



Frameworks for Measuring Innovation: Initial Approaches

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About Athena Alliance

Athena Alliance is in the vanguard of identifying, understanding, analyzing, and educating on the information, intangibles, and innovation (I³ or I-Cubed) economy. Information, knowledge, and other intangibles now power economic prosperity and wealth creation. Intangible assets—worker skills and know-how, informal relationships that feed creativity and new ideas, high-performance work organizations, formal intellectual property, and brand names—are the new keys to competitive advantage. Intangibles and information drive innovation through a combination of formal research and informal creativity. These elements come together to power the productivity gains and process improvements that enhance prosperity in the 21st century.

While the economic rules have changed, public policy has not caught up. Governments are struggling with ways to utilize information, foster development of intangibles, and promote innovation and competitiveness in this new economy. Policymakers are grappling with the urgent need to frame policy questions in light of the changing economic situation.

Issues of developing and utilizing information, managing intangibles, and fostering innovation underlie discussions on a variety of subjects, such as intellectual property rights, education and training policy, economic development, technology policy, and trade policy. Crafting new policies in these areas requires infusing a better understanding of intangibles and the information economy into the public debate.

As a nonprofit public policy research organization, Athena Alliance seeks to close the gap between the changed economy and current public policy through activities to reshape the debate and craft new solutions. Recent activities include working with the District of Columbia to create an innovation-led economic development strategy, co-hosting Congressional luncheon policy briefings, co-hosting a D.C.-based conference on innovation in India and China with the National Academy of Sciences, co-hosting a New York City-based conference on financial reporting and intangibles with the Intangible Asset Finance Society, and publishing policy reports on intangible assets, including *Reporting Intangibles* (2005), *Measuring Intangibles* (2007) and *Intangible Asset Monetization* (2008).

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Introduction

In January 2008, the U.S. Department of Commerce released a report, *Innovation Measurement: Tracking the State of Innovation in the American Economy* (DOC, 2008), which recommended “a stronger framework for identifying and measuring innovation in the national economy.”

As part of that work, the U.S. Bureau of Economic Analysis (BEA) requested that the Science and Technology Policy Institute (STPI) explore the business perspectives of innovation. The resulting report, *Measuring Innovation and Intangibles: A Business Perspective* (Stone et al., 2008,) created a compendium of the logic and methods businesses use to measure and monetize innovation. It also identified sources for, and gaps in, innovation data and outlined critical areas for future research.

This report extends that work and presents two alternative frameworks for measuring innovation. The first framework focuses on measuring innovation activities at the firm/organization level. The second takes a broader macro-level look at the fundamental investments that allow firms and other organizations to carry out innovation activities.

Defining and Measuring Innovation

Innovation has long been recognized as an important driver of economic growth. Most empirical research and surveys of firms show that innovation leads to new products and services that are higher in quality and lower in price. Historically, innovation has been treated as a residual measure after accounting for other factors of growth (mostly labor and capital). The primary goal in measuring innovation is to improve our understanding of growth. The actual output of innovation in terms of new goods and services or improved processes is already captured in the gross domestic product (GDP) and the National Income and Product Accounts (NIPAs). The amount and type of investment that lead to innovation, however, are not captured. This type of information is needed to improve our understanding of economic growth.¹

A Basic Definition of Innovation

In undertaking the analysis reported in Stone et al. (2008), the first task was to define the term “innovation.” We selected definitions from two authoritative sources—the Organization for Economic and Community Development (OECD) and the U.S. Department of Commerce (DOC).

¹ For example, if General Motors develops a database of customer-desired features—such as back-up cameras on sport utility vehicles—the database continues to provide value to the company. Therefore, the database is an investment and not an expenditure and should be treated as such in the national accounts.

- In OECD's *Oslo Manual*, which provides guidelines for collecting and interpreting innovation data, innovation is defined as the implementation of products or production and delivery processes with new or significantly improved characteristics. The third edition of the *Oslo Manual* extends the definition to include new organizational methods in business practices, workplace organization, or external relations (OECD 2005).
- DOC defines innovation as the design, development, and implementation of new or altered products, services, processes, organizational structures, and business models to create value for the customer and financial returns for the firm practicing innovation (DOC 2008).

Both definitions do more than make innovation synonymous with research and development (R&D); they also recognize the strategic application of knowledge in all innovation activities and the importance of commercialization activities in facilitating financial returns to the innovative firm and social returns to consumers.

These definitions also make it clear that innovative activities emerge from the application of intangible assets that integrate knowledge, skills, and technologies in the development and commercialization of products and processes. (Intangible assets are those that do not have a physical or tangible existence, such as good will, brand value, and patents.)

