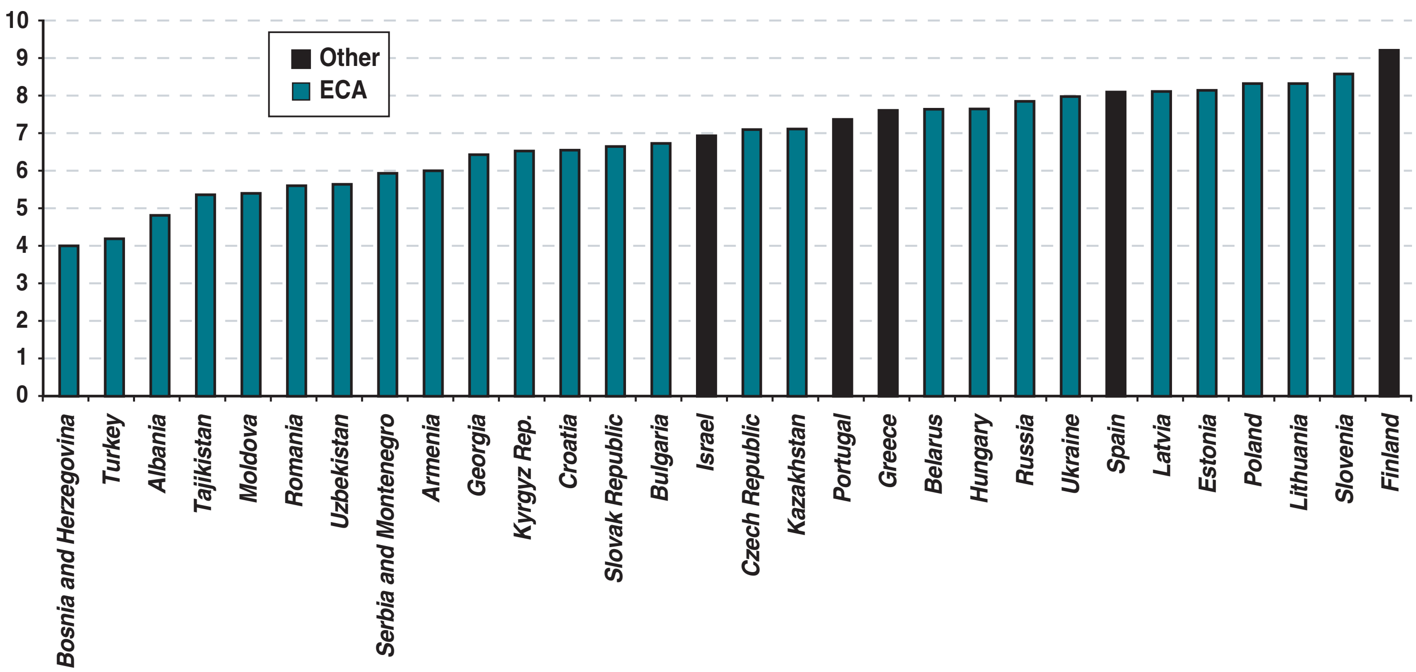

Figure A5. KE Pillar: Information Infrastructure

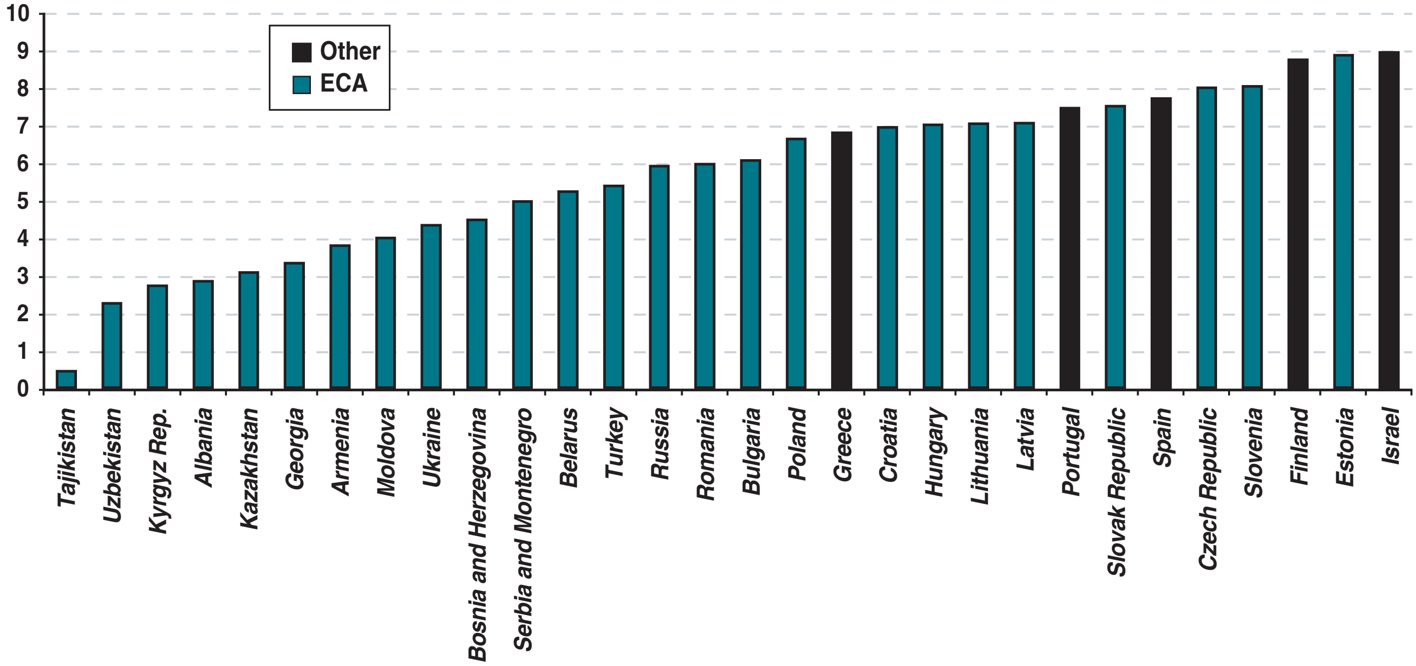

