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What Are Innovation and Innovation Policy and Why Are They Important?

Innovation has become the central driver of national economic well-being and competitiveness—and this is why so many nations are engaged in the race for global innovation advantage. But what actually is innovation? Most believe innovation is only technological in nature, resulting in shiny new products like Apple's iPad or Boeing's 787 Dreamliner. Others believe it pertains only to the research and development (R&D) activity going on at universities, national laboratories, and corporations.

While that is all true, it is much too limiting; innovation is about much more. The Organization for Economic Cooperation and Development (OECD) defines innovation as "the implementation of a new or significantly improved product (that is, a physical good or service), process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations."[1] Innovations can arise at many different points in the innovation process, including conception or ideation, R&D, transfer (the shift of the "technology" to the production organization), production and deployment, or marketplace usage.

Innovation Defined

By definition, all innovations must contain a degree of novelty, whether that novelty is new to the firm, to the market, or to the world. It's also important to remember that an innovation is not just anything new; it must also constitute a viable business concept.

General Electric (GE) offers a useful definition for innovation, contending that "to innovate . . . is to challenge and change the status quo to enhance the customer's experience and bring new forms of value to them." Two attributes are attractive in GE's definition. First, it places focus on challenging the status quo and upsetting the established order, evoking Joseph Schumpeter's dictum that "every piece of business strategy must be understood against the perennial gale of creative destruction."[2] Second, it reminds us that organizations ultimately innovate in service of their customers and that genuine innovation must create real value for them, even if it's an innovation they never see, such as new kinds of machines to produce a product at a lower price. Another useful, aspirational definition of innovation comes from author John Kao, who describes innovation as "the transformation of existing conditions into preferred ones."[3]

Innovation traditionally has been understood in an engineering context, entailing either the creation of new or improved consumer-product goods, such as the original iPod and its brethren, or enhanced machines and devices, such as lasers and the computer-controlled machine tools by which products are manufactured. But innovation in services has become increasingly important, as services industries now account for more than 80 percent of the U.S. economy and 75 percent or more of most European ones.[4] Thus, the understanding of innovation has broadened from a purely scientific and technical focus to include the application and use of information technologies, evolution of new business models, and creation of new customer experience or service delivery approaches. These have the potential to transform virtually all service sectors, from retail, logistics, and hospitality to health care, professional services, and financial services.

Why Innovation Is Important

However defined, innovation is vitally important because it drives economic, employment, and income growth; quality of life improvements; and the competitiveness of nations. As OECD secretary-general Angel Gurría commented at the release of the OECD's Innovation Strategy in March 2010, "Countries need to harness innovation and entrepreneurship to boost growth and employment, for innovation is the key to a sustainable rise in living standards."[5]

In recent years, a small but growing number of economists have come to see that it is not so much the accumulation of more savings or capital that is the key to improving standards of living. Rather, it is innovation that drives a country's long-run economic growth.[6] For example, two-thirds of U.K. private-sector productivity growth between 2000 and 2007 was a result of innovation.[7] And when Klenow and Rodriguez-Clare decomposed the cross-country differences in income per worker into shares that could be attributed to physical capital, human capital, and total factor productivity, they found that more than 90 percent of the variation in the growth of income per worker was a result of how effectively capital is used (that is, innovation), with differences in the actual amount of human and financial capital accounting for just 9 percent.[8] Moreover, technological innovation in particular delivers substantial economic returns. For example, a study of a sample of fourteen research projects funded by the U.S. Department of Commerce showed a median rate of return to society of 144 percent, far higher than their cost of capital.[9] And economist Edwin Mansfield found the social rate of return from investment in academic research (in terms of its impact on product and process development in U.S. firms) to be at least 40 percent.[10]

Innovation—the wellspring of that "gale of creative destruction" of which Schumpeter wrote—achieves its outsize economic impact through two principal channels: empowering productivity improvements and spurring the dynamic creation of new firms or activities that create new value. With regard to the former, during the 2000s, in industry after industry, firms have adopted computers, telecommunications, and software to streamline operations and boost efficiency. As a result, the production and innovative

use of information technology (IT) has been responsible for at least 50 percent of the acceleration in the growth in U.S. total factor productivity between 1995 and 2008, contributing to a U.S. economy that is approximately $2 trillion larger in terms of annual gross domestic product (GDP) than it would be otherwise.[11]

In addition to enabling productivity improvements within existing firms, innovation empowers the creation of new (and often more productive and competitive) firms—and industries. And these innovative firms and industries tend to pay higher wages. In the United States, average compensation per employee in innovation-intensive sectors increased 50 percent between 1990 and 2007—nearly two and a half times the national average.[12] This is a major reason why so many nations are competing so fiercely in the race for global innovation advantage; they want to be the home to the next thousand high-paying innovation jobs.

Innovation, however, is not just about the creation of new value but also the replacement of old firms and activities. Indeed, this turbulent, dynamic process of firm churn and turnover is a vital source of renewal and growth in the economy. (If innovation were a coin, the other side of that coin would certainly be change, for the two are inextricably linked.) Innovation's demand for constant renewal holds true at both the firm and economy levels. At the firm level, research by Carl Franklin and Larry Keeley suggests that firms not replacing at least 10 percent of their revenue stream annually with new products or services are likely to be out of business within five years.[13] The information technology revolution has only accelerated this dynamic, across both the IT production and consumer industries. As Massachusetts Institute of Technology (MIT) economist Eric Brynjolfsson writes, "We see much greater turbulence and volatility in the information industries, reflecting the gale of creative destruction that inevitably accompanies disruptive innovation."[14] In fact, this has contributed to a dramatic widening since the mid-1990s in the disparity in profits between the leading firms in industries that use technology intensively. Today, the leaders truly benefit from innovation while the innovation laggards pay a stiff price, and sometimes the ultimate one—bankruptcy and dissolution.

