Using New Growth Theory to Sharpen the Focus on People and Places in Innovation Measurement

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Summary/Abstract

This paper builds upon the firm-based perspective of the *Oslo Manual* and details the areas where significant policy questions can be understood through an integration of data collected within that framework along with data that more explicitly address innovation as it relates to people and places, or human capital and geography. The perspective of "new growth theory" motivates the identification of gaps in existing innovation data to address the role of human capital in business innovation and the aspects of innovation activity that are geographically-localized. The paper concludes with opportunities for data development and data linkage that such integration offers.

Introduction

Innovation has become an aspirational goal of institutions across sectors of the global economy, as well as a common praiseword for creative or otherwise valued output. At the same time, this interest is accompanied by slippery ideas about what innovation is, how it comes about, and what its effects are. By providing guidance for the collection and interpretation of innovation data, the framework of the *Oslo Manual* focuses survey measurement at the firm level, providing an effective counterweight to vague and ambiguous concepts. For policy purposes, a framework that enhances the linkages between firms and measures of human capital and its mobility, and deepens the granularity of geographically-

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detailed data would increase the value and relevance of firm-based innovation data without sacrificing the benefits of clarity and comparability.

Broadly speaking, common goals for innovation policy at the national level include sustainable economic growth, good quality jobs, an increased standard of living, and addressing key health, environmental and social challenges (OSTP 2015, OECD 2014, OECD 2016). Many countries envision enhancing both firm-based innovation and entrepreneurship as key paths toward those goals (OSTP 2015, OECD 2010). These paths intersect as entrepreneurs start new firms that create new products and introduce new processes. Thus, innovation data for policy purposes should not only identify innovation within the firm, but also provide data and indicators of the actors involved and the dynamics of the process.

Firm-based data on innovation provides the structural foundation for identifying the introduction of new products and processes into the market. By integrating longitudinal firm level data with data about people and the geographic environment where they work, human capital inputs can be linked to innovation outputs. Systematic ways are emerging to link and structure innovation-related data so that we can understand it from multiple dimensions—the individual, the firm, and the community. The opportunities and challenges in exploiting new data sources makes this topic particularly timely. Linking of administrative records data with other data -- including survey data for individuals and businesses, patenting data, and external data sets-- provide opportunities to create and enhance data systems. Further integration employer/employee datasets with innovation surveys would increase the value of the rich firm-based data that is collected with the guidance of the *Oslo Manual*.

Administrative records data that link business registrations to employment and output levels for the US and for several European and other developed nations have shown a decline in the number of young, fast growing firms in the years since 2000 (Decker, et al, 2015, Bravo-Biosca et al, 2013, Criscuolo, et al, 2014). For the US this decline in fast growing young firms has been preceded by a long term decline in startups overall (Haltiwanger, Jarmin, Miranda, 2012). Given the role of entrepreneurship in the innovation strategies of many nations, this puzzle has drawn the attention of policy makers who note the relationship between startups and the introduction of new products into the economy (Council of Economic Advisors, US, 2016).

Part of the puzzle comes directly from the measurement challenge: identifying the incidence of innovation is a measurement problem with similarities to other hard-to-measure outputs. The output is intangible, often unique, and while products created by innovation are produced and sold in the market, non-product innovations are hard to identify. As a result, indicators of innovation are frequently proxied by inputs, such as R&D activity, indicators of invention, such as patenting, and indicators of overall technological change in the sector or economy, such as total factor productivity.

The approach we take here lays out a conceptual basis for identifying additional data and indicators using new growth theory as a focus. This extension of traditional economic growth theory provides the basis for an internally consistent framework for a large portion of data on the innovation process. The economic production approach is a tool to help to unpack the slippery language that results from difficult measurement concepts. The unifying features of these production models are the interactions between actors, which include individuals as well as institutions; inputs, which include physical capital, intangible capital, and useful knowledge; the activities they engage in; the environment that influences them; the outputs created by their activities; and the outcomes that flow from the activities. It is these outcomes that are often the ultimate targets of innovation policy.