Innovation has been studied extensively by scholars and practitioners. There is even an emerging “innovation economics” subdiscipline that explores the complex relationship between investments in innovation and financial outcomes. At the practitioner end, leading consultancies—Boston Consulting Group, McKinsey & Company, and Booz Allen Hamilton, to name just a few—examine innovation and ways to nurture it within firms and other organizations.

The 10 Attributes of Innovation

As we noted in our previous work (Stone et al., 2008), innovation has a number of attributes.

Attribute 1. Innovation involves the combination of inputs in the creation of outputs. Something novel is created during innovation. Certain crucial inputs must be available for innovation to occur, and the exact nature of those inputs differs depending on the desired outputs and outcomes.

Attribute 2. Inputs to innovation can be tangible and intangible. Innovation activities draw on a variety of inputs, which can be both tangible and intangible (**Table 1**). Tangible inputs have a physical embodiment and cost. Intangible inputs do not have a physical embodiment (Blair and Wallman, 2001; Jarboe and Furrow, 2008; Lev, 2001) but may have a cost. Intangible inputs are commonly referred to in economic literature as

“knowledge assets” and in business management literature as “intellectual assets.” Inputs are considered assets if they engender future benefits (Lev, 2001).

Table 1. Tangible and intangible assets.

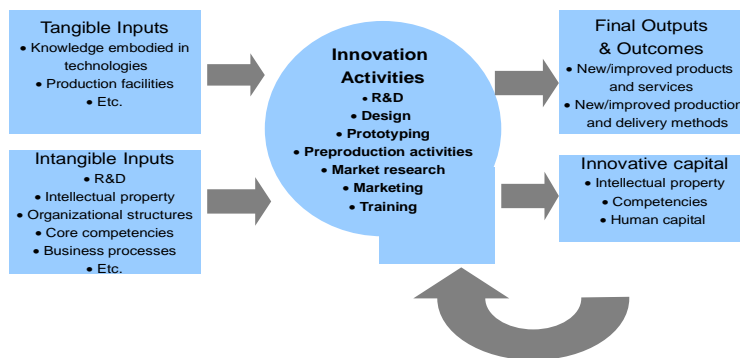
Tangible Assets	Intangible Assets
Information and communications technology infrastructure	Patents
Production materials	Databases
Production machinery and facilities	R&D progress
	Organizational processes
	Knowledge and skills of labor force

Attribute 3. Knowledge is a key input to innovation. Innovation involves the application of knowledge in creative activities. Innovation cannot take place without an understanding of the resources, tools, technologies, materials, markets, and needs in the situation at hand. In recognition of the tremendous importance of knowledge to the innovation process, innovating organizations willingly spend significant amounts of resources on research and the acquisition of knowledge (e.g., intellectual property).

Attribute 4. The inputs to innovation are assets. Most innovation inputs are considered assets because they are used repeatedly after being created for a single innovation pipeline or are used in a pipeline in a way that results in a different product (Arundel, 2007). Intangible assets—which typically are not reported on balance sheets because they are difficult to measure—are increasingly being recognized as critical to the innovation process.

We therefore propose a relationship between intangibles and innovation (**Figure 1**). Innovation is driven by a firm’s (or any entity’s) investment in tangible capital (such as computer networks) or intangible capital (such as organizational structure or human capital/training). These innovative activities could lead to tangible outputs (e.g., new or improved products or processes) or intangible ones (e.g., more experienced employees, who are more likely to engage in future innovations).

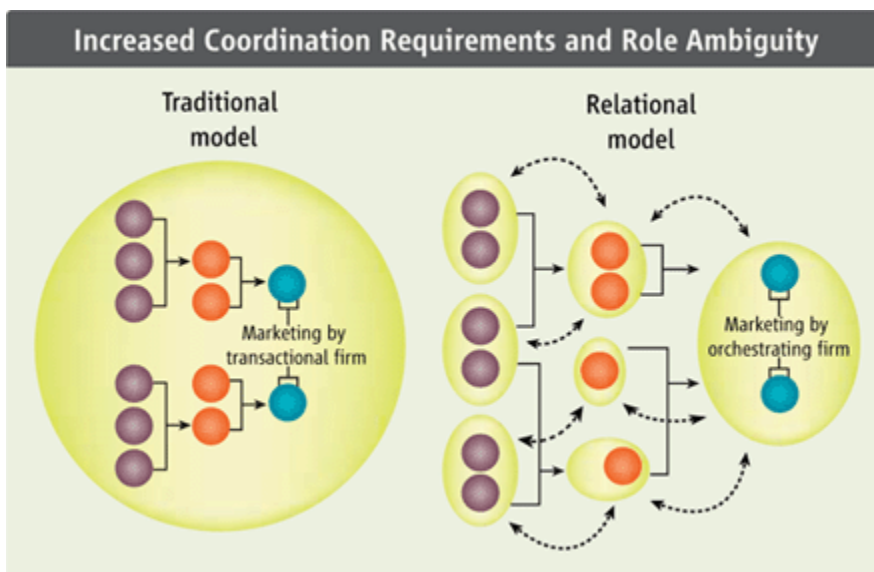
Figure 1. Relating intangible and tangible assets to innovation.