Just as businesses must constantly renew themselves through innovation, so must economies. For example, within U.S. manufacturing, the

reallocation of production from less productive to more productive firms accounted for significantly more than half the growth in manufacturing productivity between 1976 and 1996.[15] Firms either innovated and became more productive, or they lost market share and jobs. Innovation likewise accelerates the pace of turnover of firms in an economy. Whereas, at the beginning of the last century, the average life span of a S&P 500 company was greater than sixty years, today the average life span is just twenty years. Ninety-eight percent of American companies disappear within eleven years.[16] The average life span of a company in Japan and Europe is twelve and a half years. Despite sounding regressive, this process of churn is actually vitally important to a nation's economic health. In fact, before the Great Recession, approximately 750,000 new establishments opened in the United States each year—500,000 of which were new start-up companies—creating more than seven million new jobs. At the same time, nearly 700,000 establishments closed each year, destroying more than six million jobs in the process.[17] In a study of twenty-three OECD countries, Audretsch et al. found that such sustained rates of entrepreneurship are essential for economic growth.[18] As the Kaufman Foundation's Robert Litan notes, if just sixty of these new start-up companies were to grow up to be $1 billion companies (and, in so doing, create new markets), then the United States could add one additional percentage point to its annual economic growth, and U.S. GDP would double in size six years earlier than it otherwise would (eighteen years versus twenty-four years).[19] Countries in which either firm creation or dissolution is impaired constrain the dynamic effects that innovation brings to an economy.

Thus, the ability to innovate is inextricably linked to the competitiveness of both individual firms and entire economies—and the impact on both from failing to innovate is greater than ever before. In both organizations and nations, before the emergence of the race for global innovation advantage since about 1995, failure to innovate usually just meant slower growth, much as overeating and lack of exercise result in people becoming tired "couch potatoes." But today the failure to innovate, particularly for developed nations, leads to failed companies, loss of national export competitiveness, and ultimately structural economic crises. Today, failure to innovate fast and effectively enough leads to the economic equivalent of a heart attack. As Schumpeter elaborated, "In capitalist reality, as distinguished from its textbook picture, it is not [price] competition which counts but the competition from the new commodity, the new technology . . . which strikes not at the margins of the profits of the existing firms but at their very lives."[20] Today, it is this competition for innovation advantage that strikes at the very economic lives of firms and national economies.

Now, more than ever, nations need innovation to remain globally competitive. This is especially true for developed nations, which without innovation have a hard time competing with low-income, low-wage nations. Especially critical is their ability to lead in process innovation (to automate production and produce more with fewer workers) and to move up the value chain to develop higher-value-added products and services that less-developed nations simply can't make, at least not as well for the near and medium term. Moreover, for large nations like the United States to succeed, they must innovate not just in new high-growth start-ups—the focus of much of U.S. innovation policy—but also in a wide array of midsized and large firms and establishments. Doing this will enable America to reduce its trade deficit while creating higher-wage jobs. And it's much easier to create jobs in an economy not running large sustained trade deficits because, at least in the United States, a dollar of exports produces twice as much employment as a dollar of domestic consumption.[21] Finally, a healthy traded sector enables economies to avoid high trade debts that will ultimately have to be paid off by future generations consuming less of what they produce.

What Is Innovation Policy?

Since the late 1990s, dozens of countries—small and large, rich and poor, North and South—have created and implemented national innovation strategies designed to boost the potential of their economies to produce a stream of commercially successful innovations. These countries recognize that innovation drives economic growth and that losing the race for innovation advantage can result in a relatively lower standard of living as nations lose higher-value-added sectors. They know that success in the competition to develop globally competitive domestic companies and industries, to attract

internationally mobile innovation-based economic activities, and thus to achieve high and sustainable levels of economic and employment growth increasingly depends on the strength of their innovation ecosystems. The more advanced countries also realize that innovation-based economic activity is not just about moving up the value chain to higher-value-added activities in traded sectors, but also about boosting the productivity of sectors across the board and developing new capabilities and functionalities in their economies. All of these nations have come to understand that relying on markets shaped by price signals alone will not usually be as effective as smart public-private partnerships in spurring higher productivity and greater innovation. They understand that government can—and must—play a constructive role in helping the private sector compete. Therefore, they see the promotion of innovation as a focal point of their economic growth and competitiveness strategies.

Just as we defined innovation as more than the development of shiny new widgets, we define innovation policy as more than just science policy. Innovation policy involves the same set of policy issues that countries deal with all the time, but focuses on how countries can address those issues with a view toward maximizing innovation and productivity. For example, countries can operate their government procurement practices the same way they always have, or they can reorganize their practices in a manner specifically designed to promote innovation. Likewise, countries can organize their corporate tax systems simply to raise revenues, or to raise revenues in ways that also drive innovation and traded-sector competitiveness.[22] They can set up their science policies just to support science, or organize their investments in scientific research in ways that also support technology commercialization and the innovation needs of industry.