By focusing on people and places several salient policy questions can be addressed, these include:

- What are the pathways through which education, invention, and entrepreneurial experiences result in innovation?
- What activities augment education in developing human capital? What kind of skills are acquired on the job? What impact do these activities have on outcomes?
- What factors drive differences in the level and growth rates of innovative activity across geography?
- What does the flow of skilled workers by industry sector and location tell us about the people engaged in innovative activity?
- What relationships between workers propel innovation?
- Do recent declines in the presence of small fast growing firms in many parts of the developed world reflect a decline in innovation?

Background

The scope of innovation and its operational definitions trace back to the foundational theorist of innovation, Joseph Schumpeter. He viewed economic development as carrying out new combinations, a concept he identified with five cases: 1) new and improved products, 2) new and improved production methods, 3) the opening of new markets, 4) the acquisition of new sources for raw or intermediate inputs, and 5) organizational changes in the firm or sector, including the creation or destruction of a monopoly position (Schumpeter, 1934). The scope of his writing included the role of individuals in economic development through new combinations of enterprises; these individuals he called "entrepreneurs." The dynamic process of new combinations appearing and old technologies being replaced led Schumpeter to identify the defining feature of innovation as "creative destruction," characterized by the birth and death of firms.

This perspective is further developed in the "Schumpeterian theory" of economic growth, where long-run economic growth is due primarily to innovation. This growth is the result of investments in

R&D and human and physical capital, driven by the activities of entrepreneurs within a set of institutions and policies, as well as by creative destruction (Aghion, 2016).

Innovation as a driver of growth has also become rooted in the innovation policies of many nations as well as subnational units of geography, where outcome measures of innovation are jobs, firm creation, wage growth, and growth in economic productivity.

This last measure, productivity, holds a central role in estimating the overall impact of innovation in the economy. Using national economic accounts data, changes in total economic output can be decomposed into the effect due to the changes in inputs and a residual not accounted for directly by inputs, referred to as total factor productivity (TFP) or multifactor productivity (MFP). Standard inputs are labor, physical capital and intangible capital. The contribution of capital inputs is measured by the accumulated stock of these inputs over time, after accounting for depreciation, which includes obsolescence. These physical and intangible capital inputs are based on the flow of services from the accumulation of capital.

The growth accounting framework can provide an organized and comprehensive way to look at the growth of inputs and its relationship to the growth in outputs. The grounding of growth accounting in the framework of national income accounting and the linkages to economic sectors and industries makes the analysis very broadly useful for research, policy, and international comparisons. It can provide a measure of the relative contributions of different inputs and types of capital to GDP growth. The residual after accounting for these inputs, TFP, is understood to be a broad measure of the impact of innovation.

The Oslo Framework and the Incidence of Innovation

The Oslo innovation framework focuses on the activity of firms, building from Joseph Schumpeter's view of the central role of firms driving innovation in a market economy. The Manual's great strength is this focus on firms, whose rent-seeking behavior and differential successes drive innovation and economic outcomes. *Innovation* is intangible, often unique, and while products created by innovation are produced and sold in the market, the incidence of innovation is difficult to identify as a discrete transaction at a particular point in time. According to the third edition of the *Oslo Manual*:

> "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in businesses practices, workplace organization or external relations.
>
> A new or improved product is implemented when it is introduced on the market. New processes, marketing methods, or organizational methods are implemented when they are brought into actual use in the firm's operations.
>
> An innovation must be new to the firm. This includes products, processes and methods that firms are first to develop, and those they have adopted from other firms or organizations (OECD European Communities 2005)."

Because its survey recommendations provide a clear focus on the incidence of innovation in a firm as a distinct measure compared with innovation inputs and related activities, the *Oslo Manual* definition of innovation is broadly used. The relative clarity of these recommendations has provided a reference point for researchers and policy-makers, whose practice requires the use of partial indicators and proxy measures.