Attribute 5. Innovation involves activity for the purpose of creating economic value. Fundamental to the concept of innovation is the innovator’s intention to create something of economic value—something that offers benefits to consumers and provides economic returns to the innovator. Commercialization—the mechanism through which the consumer obtains the benefits of innovation and the innovator obtains the return—is therefore critical to the innovative process.

Attribute 6. The process of innovation is complex. Innovation is a complex process not easily reduced to measurable elements (e.g., R&D dollars spent; number or value of patents obtained). Nor is it linear. Instead, it is often iterative—the outputs of early activities become the inputs for later processes. Innovation is also not a linear combination of component factors or limited within the boundaries of firms. In a recent article in the journal *Science*, Lewis Branscomb (2008) gives several examples of relational (i.e., cooperative agreement) innovations that did not emerge in R&D labs. **Figure 2** conveys the feedback loops that occur in the nonlinear, nonhierarchical relational models associated with innovation.

Figure 2. Models of traditional and relational company structures.



Source: Branscomb, 2008

Attribute 7. Innovation involves risk. The combination of inputs often fails to produce the desired innovation and returns. There is always some probability that the innovation process will not be successful.

Attribute 8. The outputs in innovation are unpredictable. The inputs to innovation are easy to characterize; they will always be resources and assets. The outputs, however, are difficult to characterize, especially before the process is complete. The outputs are unpredictable because innovation is complex, nonlinear, and risky; responds to opportunities; and inherently includes aspects of serendipity.

Attribute 9. Knowledge is a key output of innovation. Whatever the outputs of innovation may be, they incorporate the firm's knowledge at the time. Every tangible and intangible (i.e., product and process) output reflects the firm's knowledge of its resources, technologies, markets, and consumers.

Attribute 10. Innovation involves research, development, and commercialization. Innovation typically involves the following three interconnected stages (Lev, 2001):

1. Learning and discovery – Whether internal to an organization or external in networks or with partners, this stage focuses on the generation and acquisition of knowledge and skills (the research stage).
2. Implementation – Demonstrating technical feasibility (the development stage).
3. Commercialization – Promoting product diffusion and facilitating financial and economic returns.

In the movement from stage to stage, the complexities of the innovative process become obvious as outputs from different phases become inputs for others.

The attributes of innovation make it difficult to measure. Nonetheless, experts have developed a number of metrics for innovation (Milbergs, 2007; OECD's *Oslo Manual*, 2005) and an infrastructure that can be used for data collection does exist (the European Union's [EU] Community Innovation Surveys).

Milbergs and Vonortas (2004) have portrayed innovation metrics as evolving through the following four generations (**Table 2**):

- *First generation* metrics reflect a linear conception of innovation focusing on *inputs* such as R&D investment.
- *Second generation* complements input indicators by accounting for the *intermediate outputs* of science and technology (S&T) activities.
- *Third generation* metrics focus on a richer set of *innovation indicators and indexes* based on surveys and the integration of publicly available data.
- *Fourth generation* metrics, grounded in a knowledge-based networked economy, remain ad hoc and are the subject of measurement.

Innovation measures tend to be index-oriented—composites of the perceived components of innovation (e.g., EU Innovation ScoreCard, Massachusetts Innovation Index, and many other state and country indices) that rank regions or nations with respect to their degree of innovation. However, when it comes to monetizing innovation, the discussion turns quickly to the measurement of intangible assets (Jarboe, 2007; Lev, 2001).

Table 2. Examples of evolution of innovation metrics by generation.

First Generation Input Indicators (1950s–60s)	Second Generation Output Indicators (1970s–80s)	Third Generation Innovation Indicators (1990s)	Fourth Generation Process Indicators (2000s plus emerging focus)
<ul style="list-style-type: none"> • R&D expenditures • S&T personnel • Capital • Tech intensity 	<ul style="list-style-type: none"> • Patents • Publications • Products • Quality change 	<ul style="list-style-type: none"> • Innovation surveys • Indexing • Benchmarking innovation capacity 	<ul style="list-style-type: none"> • Knowledge • Intangibles • Networks • Demand • Clusters • Management techniques • Risk/return • System dynamics

Source: Milbergs and Vonortas, 2004

When measuring innovation, experts tend to measure intangible assets without making the relationship between these assets and innovation explicit. Thus, we propose using the framework shown in **Figure 1** to describe the relationship between intangibles and innovation. They are not identical concepts, which may be inferred by reviewing existing studies on measuring innovation.