The most sophisticated countries recognize this. Their innovation strategies constitute a coherent approach that seeks to coordinate disparate policies toward scientific research, technology commercialization, IT investments, education and skills development, tax, trade, intellectual property (IP), government procurement, and regulatory policies in an integrated fashion that drives economic growth by fostering innovation. As Finland's National Innovation Strategy argues, it is vital that a nation's innovation

strategy comprehensively addresses a broad set of policy issues because "piecemeal policy measures will not suffice in ensuring a nation's pioneering position in innovation activity, and thus growth in national productivity and competitive ability."[23]

Ultimately, a country's innovation policy aims to explicitly link science, technology, and innovation with economic and employment growth, effectively creating a game plan to compete and win in innovation-based economic activity. That's why Finland placed its national agency charged with spurring innovation, Tekes, within its Ministry of Economy and Employment: to make explicit the linkage between innovation and economic and employment growth. As Annabelle Malins, a British consul general to the United States, explained Britain's decision to develop a national innovation strategy, "The United Kingdom has made a conscientious decision to place innovation at the center of our nation's economic growth strategy."[24] If countries want to succeed in the race for global innovation advantage, they need a well-articulated, generously funded, and effectively implemented innovation strategy. But not everything that passes as an innovation policy is effective. Chapters 6 and 7 explore how countries can implement their innovation strategies in ways that are effective (win-win) for the country and the world, in ways that benefit the country at the expense of others, or in ways that are outright ineffective.

Is Innovation Policy Just Another Name for Industrial Policy?

Just what is the appropriate role of government in facilitating innovation, boosting productivity, and driving traded-sector competitiveness? Is growth best left to markets and private enterprise alone, as many free-market conservatives stubbornly believe, or does government play a role? In his seminal book *The Wealth of Nations*, released in 1776, Adam Smith observed that debate about the appropriate role of the state in technology development and in fostering economic growth had already raged for more than two hundred years.[25] Clearly, the debate has not abated in the centuries since, perhaps even picking up steam during the recent economic downturn as countries have increasingly intervened in their economies to support faltering corporations or to restore growth.[26]

In the United States and most British Commonwealth countries, many scholars, policy analysts, and policymakers interested in these questions subscribe to the neoclassical economics view that most innovations come from the private sector acting alone and that government's role in supporting innovation should be strictly limited. As a result, they restrict their recommendations regarding government's role to at most supporting "innovation environment" measures—ensuring a good business climate and backing basic science research and education—that will enable the private sector to have the inputs it needs to innovate on its own. They believe that the vitality of economies rests almost exclusively on the private sector acting on its own volition with no guidance or influence from the public sector. As such, for them, a too-active government innovation policy amounts to "industrial policy"—a shorthand pejorative for inappropriate intervention into markets that either hinders private firms from developing innovative technologies and/or distorts the supposedly efficient market-based allocation of resources. In fact, according to this view, many policy efforts to help firms become more innovative or productive only make matters worse, for the worst possible sin in the eyes of neoclassical economists is to "pick winners and losers." Substituting for the wisdom of the market can only lead to a worse, not better, allocation of resources, they opine. For such individuals, innovation policy is simply a more politically correct term for "industrial policy," a distinction without a difference.

For example, the August 2010 *Economist* article "Picking Winners, Saving Losers" assails industrial policy, painting an insidious picture of governments' increasing intervention in market economies, arguing that the hideous Leviathan of the state was gobbling up one sector after another and warning that "picking industrial winners nearly always fails."[27] As the article asserts, "Industrial policy may be designed to support or restructure old struggling sectors, such as steel or textiles, or to try to construct new industries, such as robotics or nanotechnology. Neither track has met with much success. Governments rarely evaluate the costs and benefits properly."[28] But there are three problems with the *Economist*'s argument. First, it is flat wrong in its contention that such activities "nearly always fail." Second, it's not as if governments evaluate the costs and benefits of neoclassical recommendations, such as instituting a flat tax. But that doesn't stop

them from advocating for them. Third, the *Economist* (reflecting the general neoclassical view regarding government's role in fostering economic growth) bandies indiscriminately about a number of terms—"industrial policy," "innovation policy," "picking winners"—without adequately distinguishing between them. And it brands them all as inappropriate manifestations of government economic intervention, all the while making claims with the flimsiest of evidence—usually a few often-misinterpreted anecdotes.

Notwithstanding the efforts of free-market ideologues to blur the differences, distinctions between "innovation policy" and "industrial policy" are, in fact, real and important. To illustrate this, it is useful to envision a continuum of government-market engagement, increasing from left to right in four steps: from (1) a "laissez-faire, leave it to the market" approach, to (2) "supporting factor conditions for innovation," going further by (3) "supporting key broad technologies/industries" and, at the most extreme, (4) "picking specific technologies/firms," which is tantamount to industrial policy, as shown in figure 5.1.

The debate in the United States (and most Commonwealth nations) is usually framed in terms of two choices: either leave economic growth principally to the market (position 1), or engage in industrial policy to pick specific technologies and/or specific firms (position 4). For example, one high-ranking Obama administration economic official told us that the United States won't win the race for global innovation against China if we become like China. For him and many others, there are only two choices: American laissez-faire capitalism or some kind of foreign-inspired, heavy-handed

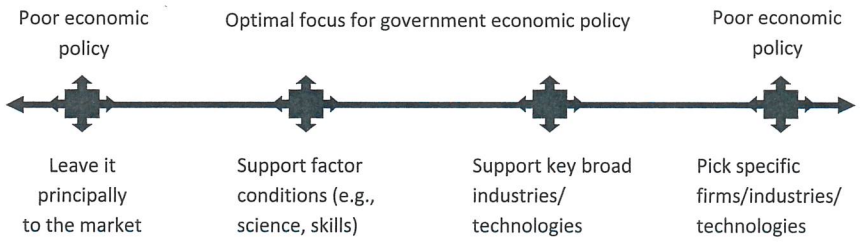

Figure 5.1 The Innovation Policy Continuum

industrial policy that is just one short step away from nationalized industries and state socialism.