The activities of firms do not take place in isolation; flows of knowledge are important components of systems approaches to innovation. They emphasize that innovation policies, infrastructure, institutional framework, and educational institutions interact with firms in ways that affect demand for the firms output as well as the cost of inputs (OECD/ European Communities, 2005). While these systems approaches emphasize dynamics, much useful data that can inform important policy-related questions about innovation appear outside of the *Oslo Manual's* explicit guidance. The manual notes that although human resources are important, "methods for measuring the role of human capital in innovation are not well developed, and limited information is available from surveys (OECD/European Communities, 2005 para 5.7.1). Although the manual identifies the regional innovation systems as potentially important for infrastructure, clustering, and for creating a strong entrepreneurial environment, guidance for relevant data collection is not provided (OECD/European Communities, 2005 para 4.4).

From Growth Accounting to New Growth Theory

New Growth Theory focuses on the transformation of inputs to outputs, and augments standard growth accounting to emphasize the feedback from accumulated stocks of technological knowledge that fuels further economic growth (Romer, 1986, 1991, Lucas, 1988). Key features are that production creates useful knowledge, and that this knowledge can be used by many and used repeatedly without being exhausted. Knowledge is both an input to the creation of new goods and the creation of an output that adds to future input. This knowledge can be intangible assets such as patents, blueprints, and designs that are the result of formal R&D activities as well as learning by doing and other forms of knowledge acquired by workers and business owners. Knowledge also spills over to users outside the firm. As knowledge and human capital accumulate, increasing returns are possible.

As a market-driven activity, innovation tends to take place where human capital is relatively abundant and low cost. As knowledge investments diffuse, they produce growth benefits or spillovers with a localized dimension that drive additional growth (Grossman and Helpman, 1991). These localized spillovers are in part the result of the transmission of informal knowledge between people as they work together and otherwise interact. While electronic communication allows knowledge that is recorded, such as in publications, patent applications, algorithms, and software code to be repeatedly accessed, stored and transmitted around the world without person to person contact, informal knowledge resides in the mind of individuals. It can be information about processes that has not yet been recorded, and in some cases may never be. It is gained by experience and by person to person contact. As a result, while recorded knowledge can travel very broadly, informal knowledge tends to have a geographically local focus.

Several implications of new growth theory then are that knowledge and intangibles can be used by multiple users without diminishing the benefit to each, that human capital is a key input to research and innovation activity, that both types of capital inputs produce spillovers that can drive growth for other firms. All of these implications of new growth theory suggest an enhanced importance for innovation activities and outcomes at geographically localized levels.

Why Geographically-localized Innovation Matters

While geographically localized benefits from localized knowledge are a direct implication of new growth theory, they are not the only factors driving the geographic concentration of innovative activity. The local density of workers with specialized skills and concentration of other inputs also lead to increased efficiency and lower costs for nearby firms in related industries.[2]

[2] These effects are known as MAR flows, for the three intellectual threads that join them, Alfred Marshall, Kenneth Arrow, and Paul Romer.

Geographic cluster models describe the way that localized spillovers can allow firms to achieve economies of scale without actually becoming a larger firm. We observe geographic concentration in R&D activity (Shackelford, 2012), as well as of innovation (Feldman and Kogler, 2012), and of venture capital funding (National Science Board, 2016).[3] The concentration of knowledge, local capacities and scale economies enhance the ability of firms within these clusters to produce innovations (Porter, 1990, 1999).

The knowledge flows emphasized in new growth theory operate in the context of other geographically-localized spillovers. Uneven distribution and subsequent growth of these factors can lead to divergence in outcomes across locations, with the potential to foster increasingly uneven outcomes across regions within a country. The ability of local clusters to generate faster growth has implications for innovation policy and data needs. National innovative capacity is a function of the ability of regions and clusters to produce and commercialize innovations, and the distribution of this capacity is skewed across regions. The skewness of regional performance implies that national innovation and its impacts are dependent on the performance of regional systems of innovation. Increasing a region's capacity for innovation is one area where national and regional policies intersect.