Our work in identifying intangible assets and data sources for these assets does not replicate the work of others (such as Nakamura, 2001, or Corrado, Hulten, and Sichel, 2006). Their intent was to monetize all intangibles with the goal of measuring overall economic growth, but they did not measure whether the intangibles led to innovation.

Our focus is to identify only those intangibles that lead to innovation using the term “capital” to make this distinction. For example, “brand” is an intangible asset that does not drive innovation (though it may be the outcome of innovation). Therefore, we did not include it in our framework.

Frameworks for Measuring Innovation

Based on our review of the literature on innovation and intangibles, interviews with senior leaders at U.S. firms, and a review of international efforts related to innovation, we propose the following two frameworks for measuring innovation:

- **Framework 1** – Measures innovation activity by measuring the intangible assets that are created by and fed back into the innovation process at the firm or organizational level, which can then be scaled to the national level.
- **Framework 2** – Measures innovation investments, especially the broader investments that set the stage for innovation.

Three sources of information provide the basis for these proposed frameworks: (1) the business and financial literature, which assess how businesses measure innovative activities (primarily intangibles); (2) interviews with senior leaders at U.S. firms; and (3) international efforts to measure innovation, primarily through Community Innovation Surveys (Stone et al., 2008).² Future work would involve developing new surveys or adding questions to existing surveys to systematically collect the data needed.

The actual output of innovation—manifest through new goods and services or improved processes—is already captured in the GDP accounts (albeit with a time lag relative to the investment that generated the innovation). The amount and type of investment that led to the innovation, however, is not captured—at least not explicitly as investment. It is traditionally considered part of the cost of goods sold and treated as an intermediate good in GDP.

By convention, production for use by households is not counted in the national accounts; thus, cooking at home does not increase GDP, but purchasing a meal in a restaurant does. Investment by households is also treated differently than investment by firms. For example, home ownership is treated as the consumption of “housing services” rather than an investment. The development of human capital (i.e., education) is typically financed by individuals. The national accounts treat education expenses as consumption, not investment. This presents a problem for how we measure innovation because human capital is an important investment in innovation.³

In this regard, we follow Hill and Youngman’s (2003) radical departure from the conventional treatment of human capital formation as consumption. The authors point out that students use teaching services as intermediate inputs in the production of knowledge and skills. The knowledge and skills produced are assets that can be used in the market production of other goods and services. Hill and Youngman call for including vocational education as capital formation in GDP. We expand on their approach in the second framework.

² Stone (2008) summarizes discussions with senior leaders at several types of firms, which can be divided into three categories. The first category consisted of large, well-known companies that represent a variety of industries—chemicals, insurance, consumer products, retail supplies, and information technology. The second category consisted of small firms that are developing and commercializing high-risk technologies. The third category consists of what can be called “innovation facilitators,” companies that span industries and assist other companies with innovation—including a company that facilitates open innovation, a venture capital firm, and a business-consulting firm. Each firm provided different perspectives on measuring innovative activities internally and at the firms of their clients.

³ Corrado, Hulten, and Sichel (2006) sidestepped this issue by focusing only on firm investment in intangibles and measuring only employer-provided training. We follow their lead in our first framework, which largely tracks the prior literature and measures the specific investments that are created by and fed back into the innovation process, helping to better understand the innovation process.

Framework 1: Measuring Innovative Activity

This framework focuses on measuring intangible capital, which implicitly endorses a multifactor productivity approach to innovation (Meyer and Harper, 2005).^{4,5}

Intangible capital is categorized into three types—human capital, intellectual property, and organizational capital—with activities that generate intangible assets that feed back into the innovative process.

- **Human capital** represents the knowledge and skills possessed by individuals. Firms acquire human capital by hiring skilled employees. They invest in human capital by providing training for their employees. Because firm-specific investments (such as marketing expertise) are measured, *only employer-provided training is specified in this framework*.⁶ Although individuals invest in human capital by pursuing education and developing knowledge and skills, this investment is reflected in the wages paid to them by firms. Counting all higher education in this framework could result in double counting.
- **Intellectual capital** represents technical inputs to the innovation process. Traditionally, the outputs of R&D, patents, and trade secrets, which can be produced in house or purchased externally, provide companies with the so-called “freedom to operate.”⁷ Databases (especially proprietary ones) are also included in intellectual property. Once created, a customer database provides firms with future opportunities to sell new products or to learn more about how customers use a firm’s products.
- **Organizational capital** refers to business models and processes, networks and alliances, and special competencies of the firm, such as marketing or design. Business models that encourage sharing of information among employees or encourage interdisciplinary interaction may encourage innovation.