Clearly, the market view is against innovation policy in principle, holding that policies should not be designed particularly to spur innovation or address the different challenges facing different industries. Government should just go about its business, raising revenues, regulating what it needs to (which is not much), managing macroeconomic policy (preferably through monetary policy only), and enforcing the rule of law, all ideally as lightly and unobtrusively as possible. Leave it to entrepreneurs motivated by making a profit (ideally with no capital gains tax) and all will be well.

The industrial policy view is also clear. Industrial policy is designed to intervene in an economy to support, favor, or restructure specific businesses, such as particular automobile or steel companies, or narrowly defined technologies (e.g., lithium-ion batteries). Industrial policies often seek to pick specific national champion companies or technologies. For example, France's investment of 56 billion francs ($11.4 billion) between 1976 and 1996 in Minitel, a monochrome teletext phone system, is a classic case of a country trying to pick a national champion,[29] as is Groupe Bull, France's state-sponsored computer giant.[30] French president Jacques Chirac's ill-fated gambit to introduce the French-backed search engine Quaero "as the next Google-killer" was also a clear manifestation of industrial policy.[31] No wonder industrial policy has gotten a bad name with ill-advised policies like this.

The practices of Japan and Korea after World War II (WWII), in which specific companies or networks of companies (the chaebol in Korea and the zaibatsu in Japan) were selected as national champions to lead certain industries such as automobiles, electronics, concrete, or shipbuilding, also qualify as industrial policy. The Synthetic Fuels Corporation, a U.S. government–funded corporation established in 1980 to create a financial bridge for the development and construction of commercial synthetic fuel manufacturing plants (such as coal gasification), was industrial policy aimed at producing alternatives to imported fossil fuels (and would probably have worked if oil prices had stayed high). The U.S. government's action in 2009 to bail out General Motors and Chrysler—an intervention in the economy to assist two very specific firms—was industrial policy, albeit done in the context of business cycle policy.

The choice, however, should not be between the extremes of laissez-faire and industrial policy. There is a range of activities between these two poles that governments can and should take to spur innovation. Governments support economic growth best by engaging at points 2 and 3 on the spectrum depicted in figure 5.1: supporting factor conditions (including tax policy designed to encourage innovation and designing incentives to spur institutional innovations like better technology transfer from universities) and placing strategic bets to support potentially breakthrough nascent technologies (such as the Internet, nanotechnology, human genome mapping, robotics, or advanced batteries) and industries rather than specific firms (such as broadband telecommunications, life sciences, software, and clean energy), all the while enabling competitive markets and a beneficial business climate.

Engaging between the extremes requires thoughtful policies to support innovation, including strategic investments to spur emerging technologies with the potential to form the basis for the industries, companies, and jobs of the future. But smart policy can do this successfully. In fact, U.S. government support has a long and distinguished history of playing a fundamental role in bringing to realization an extensive and compelling list of technologies. These include: interchangeable parts, the manufacturing assembly line, the microwave, the calculator, the transistor and semiconductor, the relational database, the laser, jet propulsion, nuclear energy, the Internet, the graphical user interface, and the global positioning system (GPS), among many others. Research supported by the National Institutes of Health practically created the U.S. biotechnology industry. And yes, even Google, the Web search darling, isn't a purebred creature of the free market; the search algorithm it uses was developed as part of the National Science Foundation (NSF)–funded Digital Library Initiative. Google got off the ground, in part, through a portion of a $4.5 million digital libraries research grant from the NSF to Stanford University, which sought to better understand, sort, and find information using the World Wide Web—and has since transformed from a two-person start-up to a global company that employs twenty-five thousand Americans and boasts a market value greater than $200 billion.

Neoclassical economists will certainly object, "But isn't this an industrial policy process of picking winners?" It is, insofar as it means government

identifying industries and technologies broadly where the country needs to be more innovative and productive and then developing and implementing policies to work with the private sector to ensure that result. But this is not the derided "industrial policy" in which the government selects specific firms or extremely narrow technologies, nationalizes industries, or impedes beneficial market forces.[32]

In contrast, innovation policy is concerned with enhancing the strength of a nation's innovation ecosystem. Innovation policy recognizes that businesses innovate with the help of many other institutions and that public policies can either spur or retard the innovation activities of companies. It further recognizes that technological progress depends on certain tangible and intangible infrastructure investments and on specific innovations that are too risky, complex, or interdependent with other breakthroughs for private firms to risk the substantial investments that are needed.[33] Indeed, government funding beyond support for basic research and procurement has played a key role in the technological advances that have sustained U.S. industry's global predominance since WWII. Likewise, the government's role in coordinating collaborations between private industry and publicly funded research in university and government laboratories has spilled far beyond the defense sector to include large parts of the civilian economy.[34]

A current example is the U.S. government's support for battery technology. Advanced batteries will be key to the clean economy of the future and without government support for battery research, innovation will lag behind what is societally optimal. This is in part because the spillovers—or benefits that accrue to society and not the innovating firm—from battery research are huge. It would be industrial policy if the U.S. government picked a particular national battery champion (e.g., Duracell) or a specific technology that government planners thought was the best (e.g., lithium-ion). But it is innovation policy when the government, as it does through the Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) agency, supports a wide range of firms (including start-ups) and technologies (such as lithium-ion, lithium-air, Zinc-air, all electron, metal-molten salt, or magnesium-ion), recognizing that while it needs to support the private sector in its efforts to spur battery innovation, neither it nor the private sector can adequately predict which firms and technologies will ultimately win.