Clusters and Economic Performance

Despite the importance of local activity in understanding the impact of knowledge creation and innovation activities, data at the subnational level is inadequate for tracking the relationships between inputs and outputs, and for evaluating innovative capacity. Three specific limitations that decrease the

[3] In the United States in 2014 three quarters of this funding went to just three states, California, New York, and Massachusetts (NSF data, 2016 Indicators), while these states made up about one quarter of GDP in 2014.

value of existing data for policy purposes are insufficient granularity, limited data on outcomes, and delays in data publication (Feldman, 2016). Survey-based data are often not designed to provide state and industry cross-tabulations of variables. For these subnational areas, confidentiality issues and resource costs also substantially limit the ability of survey data to replicate the innovation outputs and outcomes data that are available at the national level. Outcomes measures that reflect the strength of local clusters are growth in employment, wages, establishments, and patenting (Delgado, Porter, and Stern, 2002). The US Cluster Mapping Project uses county data at the detailed industry level and occupational statistics to model and map industry clusters, using inter-industry relationships from national and regional data sources.

These business-based statistics show the industries that are linked together by input-output relationships, and by occupational similarities, and are measures for evaluating aspects of a region's capacity for innovation. This capacity can be characterized at the local level by measures of highly trained scientists and engineers whose skills match the local opportunities, a local competitive environment that rewards firms as well as innovators, local demand for the cluster's products, and the density of interrelated firms (Stern, Porter, Furman, 2000). Cluster mapping work has produced interactive datasets available for researcher and policy-makers to understand the composition of clusters in their region (for example, Harvard University and US Economic Development Agency Cluster Mapping Project).

This project and others have been inventive, if not innovative efforts to fill in the data gaps for regional innovation. Regional models often rely on administrative records data like local business registration data, patents and trademarks, and university-level resources devoted to R&D. Administrative records data, such as patents or firm startups, have more robust coverage because they account for each relevant unit and include location as part of the record. However, because the interrelationships of firms within a region are the product a dynamic process of firms emerging, growing, and shrinking over time, to provide policy-makers with the tools they need, these data need to be enhanced and organized longitudinally to show the actions, interactions, and outcomes of inventors, institutions, entrepreneurs, investors, and workers (Feldman, et al, 2012).

As Decker et al (2015) and others have shown small fast growing firms have been declining in recent years. This leads to concerns about the implications for business dynamism and innovation. Small, fast growing firms have played an outsized role in job creation, such firms are also a very small share of all firms, thus understanding the characteristics of these firms can shed light on the factors that led to this decline. While Guzman and Stern (2015) show that business records data collected on owners and the characteristics of their new business have value as indicators of firm formation and intention to grow, local factors external to the firm have an influence as well.

The presence of capital to fund early growth of small firms is an important component of capacity to innovate. However, the distribution of venture capital funding is sharply concentrated. For example, just three US states, California, Massachusetts, and New York received 75% of the venture capital funding in the U.S in 2014. This skewness in the distribution of funding has become more concentrated over time (2016 Indicators, Chapter 6).

Potential explanations for this include underdeveloped support systems for young and small innovation-based companies and funding gaps in local markets for entrepreneurial capital. The result can be out-migration of these small companies toward regions with stronger support for these firms as they grow (Zeidonis 2016). Thus, in addition to information about the firm and its founders, characteristics of the regional system in terms of access to support, mentorship, and funding also help researchers and policy-makers understand the dynamics that support regional innovation and design policies to support it.

The kind of data needed for the evaluation of regional innovation policy also needs to address treatment effects, or the differential outcome for firms when they have participated in a particular program compared with those that have not participated. National level programs like the US Small Business Innovation Research program provide competitive funding or loans to small business to commercialize their research, and several states have developed programs that either enhance this funding for local activity, or create their own similar programs (Feldman and Lanahan 2014, Zeidonis, 2016). However, the impact of these decentralized local programs are hard to evaluate because the data are not collected comprehensively and integrated with other funding sources. Zeidonis (2016) describes the challenge of collecting limited data on one such R&D loan program for the state of Michigan.