Figure A6. LGDP (2004) on KEIECON

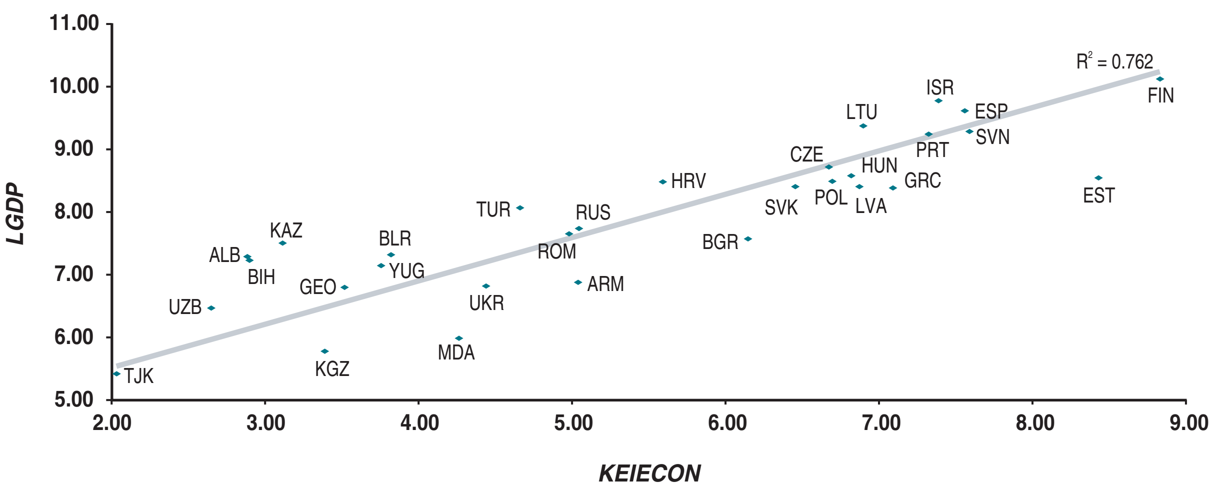

Figure A7. LGDP (2004) on KEIINN