Economist Dani Rodrik paints a helpful picture of the appropriate relationship between government and business with respect to innovation policy when he describes "an interactive process of strategic cooperation between the public and private sectors which, on the one hand, serves to elicit information on business opportunities and constraints and, on the other hand, generates policy initiatives in response."[35] As the Obama administration's September 2009 "Strategy for American Innovation" wisely argued, "The true choice in innovation is not between government and no government, but about the right type of government involvement in support of innovation."[36] In summary, innovation policy recognizes that while the private sector should lead innovation, in an era of globalized innovation and intensely competitive markets, governments can and should play an important enabling role in supporting private-sector innovation efforts at both the firm and industry level.

But still, free-market advocates will contend that markets generally get it right and will provide what the market needs (one definition of innovation) if they are just left to their own devices and the motivation to make a profit. "We don't need no innovation policy!" they insist. But as we describe next, unlike the production of commodity-type widgets, innovation is subject to a vast array of "market failures," such that in the absence of effective innovation policies, markets will underproduce innovation and economies will suffer.

Why Do Nations Need an Innovation Policy?

It's one thing to want more innovation; it's quite another to take the next step and say that an innovation policy is needed to maximize innovation. But nations with innovation policies understand—in contrast to what the conventional neoclassical economic doctrine holds—that while markets acting on their own might produce societally optimal numbers of commodity-based widgets, they will produce suboptimal levels of innovation, for there are a significant number of systemic market failures around innovation, including externalities, network failures, system interdependencies, and the public-goods nature of technology platforms. Moreover, even if these failures did not exist, most nations recognize that they need an innovation

policy because the stakes have been raised as innovation competition intensifies among nations. Nations without innovation policies are like soccer teams taking to the field without coaches, trainers, or a game plan; they're just a collection of players (businesses) running around, competing against other players (businesses in nations with effective innovation policies) that are well equipped, well coached, and running specific, well-designed plays.

Finally, even if there weren't systemic market failures or tough new competition, smart countries would still want innovation policies, if for no other reason than because addressing complex and systemic challenges—such as providing universal and much less costly health care to growing and aging populations, combating climate change and environmental degradation, achieving sustainable energy production, and deploying complex digital infrastructures—requires coordinated strategies that leverage the limited resources of a nation's businesses, academic institutions, and government agencies.

How the Free Market Acting Alone Fails Innovation

It's bad enough that conventional economists give short shrift to innovation; worse, they give little consideration to the role of government in spurring innovation. Endlessly repeating the mantra "markets are best at allocating resources," most conventional economists see government intervention as likely to hurt innovation and growth because, by definition, it distorts market-based allocation. For them, there is little risk of market failure, but a high risk of government failure. As a result, in order to justify any government action to stimulate innovation, advocates must come before the high court of neoclassical economics and present in chapter and verse why what they are proposing responds effectively to an actual "market failure," and why the risk of government failure is low. Ninety-nine times out of a hundred, the verdict is "guilty: no market failure here, go back to leaving it to the wisdom of the market." And it's not as if the rejection is based on any kind of objective analysis (academic research is neither consulted nor rejected)—it's ideological in nature, pure and simple. While this might be a reasonable way to look at markets for commodities like barley or wheat, it's a completely inappropriate concept for looking at innovation systems.

As Douglas North argued in his 1993 Nobel Prize lecture, neoclassical economic theory is an inappropriate tool for analyzing the processes of economic development and innovation.[37] Or, as British economist John Barber elaborates, the standard neoclassical model "has become increasingly unsatisfactory as research into innovation and analysis of innovation policy measures means that the list of identified market failures has become longer and longer so that the standard neoclassical model becomes modified to a degree which undermines its validity."[38] When it comes to innovation systems, the very concept of market failures is a faulty one in the first place, for it assumes that markets for innovation work most of the time and, at worst, suffer from occasional minor failures. A better frame is the notion of maximizing the potential of complex national innovation systems, which absent a facilitating innovation policy will underperform. But, because the neoclassical "high court" demands proof of "market failure" before they even consider blessing any government action, we present ten leading market failures that cause markets to innovate suboptimally:

1. Because Individual Firms and Entrepreneurs Cannot Capture All the Benefits of Their Own Innovative Activity, They Will Produce Less Innovation Activity than Society Needs

When Steve Jobs launched the Apple iPad—a novel innovation that combined new capabilities in hardware, software, and communications—in April 2010, he rightly intended for Apple to make money. And while Apple has clearly profited from its innovation, there are now dozens of other companies selling similar tablet computers in competition with the iPad (in fact, the 2011 Consumer Electronics Show in Las Vegas saw eighty new tablet computers introduced by a variety of vendors),[39] suggesting that Apple was not able to capture anywhere near all the returns from its innovation. This is an example of the first market failure from innovation: the inability to appropriate full benefit from one's own innovative activity.

The knowledge needed to create new products, processes, and organizational forms cannot be contained completely within an individual firm, even when the firm patents its discoveries. It inevitably spills over to other firms and individuals, who can use it without paying the costs of creating it. For example: an entrepreneur like Michael Dell develops a new business

model for building and selling computers that others copy; a university transfers discoveries from the lab to the marketplace; or a company makes a breakthrough that forms the basis of innovations that other companies can use. Such spillovers are rampant in innovation, arising from product R&D, process R&D, technology adoption (particularly IT adoption), and the development of new business and organizational models.