While this framework largely follows the established literature, it departs by not including all intangible assets. An example is “brand.” Researchers such as Corrado, Hulten, and Sichel (CHS, 2006) and Nakamura (2001) have listed a brand (e.g., Coca-Cola or De Beers) as an intangible asset that should be included in national accounts.

⁴ Meyer and Harper write that “multifactor productivity change results from joint influences on economic output of technological change; efficiency improvements (for example, because of better transportation or communications); returns to scale; reallocation of resources (such as shifts of labor among industries); and other factors, after allowing for the effects of capital and labor growth.” An example of a source of efficiency improvement is the Internet.

⁵ This is not the only approach available. Innovation has been treated as a residual in many growth models. In this report, this method is discarded because we do not think it provides enough insight into the factors that lead to innovation.

⁶ This mimics the method of Corrado, Hulten, and Sichel (2006).

⁷ Based on the summary of the Venture Capitalist interview in Stone et al. (2008).

We agree that brand is an intangible asset, but we do not believe that it feeds directly or materially into the innovation process. As a result, we do not include it here—our focus is on capital, tangible or otherwise, that leads to future innovation.⁸

Table 3 lists possible sources of data that could be used. *This table is illustrative rather than definitive.* The table is meant to demonstrate that appropriate data can be collected.

Direct sources for several of our categories are not available; however, for some categories, proxies are identified that could be used until better data sources are developed. For example, there does not appear to be a source for business spending on networks or alliances, so the revenues of professional, business, and trade organizations are used as a proxy.

These data sources are not designed to measure intangible capital. Therefore, as in Nakamura (2001) and CHS (2006), crude guesses about the proportion of spending that is investment would have to be made. Lack of data, by itself, is not a reason to abandon this framework. Neither are definitional issues. For example, the International Accounting Standards Board (IASB) offers inconsistent and sometimes conflicting guidelines for the treatment of intangible assets. In time, the standards can be resolved and appropriate data sources developed for measuring intangibles. The same is true for measuring innovative activity.

Capturing incremental innovation is likely to remain difficult even if problems with accounting standards are resolved. For example, some retail firms consider incremental innovation a continuous process that is part of daily operation of all employees, rather than a periodic activity to be engaged in by a subset of senior executives. In such cases, tracking innovation would require employees to record their time as “innovation” or “other”—an onerous task that would be unlikely to occur at many firms. As a result, incremental innovation may be missed in any data-collection scheme.⁹

Another factor typically not included in intangibles relates to foreign workers. Workers who move to the United States each year bring with them a “mother lode of education and skills—human capital—for free” (Mandel, 2006).

⁸ Note that the primary tangible capital that leads to innovation is information and communications technology (ICT) infrastructure.

⁹ Examples are from interviews conducted for the study by Stone et al. (2008).

Table 3. Framework 1: Measuring Innovative Activity

Type of Asset	Description	Data Source
Human Capital	Employer-Provided Training	American Society for Training & Development (ASTD) conducts an annual survey of members. The U.S. Department of Labor also has surveyed employer-provided training, although the most recent survey is from 1995.
	Experience	No measure found. Ideally, this would be measured as the differential pay that can be attributed to an individual's additional years of work.
Intellectual Capital	R&D	National Science Foundation collects data on R&D spending in the biological science, engineering, computer science, and physical science industries. The first survey was conducted in 1957. ¹⁰
	Databases	Database development is normally included in information technology (IT) budgets (see below, ICT infrastructure).
	Movie Development	Motion Picture Association of America (MPAA) collects data on film production costs.
	Music and Book Development	U.S. Census Bureau's Economic Census collects information on payrolls of performing arts groups as well as record companies. This could be used as a proxy. In addition, the Economic Census collects data on the book publishing industry.
	Patents and License Fees	No national database covering trade in patents or license fees exists. The U.S. Bureau of Economic Analysis International Survey covers international trade in intellectual property.
	Trade Secrets	No source found.
Organizational Capital	ICT Infrastructure	Computer Economics collects data on IT spending, staffing, and technology trends and publishes it in an annual report. The first report was published in 1989. AMR Research also collects trend data on IT spending for both software and infrastructure.
	Alliances and Networks	Proxied by the revenues of business, trade, and professional organizations. The data are collected by the U.S. Census Bureau's Economic Census.
	Marketing	Blackfriars Communications Inc. conducts a quarterly survey of 100 senior marketing executives. The company collects data on 12 types of marketing spending.
	Business Models	Proxied by the revenues of management consulting firms. The data are collected by the U.S. Census Bureau's Economic Census. The International Franchise Association released a PricewaterhouseCoopers study (highlighted here) on the economic output of franchises. This study contains data on the number of franchises and the minimum required investment for each.
	Design and Prototyping	Proxied by the revenues of engineering and design firms. The data are collected by the U.S. Census Bureau's Economic Census.