A dataset that tracks the characteristics and outcomes for participants in two Seed Accelerators, collected by web-scraping data from the LinkedIn and Crunchbase pages of the participants, provides information for these participants and almost 400 startups overtime (Winston-Smith, 2016). These programs provide short term support to startup firms in the form of work space, networking support and mentorship, and limited capital. As with the location of venture capital, the distribution of these accelerators is very concentrated.

A particularly granular data collection effort for the Research Triangle region in North Carolina provides detailed longitudinal information about the growth and change of a regional technology cluster. Feldman and colleagues update and maintain another unique dataset created for the Research Triangle region in North Carolina. This relational database focuses on the emergence and lifecycle of local technology firms for a large multicounty region. While the dataset has been collected from local sources over many years, it provides a model for use in other regions for long term dynamics of local technology firms. It links information history, employment, sector and technology, patenting, licensing, government grants and funding institutional supports on the firm side with data about the firm's founder, their education, work history and university and other institutional relationships. Relevant questions it can address include history of the creation and growth of firms within the regional economy, including the mobility of founders within the region, and the number of firms that have spun off over time from universities and R&D intensive firms (Feldman, 2016).

Human Capital and Innovation, Human Capital and Skilled Workers

New growth theory suggests human capital has a central role in productivity and in innovation, as a stock of useful knowledge that can generate continued growth. Human capital is the sum of the attributes of individuals that, when used in production, yield income to the individual over the long term. Investments in human capital include formal investments in education, training, and health, as well as experience gained through on the job training and other activities (Becker, 2008). Human capital is an input to innovation in several ways. First, through the skill and experience of the workforce of existing firms, second, through the creation of new firms that introduce innovations, and third, through the interactions between firms and other institutions that transfer ideas, knowledge, and technology.

Human resource data provides an underutilized source of information on the education, skills, and experience of human capital that can be linked to firm-based data, to data on entrepreneurship, business creation, patenting, and on collaborations between individuals. This section describes several dimensions of human capital that enhance its value for innovation. Intangible capital in the form of R&D and human capital are both inputs to innovation, but they are knowledge flows with different dimensions and dynamics. The hiring of new PhDs into industry is a pathway for the transmission of new knowledge into R&D labs, these flows go to other industry workplaces as well. Analysis of US data has shown the spatial pattern of these flows is less geographically concentrated than R&D expenditures and judging by the flows of new PhDs, small firms have a contribution to innovation not reflected in R&D expenditures (Stephan, 2006).

Supplementary data like these on inputs to innovation are useful because important sources of the ideas for innovation come from outside of firm R&D labs. Evidence for this comes from Community Innovation Survey data (Frenz and Lambert, 2012) and, for U.S. manufacturing firms, the Duke/Georgia Tech American Competitiveness Survey (Arora, Cohen, and Walsh 2014). For the latter, about half of the respondents to that survey report that the invention underlying their most important innovation was external to the firm, with the customer as the most frequent source, followed by outside technology specialists, then suppliers. Other channels include service contracts, licensing, cooperative R&D, and joint ventures.

Data on the regional and industry patterns of hires of new PhDs thus may help understand the patterns of innovation missed in firm-based R&D data, as well as providing data to understand how human capital contributes to firm-level performance and innovation. (Stephan, 2016). City-level flows of new PhDs and flows from universities to cities or MSAs can show a more geographically focused measure of human capital flows to firms; data classified by field of science provides a further dimension of the demands of industry for this input.

When these data on PhDs and other highly skilled workers are integrated with employer/ employee data, these human capital flows can begin to be quantified in terms of their value to the firm. This is relevant for the kinds of outcomes that national and subnational policy-maker are concerned with: earnings and economic growth for workers with high levels of human capital as well as other workers in the firms where they are employed. A recent proof of concept working paper linking data on new PhDs to employment and earnings data at the establishment level provide indicators of the returns to different types of degrees, (Zolas, et al, 2015).