A plethora of studies have found that the rate of return to society from corporate R&D and innovation activities is at least twice the estimated returns that the company itself receives.[40] For example, Tewksbury, Crandall, and Crane examined the rate of return from twenty prominent innovations and found a median private rate of return of 27 percent but a median social rate of return of a whopping 99 percent, almost four times higher.[41] Yale economist William Nordhaus estimates that inventors capture just 4 percent of the total social gains from their innovations; the rest spill over to other companies and to society as a whole.[42]

And these spillovers are not confined to breakthrough products like the iPad. There are also significant spillovers from process R&D (that is, the R&D conducted to help organizations produce things better). Hitt and Tambe find that spillovers from firms' investments in IT are "significant and almost as large in size as the effects of their own IT investment."[43] On average, firms capture only about half the total societal benefits from their investments in computers, software, and telecommunications, suggesting that current levels of IT investment are significantly less than societally optimal. Ornaghi also finds "statistically significant knowledge spillover associations for process and product innovation."[44] He asserts that these "knowledge spillovers play an important role in improving the quality of products, and to a lesser extent, in increasing the productivity of the firm."[45] At least one study finds that firms invest more in product R&D when they invest more in process R&D, meaning that spurring process R&D also stimulates product R&D.[46] Cefis, Rosenkranz, and Weitzel observe that positive externalities in process R&D indicate relatively high technological spillovers in this type of innovation.[47]

The problem with standard neoclassical economic theory is its insistence that firms should keep investing only until their net present value rate of return equals their cost of capital. But if the actual rate of return

to society is much greater than to the firm, firms will stop investing long before the societal rate of return equals the cost of capital. In other words, the inability of firms to capture all the benefits of their own innovative activity means that, left on their own, they will invest less in innovation-spurring activities than is optimal for society. This is the key rationale for policies such as the R&D tax credit, which is designed to stimulate additional private R&D activity by increasing the private rate of return from R&D closer to the public rate of return. Neoclassical defenders will argue that patents, copyright, and other means by which companies can protect their discoveries from being used by others solve the appropriability problem and obviate the need for government innovation policies like the R&D tax credit, but the reality is that not everything can be protected, and even if it could be, there are still significant spillovers that keep firms from appropriating all the benefits from their innovations.

2. High Levels of Risk, Expense, and Differing Time Horizons Stifle the Development of Complex New Technology Platforms

Even "rational" companies are reluctant to invest in next-generation technologies, especially when it involves high levels of risk and exceedingly lengthy R&D time frames. This is the principal reason it was the U.S. government's Defense Advanced Research Projects Agency (DARPA) that supported the initial development of the Internet (then the ARPANET) and not private communications or computer companies. At its beginning, the private sector was reticent to invest in the "Internet" because the sums required were significant and the nascent technology was so far from potential commercialization that companies were unable to foresee how they could monetize potential investments. Accordingly, the government stepped in and provided initial R&D funding; helped coordinate research among the military, universities, and industry; and created interoperable standards, thus seeding development of a breakthrough digital infrastructure platform, making the Internet a reality decades before the free market would have (if ever) left to its own devices. In fact, the Defense Department has played this role with regard to multiple technologies that have become critical to U.S. innovation leadership.[48]

Yet even if defenders of neoclassical economics acknowledged this point, they would contend that government is most likely to invest in unwise, money-losing projects; in other words, that government is a dumb investor. The market shows itself to be the wise investor by staying on the sidelines. But leaving aside the fact that the market was an incredibly dumb investor during the U.S. housing bubble, the market only invests, at least in theory, in activities where the private rate of return is above the cost of capital. But as noted above there are many, many innovation investments where the return to society is much, much higher. Without innovation policy, the market won't invest in these innovations, because the market is completely indifferent to societal rates of return.

Take the Internet, where the return on investment has been astronomical. In fact, the commercial Internet adds at least $1.5 trillion to the global economy each year, vastly more money than DARPA ever invested in it, even in net present value terms.[49] It wasn't the lack of an opportunity to realize potentially high investment returns that kept the market from investing in the Internet initially; rather, it was the vast level of uncertainty involved and the inability of industry players to capture all the benefits of their investment. Moreover, when the market did invest in early stage computer networks, it came up with uncompelling, noninteroperable systems like CompuServe, Prodigy, and MCI Mail, where it was only possible to exchange e-mail if both the sender and receiver used the same service provider, obviating the scale and network effects that the fully interoperable TCP/IP-based World Wide Web ultimately delivered.

This same corporate reticence to invest on the risky future evident in the Internet's development pertains today to a range of emerging infrastructure-based technologies including biotechnology, nanotechnology, and robotics. At the same time, as Tassey notes, a related challenge is that "the complex multidisciplinary basis for new technologies demands the availability of technology platforms before efficient applied R&D leading to commercial innovation can occur."[50] In other words, the levels of investment required to research and to develop emerging technologies are so great that in many instances the private sector cannot support the effort alone, and therefore

"government must increasingly assume the role of partner with industry in managing technology research projects."[51]

Moreover, to innovate successfully, businesses rely on much more than their own efforts, or even those of the suppliers they contract with. They increasingly rely on ubiquitous "shared infratechnologies" including measurement methods, process-control techniques, and science and engineering data. These infratechnologies, which make no sense for individual firms to develop on their own, deliver substantial economic benefits. For example, a National Institute of Standards and Technology (NIST) study estimated that the U.S. semiconductor industry has invested more than $1 billion (with government assistance) to improve its measurement capabilities. The study found that these improvements generated $17 billion in economic benefits. Yet, because the public goods characteristic of technology infrastructure precludes firms from capturing all the benefits of their investments (that is, once developed, all firms who need it can benefit from it) and because they have limited funds, industry has substantially underinvests in infratechnologies, despite the fact that the societal economic benefits from such investments are substantial, as a NIST study of the biopharmaceutical industry demonstrated.[52] For the United States to overcome this market failure, it must discard its "black box model" of innovation, which views industrial technologies as homogenous private goods, and move toward a more accurate conceptual framework in which technology is understood as having both public and private components.[53]