¹⁰ The new National Science Foundation (NSF) Business R&D and Innovation Survey (BRDIS) covers a variety of data on the R&D activities of companies operating in the United States. The five main topic areas are financial measures of R&D activity; company R&D activity funded by others; R&D employment; R&D management and strategy; and intellectual property, technology transfer, and innovation.

Jonathan Ive, for example, who designed the iPod and iMac, was born in England and educated at Newcastle Polytechnic University of Northumbria before moving to the United States and joining Apple in 1992. Mandel further elaborated:

Most of the workers who immigrate to the U.S. each year have at least a high school diploma, while about a third have a college education or better. Since it costs, on average, roughly \$100,000 to provide 12 years of elementary and secondary education, and another \$100,000 to pay for a college degree, immigrants are providing a subsidy of at least \$50 billion annually to the U.S. economy in free human capital. Alternatively, valuing their contribution to the economy by the total wages they expect to earn during their lifetime would put the value of the human capital of new immigrants closer to \$200 billion per year. Either the low or high estimate would make the current account deficit look smaller.

Framework 1 provides a window into the “black box” of innovation. Measuring these intangible innovation assets in this way will allow researchers to explore the link between innovation and growth. The framework will allow researchers to estimate the relative importance of a variety of types of innovative activity.

Despite the prominence given to R&D in the innovation literature (it has been included in innovation surveys since the 1970s), CHS (2006) estimates that R&D represents only a small portion of the investment in intangibles. Because other intangibles, such as firm-specific resources and nonscientific R&D, are growing faster than scientific R&D, this framework would help researchers understand how the sources of innovation evolve over time.¹¹

Framework 2: Measuring Investments

In Framework 1, the focus is on measuring the intangible capital generated by specific innovation activities. The framework does not measure innovation per se; rather, it measures specific investments that make it more likely that innovation will occur. This framework makes specific assumptions about the activities that lead to innovation (e.g., science is important, but accounting is not). Early measures of innovation centered on the technological aspects of product and process innovations. Recently, questions about business organization and marketing innovations have been added to the innovation measures and surveys.¹²

In Framework 2, the focus is on understanding what investments are necessary for innovation and growth. This framework measures the most basic investments that create an environment in which innovation can occur. Again, based on discussions with key

¹¹ See the description of Cisco in Branscomb (2008).

¹² See Stone et al. (2008), Chapter IV, and Appendix C for details.

personnel at U.S. companies and from a review of the innovation literature, three fundamental investments are identified as necessary for innovation to take place:

- Human capital in form of skilled, educated employees.
- Technical knowledge, including information and facts employees can apply.
- ICT infrastructure, which is the way employees organize and communicate information and facts.

Human Capital

There is little disagreement that human capital is an important source for economic growth (Aizcorbe et al., 2009). The companies whose representatives we consulted also considered human capital an important input to innovation. Some firms provide extensive training for employees, while others focus on hiring individuals who already have the training and skills required for the job or strategically access knowledge and skills not internally available. Some companies use a combination of hiring trained staff and training internal staff.¹³ This fact suggests that the real source of innovation is not engineering or marketing in isolation, but rather in combination with a highly trained and skilled workforce.

Many of the activities in the first framework, such as those included under organizational capital, can also be attributed to the workforce employed. The retail firm Staples, for example, has a small procurement team that continually negotiates with suppliers. The relationships that this team has developed with its suppliers allow Staples to improve its customer service through incremental innovation (Stone et al., 2008). Forming alliances and joint ventures depends on relationships developed by individuals within the firms. Again, these examples suggest that innovation stems from the human capital rather than networks and alliances (Branscomb, 2008).

In the first framework, human capital is measured as firms' spending on employee training. Hill and Youngman (2003) propose that all vocational training should be considered capital formation. *In this framework, we go even further and suggest measuring all education, including K-12.*

Innovation, by its very nature, is constantly changing. Twenty years ago, few would have predicted the success of firms like Nintendo (developer of the Wii videogame system). Certainly there were no community college programs for videogame design. We cannot predict what other new, innovative professions will appear over time. Today, many college students do not major in their chosen career field, a trend likely to accelerate as history majors decide to become marketers or business managers or literature majors go on to graphic design. Steve Jobs, a universally acknowledged innovator, does not have formal training in any science and technology field—he dropped out of Reed College

¹³ See interview summaries with Sun Microsystems, wTe, and POM, respectively, in Stone et al. (2008), Appendix E.

after one semester. By focusing on measuring *all* education rather than just education in programming, engineering, or marketing, Framework 2 captures the broad array of educational investments that give rise to new professions.