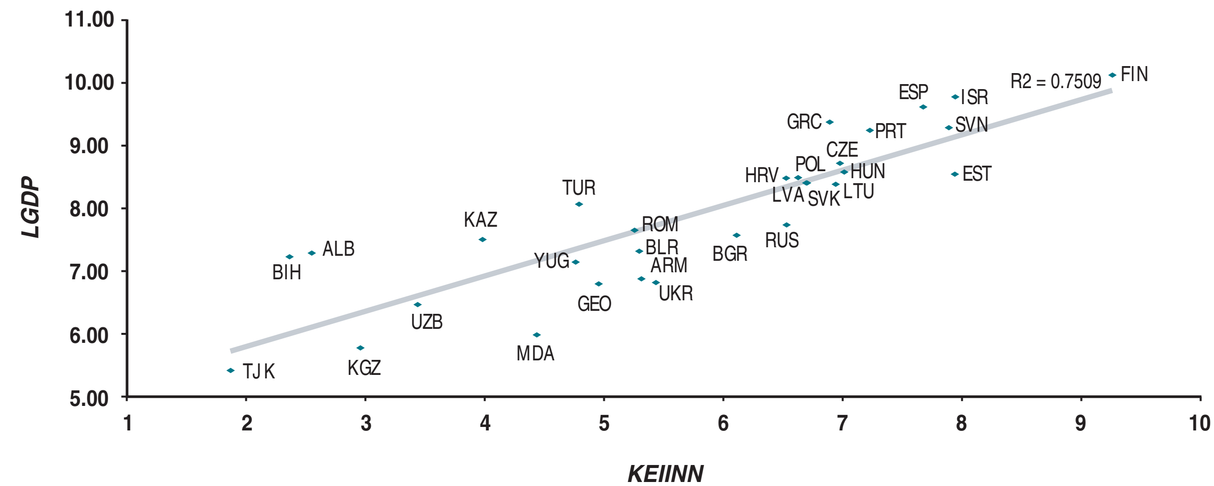

Figure A8. LGDP (2004) on KEIEDU

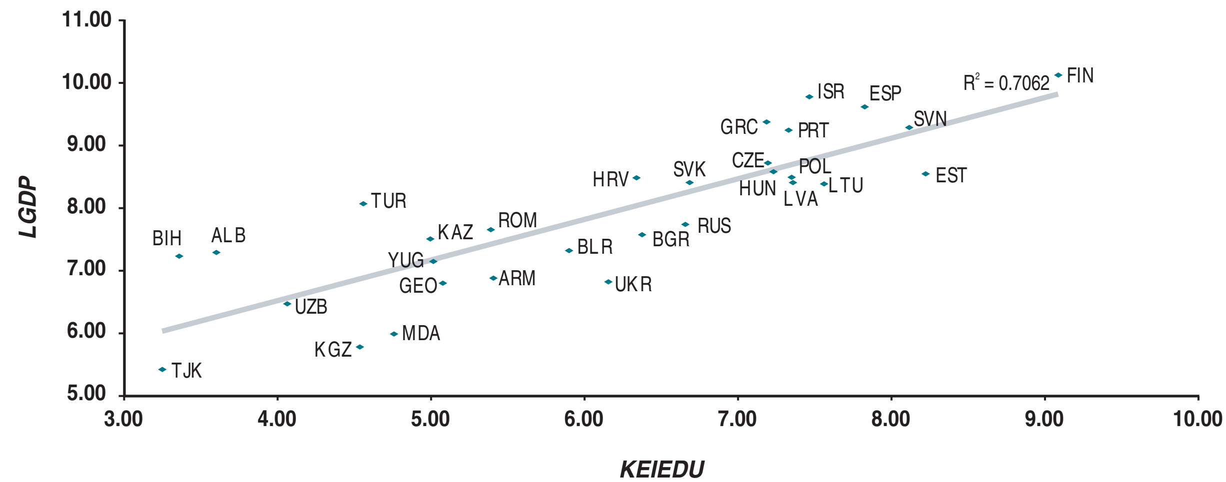

Figure A9. LGDP (2004) on KEIINF