Japan is particularly strong at facilitating cooperation between competing firms and the government in developing and deploying new technologies. Okimoto describes the importance of the Japanese government's focus on working with companies on consensus building and articulating a long-term vision in the development of new technologies.[54] The Japanese government views its role as helping firms overcome the downfalls of "bounded vision," meaning that different kinds of organizations receive various types of information as the result of their primary activities and are limited in what they search for and "see" by the overall objectives of the organization. Japan believes that the limitations in the visions of for-profit firms and of the government can be overcome by bringing the two together.[55]

3. Capital Market Failures Have Caused Private Financing of R&D to Shift Away from Innovation-Based and Entrepreneurial Efforts

The neoclassical model holds as a matter of faith that investors as a group accurately scan the market and the array of technology opportunities available and invest in the ones with rates of return above the cost of capital. Even more remarkable, their faith appears to be as rock solid even after the financial industry dumped trillions into subprime mortgages and other failed housing investments. But as we tragically saw with the housing bubble, private-sector investment is often misallocated, with grievous results. One reason, as we note in chapter 2, is that investors wrongly bought into efficient market theory. But another is that while investors may be able to deal with risk, they don't deal well with uncertainty where it's difficult if not impossible to model expected outcomes. As with the initial development of the Internet, these capital market failures occur when unfamiliar investments such as those involving new companies, novel technologies, or innovative business models appear too uncertain for investors to undertake in relation to the anticipated returns.

One manifestation of this is that private financing of R&D in the United States has shifted away from more entrepreneurial and early stage research efforts, largely because of decision makers' shorter time horizons.[56] The idea that investors make the same kinds of rational decisions with respect to investment opportunities over time is simply not true, as the history of the last thirty years shows. Before the 1980s, many U.S. corporations made investment decisions on the basis of expectations of long-term returns. But changes in the institutional system of U.S. investing and management beginning in the 1980s under the rubric of the "shareholder value movement" changed all that.

You would think that for-profit corporations should always invest to maximize shareholder value. But the real question is: which shareholders—the ones (including senior managers) currently holding stocks who want to sell in a year, six months, or six weeks, or the "widows and orphans" who are holding on for the long term? Maximizing net present value for the first set of shareholders—what the shareholder value movement meant—can lead to significantly different outcomes than maximizing net present value

for the second. But how investment funds were structured and their managers rewarded meant that funds moved money around in search of the quickest return, regardless of where long-term value was. How managers were compensated—increasingly with stock options that were not related to actual managerial performance—reflected this new view that a manager's job was to maximize value for the first set of shareholders. And because managers themselves became key short-term stockholders (through the significant growth of stock options), they made even more efforts to boost the welfare of short-term stockholders, including by boosting dividends and stock buybacks instead of reinvesting in plant and equipment. And because the short-termers were more likely to be insiders with access to better information than the long-termers, pressure from short-term investors for high short-term returns meant that companies acted differently. But this was not rational in the sense of maximizing returns for society, or even for companies (if returns are defined as maximizing the net present value of all future profits). As former General Electric CEO Jack Welch (one of the founders of the shareholder value movement) said in 2009, "On the face of it, shareholder value is the dumbest idea in the world. Shareholder value is a result, not a strategy . . . your main constituencies are your employees, your customers, and your products."[57]

As we note in chapter 3, starting in the 1980s, companies began paying out more in dividends and engaging in stock buybacks as a way to boost stock prices for short-term investors, even though this meant relatively less investment in activities that would boost long-term innovation and productivity. Similar changes have occurred in the U.S. venture capital market. Venture capitalists have found it more profitable to invest in larger deals and less risky later-stage deals at the expense of smaller, riskier, early stage efforts in basic and applied research. In fact, while total venture capital funding for zero- and first-stage deals increased from 1996 to 2008, the share of total venture capital going to these kinds of deals actually declined from 35 percent to 24 percent over the same time period.[58] Likewise, average deal size in inflation-adjusted dollars has doubled, meaning that smaller deals are harder to get funded.[59] Also, as noted previously, corporate-funded R&D is increasingly less focused on earlier stage research and more on later stage, development-related activities. While generic technology developed from

earlier stage research can produce robust returns, it can take considerable time to show payoffs for the bottom line. In contrast, development can show quick, albeit lower, returns. As economist William Lazonick notes, today "a combination of innovation, redistribution, and speculation drives the stock market," with maximizing innovation often playing second fiddle.[60]

4. Coordination Failures Undermine the Innovation Process

Because of the complexity of the innovation process, especially today, firms cannot maximize innovation by working in isolation. Adam Brandenburger and Barry Nalebuff describe this new world as "co-opetition," where competitors are competing and cooperating.[61] To do so, they need to interact with organizations such as suppliers, customers, competitors, universities, research institutes, investment banks, and government entities to gain various kinds of technology, knowledge, information, and market access. Such interactions take time, effort, and resources, and in a fast-moving world, the pattern of cooperation between firms and other agents is far from optimal, not least because of a lack of information about possible useful partners.[62] For example, multiple actors often work on similar research problems. They could share information to everyone's benefit, but they usually don't if left on their own. Such coordination failures are one reason why government agencies like DARPA have filled such a valuable niche. Perhaps more important than its role in funding actual research, DARPA orchestrates the involvement of established companies with start-ups and academic experts, supports knowledge sharing between industry competitors through invitation-only workshops, provides third-party validation of new technology directions, and supports technology platform development.[63] Without programs like DARPA; Advanced Research Projects Agency-Energy (ARPA-E), which plays a similar role for energy innovation; and NIST's Technology Innovation Program, which supports high-risk, high-reward research in areas of critical national need, the private marketplace would undersupply this coordination.