Invention

While education is a major determinant of human capital, invention can provide an additional measure of the value of human capital for the firm, as measured by the earnings received by inventors, other workers, managers, and firm owners. A growing set of literature uses administrative records data to understand the returns to inventors. Recent work with Finnish employment and income data linked with patent data provide information on the impact of inventing on earnings. Toivanen and Väänänen (2012) use a time series of patent data and matched employer/employee earnings data to examine the impact of patenting on earnings in subsequent years. They find that patent grants yield a near term impact on annual earnings of 3% to the inventor, and that highly cited patents yield a longer term impact of 30% to inventors, signaling an additional dimension of human capital distinct from education.   More recent work with the Finnish data set find that the gains from the human capital of inventors extends to other workers in the firm, with entrepreneur/owners gaining the largest increase, followed by managers, then the inventors, then by blue collar workers. For blue collar workers the gain is a near term one that decreases over time (Aghion et al, 2016).

This kind of linked analysis also provides information about the characteristics of inventers. The probability of becoming an inventor, based on patent data as the measure of invention, is many times higher for individuals from the highest income families, compared to those from the lowest income families. Using US tax records data that provide information on income, educational background, residence, and employers, Bell et al (2016) construct a database that tracks the activity of people who become inventors, based on patent data linked to both individual tax record data and childhood math test scores. In addition to the skewed relationship between family income and the propensity to patent, the linked analysis identifies other determinants of inventive activity. Exposure to science and innovation in childhood increases the probability of becoming an inventor, both through the influence of parents and by the rate of invention in the area where the individual grew up.

Human capital includes experience as well as formal education and skills, so the relationships and networks formed by collaboration are additional measures of human capital applied to innovation. A more complete measure of human capital for scientists and engineers would include patents and publications as well as entrepreneurial experience with startups. Given the spatial concentration of innovation and the localized impact of tacit or informal flows of knowledge, human resource data has an important role in modeling open innovation and the division of innovative labor, through the location and activities of skilled workers.

What linking administrative records data can tell us about human capital and innovation

Incorporating some of the fundamental insights of “new growth theory” in economics, three broad data gaps emerge: data that illustrates the impact of human capital on innovation at the firm level, data linking firms to the people who are innovating as a means to better understand how the innovations emerge, and data linking firms to the characteristics of their geographic region to better understand the policies that support the firms’ innovation activity.

While survey data collected in the Oslo framework provides information about the outputs of innovation, linking data about workers and entrepreneurs to firms provides a way to look at outcomes, through linking data on firms to data on jobs and productivity, including mobility. Because administrative records data more fully cover the population of firms compared with nationally representative survey data, more granular analysis of subnational units and industries is possible.

Several of the data analyses described here involved substantial work collecting and creating data sets that can make policy actions more effective. Longitudinal datasets support policy analysis by linking administrative data on individuals, employees, and firms. Greater integration of the available data, structured in a systematic way, can facilitate analysis at multiple levels—individual, business and community. Expanded use of these data to track innovation has the potential to reduce respondent burden and increase the scope and granularity of the data.

Business register data capture firm births and deaths to provide insights into the patterns of growth by firms of different sizes and sectors, and provide evidence of declining rates of the kinds of activities that are seen as outcomes of the process of innovation—the creation of new firms and employment growth. Widely used to understand new job creation, the US Longitudinal Employer-Household Dynamics dataset combined data collected at the state level on earnings and employment with data from national censuses and surveys to form a dataset with both firm and employee characteristics. However, like all indicators, these are partial measures. The linkage between innovation and these outcomes are not well understood without integration of these partial indicators with others. Data collected from firms within the framework of the *Oslo Manual* provide a particularly good tool to better understand the role of innovation in these outcomes by linking existing firm innovation surveys to employer/employee databases, but for many countries, innovation survey data is absent for young and very small firms.