Including K-12 education in the framework is more controversial than including all postsecondary education. But we argue there are two valid reasons for doing so. First, students cannot pursue postsecondary education without a foundation of basic education. This framework seeks to measure *necessary* investments for innovation. Decreasing investment in basic education will lessen society's ability to produce highly trained, skilled individuals. Second, implementing new technologies or processes in production requires a workforce that is literate and in possession of basic skills. In addition, many new marketing strategies—particularly Web 2.0 applications such as MySpace and Facebook—invite customer participation and customer content. A Web-based viral marketing campaign, for example, does not work if customers do not use the Internet and cannot read or write. Therefore, including K-12 education in the framework marks it as an indicator or component of the United States' innovation environment.

Hill and Youngman (2003) are concerned about the impact on production of omitting the processes that form human capital. This is why they suggest using only human capital formation that is vocational in nature. We believe that the interaction between consumers and producers is also important to innovation and that all education should be included.¹⁴

Education is not the only input into human capital. Health care, nutrition, and environmental factors, among others, also play a role. These topics are not addressed in this proposed framework. We also realize that not all inputs into human capital affect innovation. However, we do not yet understand which human capital investments lead to more innovation and which simply enhance human capital. As a result, we focus narrowly on education, rather than on the broader range of human capital inputs.

Technical Knowledge

Technical knowledge in the form of R&D, patents, or trade secrets was mentioned frequently by the firms we interviewed. Some companies employ individuals with specialized skills and protect the methods by which they carry out these skills (such as pricing models) as trade secrets. Some large companies buy smaller firms that have developed new products, and others carry out their own R&D—both in house and through open sourcing. We propose that all technical knowledge can be traced back to R&D, whether internal or outsourced. Many of the firms we interviewed seemed to use technical knowledge and expertise interchangeably (Stone et al., 2008). One company—an insurance provider—not only mentioned technical knowledge in terms of pricing models, but also in terms of knowledge about consumer behavior. Thus, our definition of technical knowledge would mirror CHS's scientific and creative property development.

¹⁴ We recognize that K-12 education will be large relative to other investments in innovation. However, we believe the focus should be on how changes in such investments affect growth.

We also suggest including nonscientific R&D, such as grants to writers, motion picture development, and other creative endeavors in the technical knowledge account.¹⁵

Information and Communications Technology (ICT) Infrastructure

ICT infrastructure is used in a variety of ways by all companies. One innovative method is the use of ICT for operations and communications—both internal and external—and for innovative processes. For example, ICT is critical for “boundary spanning” firms such as Innocentive, a portal that connects “seekers” and “solvers” of R&D and that uses the Internet to create an open innovation marketplace. Technology allows members within and outside the involved firms to communicate and collaborate despite being widely separated geographically.

Much of the ICT infrastructure is tangible and is already included as investment in GDP. The purchase of servers and the laying of fiber optic cable are examples. Software too has been added to the national accounts. We would propose adding use of the Internet for marketing (through creative Web design) as well as investment in creating “collective intelligence spaces”—social networking sites that connect innovators within and across firms. An example of the latter is Threadless, a community-centered online apparel store where members of the community submit t-shirt designs online, which are then put to a public vote. A small percentage of submitted designs are selected for printing and sold through an online store. Creators of the winning designs receive a cash prize and store credit. In this way, the firm has outsourced—or “crowdsourced”—its R&D.

This example supports our decision to include K-12 education in the innovation framework. An individual does not need to have had a college-level education to participate in this sales model—but does need to be literate and possess basic computer skills.

The recent additions to the international innovation surveys and CHS’s estimates of the rising importance of firm-specific intangibles suggest that we cannot predict which areas will be most important to innovation. Indeed, an OECD (1998) paper asks policymakers to avoid restricting their policy instruments to scientific fields. Instead, OECD (1998) recommended that “all know-how [that] contributes to social welfare should be taken into account.” Unlike our first framework, this one does not seek to define specific investments in innovation, such as marketing expertise or the development of new business models. Instead, it takes a higher-level approach that focuses on the investments that make new marketing strategies or business models possible.

This higher-level approach can not only avoid future errors of omission, but also can prevent current ones. Open source innovation (the development of Linux, for example) presents a problem for our first framework because open source products are not necessarily owned by anyone and methods to track all open innovation spending do not exist.

¹⁵ BEA plans to incorporate investments in artistic outputs in GDP accounts in 2013. These artistic outputs are mostly motion pictures and sound recordings (Aizcorbe et al., 2009).

How do we then measure the investment in knowledge and skills of the unpaid individuals creating the goods and services? The market value of publicly traded open source management firms such as Red Hat could be a proxy, but that is rather unsatisfactory. The market value measures the stock of investment rather than the flow and is subject to gyrations. Furthermore, such companies appear only after innovation begins to take place. In other words, open source innovation occurs first and then a management firm appears. Our first framework fails to capture open source innovation because it is focused on measuring investment in specific activities. The fundamental investments approach does not need to assign investment specifically to open source because it has already captured the investment in human capital and ICT infrastructure that enables open source innovation.