For example, DARPA played an instrumental role in identifying emerging directions in the research community, coordinating star scientists, and seed-funding initial research into materials technology for silicon-geranium (Si-Ge) semiconductors that was crucial in the late 1980s to perpetuating

Moore's Law. DARPA's program manager realized through his connections with the research community that three different research teams (unbeknownst to each other) at IBM, UCLA, and start-up Amberwave were independently considering exploring Si-Ge technology. As a central node to which information from the research community flowed, DARPA's program manager was able to recognize the potential of Si-Ge technology, provide funding, and coordinate research activities, thus helping to launch a research effort that led to fundamental semiconductor breakthroughs, and therefore extend Moore's Law.[64]

A related challenge pertains to the fact that, while successful technological innovation increasingly depends on collaboration between firms and universities, the interests of these collaborators are not well aligned. As we have seen, short-term competitive pressures make it difficult for even the largest firms to support applied research, much less basic research. As a result, firms are relying more on university-based research and industry-university collaborations. Yet the divergent needs of firms and universities can hinder the coordination of R&D between these two types of institutions. University researchers are not necessarily motivated to work on problems that are relevant to commercial needs. They are rewarded for things like how many peer-reviewed publications they author. Likewise, university technology-transfer offices do not always promote the licensing of university intellectual property to firms, or they do so on terms that maximize revenue but not licensing. Conversely, individual businesses sometimes want to "rent" universities' research capabilities and appropriate the resulting discoveries for themselves. All of these factors can impede the generation and transfer of knowledge that contributes to innovation.[65]

5. "Chicken-or-Egg" Challenges Inhibit Development of Technology Platforms

If innovation involved no more than a company or an entrepreneur inventing and selling something, it would be a lot easier and much more prevalent. But all too often, successful innovation depends on others. When Steve Jobs developed the iPod, he needed customers to have broadband Internet access and he needed to have music available for purchase online. Without either, the iPod would have gone the way of the Newton (an earlier,

where innovation represents a direct threat to the professionals themselves because the worker and the manager is essentially the same individual. For example, while Ford and Toyota managers might be loath to adopt managerial automation, they have strong incentives to adopt production automation because the shop floor workers don't control the means of production and consumers benefit. But in the legal, accounting, health-care, real estate, optometry, pharmacy, education, and many other industries, professional workers largely control or influence the means of production, so innovation can and often does mean cannibalizing their own jobs. Why would real estate agents embrace more efficient e-realty systems that would put many of them out of work and reduce commission rates for the rest due to increased agent productivity? Why should the legal industry not put up barriers to more efficient online provision of legal services?[71] But this is not enough to limit innovation. Even here, we would expect some intrepid entrepreneurs who are not fixated on protecting existing professionals to enter the market. This leads to the second characteristic of industries affected by the principal-agent problem: control over the marketplace. Through legal codes, required certifications, control over information platforms, monopolistic access to customers, and sometimes government rules they use their power to get enacted, these industries are able to keep innovators out. For example, in the case of realtors, the industry's professionals control the key technology platform, the Multiple Listing Service (MLS), and so they have designed the rules governing its use in ways to thwart more efficient e-realtor entrants.[72] And because the MLS is a natural monopoly, it would make no economic sense for start-up competitors to create their own, even if they had deep pockets.

There is a second problem limiting adoption of proven technologies that afflicts industries such as construction and health care, which have fragmented or atomistic structures. The extreme fragmentation of these industries, with many smaller players operating relatively inefficiently, hinders productivity growth and technology adoption in their sectors of the economy. For example, the construction industry is one of the least IT-intensive sectors of the U.S. economy, with one of the lowest rates of productivity growth. Why doesn't the market address this fragmentation? As industry expert Barry LePatner explains in his book, *Broken Buildings, Busted Budgets*, the reason for the industry's market fragmentation is that the buyers

aren't very sophisticated, usually buying construction services only occasionally.[73] As a result, they have limited ability to demand quality and price efficiency. Likewise, in the case of health care, fragmentation arises because an underdeveloped and not fully competitive marketplace results in inadequate price and quality signals for buyers. In both cases, the natural forces of innovation—market pressures leading to consolidation and scale, with more sophisticated suppliers adopting more technology—are underdeveloped. In these cases, the marketplace alone will underperform unless government intelligently intervenes to spur competition, to be a smart buyer, or to support the development and adoption of shared technology platforms.

7. The Innovation-Producing Benefits of Industry Clusters Are Under-Realized

Imagine if the entire U.S. economy operated like California's Silicon Valley, where a large agglomeration of high-tech firms, research universities such as Stanford, technical colleges to train high-tech workers, venture capitalists, and other supporting institutions created the world's most vibrant technology region. In other words, imagine if the U.S. economy were characterized by regions where firms interacted in a rich environment of cooperation and learning that enabled them to crank out innovations faster than firms located out in the hinterlands on their own. In fact, both the creation and the diffusion of innovation often occur in geographic clusters like Silicon Valley. Such industry clustering enables firms to take advantage of common resources (e.g., technical institutes, a workforce trained in particular skills, or a common supplier base), which facilitates better labor-market matching and knowledge sharing. This process may be particularly relevant in industries that rely more on the creation or the use of new knowledge, as clustering appears to spur knowledge transfers.[74] In fact, evidence suggests that industry clustering has become even more important for productivity growth since the 1980s: the extent to which an industry is geographically concentrated has been increasingly associated with subsequent productivity growth during the last three business cycles.[75]

Just as each additional broadband user makes the Internet more valuable to existing users, each firm in a cluster makes the cluster more valuable to