Patent data has just the kind of geographic, firm level, inventor, and technological granularity that can make it useful to explore the trends in small and fast growing firms, when integrated with other data. Invention is an important but partial component of the process that brings a new idea into use in the market, and patents are an important but partial measure of invention. For example, in the U.S., linking USPTO data to the Census Bureau Business Register, longitudinal firm data, and the Longitudinal Employer Household Dynamics (LEHD) provides indicators of the role of these firms in innovation. Graham, et al (2015) find that less than 1 percent of firms patent, but that small firms with less than 4 employees account for 17 percent of the total number of patenting firms, and that firms with less than 50 employees make up half of all patenting firms. By linking these data to firm employment, they find that while small patenting firms disproportionately contribute to jobs, their small number limits this impact to less than 1.5% of gross job creation.

While patenting provides a partial indicator of the way that innovation brings jobs into the economy, linked employer/employee data could also be integrated with broader measures of innovation. Business R&D and Innovation Survey data collected for the US tells us that 14.3 percent of firms in its sample reported a product or process innovation between 2008 and 2011 (Boroush and Jankowski, 2016). This suggests a much broader scope of innovation in the economy, compared with the granting of a patent as an indicator of innovation. Linking employer-employee data to Oslo-based survey data could develop more outcome measures using the relatively untapped variables on innovation surveys for firms who report innovation.

Proof of concept with US data has shown the feasibility of linking this kind of employer-employee data to US R&D and innovation data (Zola, et al 2015). For the Netherlands, Bartelsman, et al (2013) linked Community Innovation Survey data on firm measures of innovation (sales from new products for product innovation, and a binary indicator for process innovation) to the Social Statistics database for the Netherlands and used these data to evaluate the impact of innovation on productivity growth. The linkage to individual educational attainment within the data allow for human capital impacts to be estimated separately from the impact of innovation.

The Oslo Framework for understanding innovation in young and small firms is the basis for new data collections that eventually could also be linked to employer/employee datasets. The Microbusiness and Innovation Science and Technology Survey (MIST) developed by NSF's National Center for Science and Engineering Statistics will provide data for firms with fewer than 5 employees, and Census's 2014 module on the Annual Survey of Entrepreneurs includes questions about both product and process innovation and R&D costs and activities.

Entrepreneurship is a component of innovation policy for many nations (OSTP, 2015; OECD 2010). As inventors and founders of businesses move from job to job, they take knowledge and experience with them that is cumulative and is reflected in their work histories. Their mobility is an indicator of the diffusion of the knowledge they carry. Linking employment/earnings data, business register data and data from inventor's history of patenting over time could reveal insights into the career lifecycle of inventors and entrepreneurs, and through these individuals, diffusion of knowledge across careers and workplaces (Agrawal, 2016). Such data on the mobility of inventors into and out of employment and entrepreneurship answer questions about patenting in new firms, how ideas spread and how patentees become entrepreneurs (Agrawal, 2016). The knowledge, experience, and earnings of individuals, along with industry, firm size, and age of the firm where these individuals work can answer questions about the market for human capital.

Human capital data and the knowledge it embodies, gained from education, invention, entrepreneurship and other experience provide useful and underexploited data to measure inputs to innovation. A human-sized unit is well-suited to enhance firm-based data for both national and regional analysis. The substantial data gap for regional indicators of innovation include the regional capacity for innovation as well as information to understand the location specific dynamics of that process. These missing dimensions include funding sources for innovation, and outcomes from policy interventions. Already collected data from local, state, administrative sources have the potential to fill out some of the dimensions of this needed data. This can be done by linking research data sets, like those described in this paper to longitudinal employer/employee data. The path forward involves joint efforts between national agencies and research institutions. The evidence of highly skewed distributions for inputs to innovation, such as R&D, patents, and the availability of venture capital highlight the importance of more granular data, particularly at the individual and regional level.

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