Other areas to explore are the contributions to innovation made by government and other nonprofit sectors. For example, the databases created by statistical agencies such as the U.S. Census Bureau contribute to innovation; firms use the data, for example, to assess possible markets for goods and services. There are many other related areas to explore.

Table 4 presents possible data sources for Framework 2. *As with Table 3, this table is illustrative rather than definitive.* Data are much easier to find for this framework, but data availability alone is not a good enough reason to prefer it over the first one. This framework provides much less detail and it does not offer a window into the black box of innovation. Despite this, it addresses the fundamental sources of innovation and is highly flexible. More importantly, the framework puts the emphasis on the fundamental investments made by firms, government, and individuals that lead to future innovation.

Table 4. Framework 2: Measuring Investments

Type of Capital	Description	Data Source
Human Capital	Employer-Provided Training	American Society for Training & Development (ASTD) conducts an annual survey of members. The U.S. Department of Labor also has surveyed employer-provided training, although the most recent survey is from 1995.
	Higher Education	Data on state and local appropriations for higher education (including state-funded financial aid) are collected by the State Higher Education Executive Officers. National Center for Education Statistics conducts the National Postsecondary Student Aid Study (NPSAS), which examines how students pay for postsecondary education. The survey is conducted every two to three years.
	Elementary/Secondary Education	Education Finance Statistics Center (EDFIN) of the National Center for Education Statistics collects data on education finance for elementary and secondary public and private education. The group also collects data on postsecondary public and private education.
	Experience	No measure found. Ideally, this would be measured as the differential pay that can be attributed to an individual's additional years of work.
Technical Knowledge	Scientific R&D	National Science Foundation (NSF) collects data on R&D spending in biological science, engineering, computer science, and physical science industries. The first survey was conducted in 1953.
	R&D in Social Sciences and Humanities	No single source of total grants. Some social science is included in NSF data, but humanities research is not.
	Movie Development	Motion Picture Association of America (MPAA) collects data on production costs.
	Music and Book Development	U.S. Census Bureau's Economic Census collects information on payrolls of performing arts groups as well as record companies. This could be used as a proxy. In addition, the Economic Census collects data on book publishing.
ICT Infrastructure	Organizational Capital	Computer Economics collects data on information technology (IT) spending, staffing, and technology trends, which is published annually. The first report was published in 1989. AMR Research also collects trend data on IT spending for both software and infrastructure.
	Website Design	U.S. Census Bureau's Economic Census includes website design in custom computer programming.

Recommendations and Future Work

In this paper, we build on the premise that innovation, defined broadly as the application of knowledge in a novel way primarily for economic benefit, is becoming increasingly important—not just for firms, but for nations. Governments around the world view innovation as a prerequisite for competitive advantage in a globalized economy and wish to measure—and therefore manage—innovation more explicitly.

Two alternative frameworks that provide a conceptual basis for measuring innovation are proposed here. Availability of data designed to capture innovative activities at the firm level is the main stumbling block for the first framework. One purpose of proposing such a framework, however, is to identify data needs and to set the stage for collecting the information in ongoing and new surveys. The second, higher-level framework has the advantage of data availability and flexibility because new sources of innovation would be captured.

The choice of framework used depends on the goal of the exercise. If the goal is to understand which parts of innovation (for example, R&D or alliances) contribute to growth and to understand the process, the first framework is more useful. Innovation researchers would prefer this framework because it would provide more detailed insight into the innovation black box.

One drawback to the first framework is that it assigns all growth attributable to innovation to firms. Firms have a certain amount of control, but do not necessarily own the intangibles assets (e.g., trained employees).

The first framework, however, also has the advantage of data availability. It captures government investment in research and development and ICT and it is possible that changes to government accounting will also enable collection of information on business database development.

The second framework is the one most able to capture the basic investments contributing to productivity and growth. This approach is much more fundamental and flexible in that it encompasses all innovative activities, even those that are not now known. For example, a new college major, such as videogaming, may be collected in education, or a new communication technology may be covered in ICT.

While the second framework does not give insight into the innovation process, it does assign ownership of the assets with individuals owning human capital and firms owning ICT (although assigning ownership of R&D is still difficult).

The second framework is also better suited to capturing investment by government, nonprofits, and individuals in addition to business, which is critical since firms are not the only economic actors that innovate. Government, nonprofits, and individuals produce

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investments that lead to innovation. The second framework, by measuring education, also is able to capture the inputs that form human capital, which, in turn, lead to innovation.

Future work in this area should focus on further understanding what businesses can and cannot capture, through more in-depth and systematic protocol-driven interviews with a representative set of firms, and then using this feedback to develop data sources. The frameworks presented in this report aim to guide this important research.

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