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Sources of innovation and innovation type: firm-level evidence from the United States

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Abstract

Only a handful of studies on innovation empirically analyze the links between firm innovation and the sources of that innovative activity of sources of innovation on types of innovation. To fill this gap in the literature, this study provides one of the first tests to identify how important sources of new information (suppliers, customers, other business people in the industry, workers, and university) are associated with types of innovations (product, process, and marketing). Data come from the 2014 National Survey of Business Competitiveness sponsored by the Economic Research Service at the United States Department of Agriculture ($n = 10{,}952$). The results show that innovation ideas emanating from customers, workers, and universities are positively associated with all types of innovations, suggesting that these sources are critical for developing different types of innovation. In particular, universities as a source of innovation activity are especially important. In contrast, other sources, such as suppliers and people in industry do not seem to be as important as a source of innovation.

JEL classification: C18, C21, L10, O10, O30, O31, O32

1. Introduction

Innovation is one of the most discussed topics in the fields of business, economics, and management studies. Innovation can help an organization to adapt to the environment, survive, and grow (Burns and Stalker, 1961; Thompson, 2010), enhance economic growth and performance (Carlino, 2001; Verspagen, 2006), narrow the gap in productivity and economic conditions for less successful countries (Fagerberg and Godinho, 2006), increase competitiveness (Cantwell, 2006), raising living standards and prosperity of citizens (Aboal and Tacsir, 2018; Breznitz *et al.*, 2018: 883), help to reduce unemployment (Pianta, 2006), and help to deal with grand challenges such as poverty, climate change, and health (Kattel and Mazzucato, 2018; Mazzucato, 2018). Overall, innovation is a driving force of firm productivity (Stojčić and Hashi, 2014) and "central to the growth of output and productivity" of firms and nations (OECD/Eurostat, 2005: 10; see also –>Leyden and Link, 1992; Link and Siegel, 2007; Acs *et al.*, 2017).

Studies of innovation are roughly divided into two types. First, many studies treat innovation as a dependent variable, so they have examined factors affecting innovation such as determinants or conditions of innovations (e.g. Mohr, 1969; Kimberly and Evanisko, 1981; Damanpour, 1991; Greenhalgh *et al.*, 2004; Torugsa and Arundel, 2016a; Demircioglu and Audretsch, 2017a). The second type of study considers innovation as an independent variable, and examines the outcomes of innovation, such as how innovation influences efficiency, increases performance, improves the quality of services, and even increases the legitimacy of organizations (Damanpour *et al.*, 2009; Griffith *et al.*, 2006; Verhoest *et al.*, 2007; Brown and Osborne, 2012; Ballot *et al.*, 2015). This article uses the first approach and treats innovation as the dependent variable while analyzing how different sources associated with overall firm innovation activity and four types of innovations.

The magnitude and breadth of the literature on innovation and particularly sources of innovation reflects its importance. The famous conclusion attributed to Solow that innovation "falls like manna from heaven" (Aghion and Howitt, 1998; Link, 2013), may in fact ignore that innovation activity emanates from more earthly sources. Analyzing two types of knowledge spillovers—Marshall-Arrow-Romer (MAR) and Carlino (2001) point out that analyzing different sources of innovation goes back to 1890 when Alfred Marshall developed a theory on knowledge and innovation externalities. For instance, Nakamura (2000) explains how workers have been a key source of creativity and innovations for the last century. Additionally, research facilities and universities provide a source of knowledge and ideas underlying the development of many product and service innovations (Carlino, 2001). Thus, innovation sources are a crucial factor for innovation activities and different sources of innovation may result in different types of innovations.

Despite its central importance, there is only a paucity of studies actually attempting to uncover what exactly are the most important sources of innovation as well as their impacts on overall innovation activity and the various dimensions and manifestations of innovation. The handful of empirical studies found in the literature are typically restricted to descriptive, conceptual, qualitative analysis, or based on case studies (e.g. Borins, 2002; OECD, 2009; Birkland, 2011; Nasi *et al.*, 2015; Bankins *et al.*, 2017). This paucity of quantitative studies identifying and analyzing sources of new information and knowledge driving innovation activity limits both the ability of scholars to not only understand the innovation process but also thought leaders to formulate effective policies and strategies in policy and business. The purpose of this article is to make a least a start toward filling this gaping gap in the literature by analyzing how particular sources of knowledge impact both overall innovation activity as well as specific manifestations of innovation output. In particular, this article seeks to analyze how the important sources of knowledge, such as suppliers, customers, other people in industry, workers, and universities, are associated with specific types of innovations, namely, product, process, and marketing innovations. To address these questions, we analyze which particular knowledge sources generate particular types of innovations and overall innovation activity using quantitative methods.

The second important contribution of this study is to compare three distinct types of innovation—product, process, and marketing innovations, instead of just focusing on a grossly simplistic conceptual and aggregate measurement of innovation (e.g. whether innovation occurs or not). Despite difficulties in quantifying and measuring innovation activity, it is possible to measure different types of innovations (OECD/Eurostat, 2005, 2018; Smith, 2006; Bloch and Bugge, 2013; Bugge and Bloch, 2016; Demircioglu and Audretsch, 2018; Gault, 2018). Most of the extant research typically measures aggregated innovation activity by patents, as an outcome variable (e.g. Arundel and Kabla, 1998; Arundel, 2001). However, patents as an output does not capture many innovations. For instance, Arundel and Kabla (1998: 138) state that "Patents are a particularly poor measure of innovativeness in sectors such as food and tobacco, petroleum refining, basic metals, automobiles, and other transport equipment. In these sectors, the large majority of innovations are not patented." In fact, many innovations which are not patented (or aimed to be patented) are measured using the large dataset introduced in this article and explained below.

Additionally, three specific types of innovation exhibit different characteristics from each other and may emanate from distinct sources of knowledge. For example the knowledge sources underlying marketing innovations may be different than their counterparts for process innovations [see statistical results from the Policies, Appropriation, and Competitiveness in Europe (PACE), *Service des Statistiques Industrielles* (Statistical Service of the French Ministry of Industry; SESSI), Community Innovation Surveys (CIS), and Terjesen and Patel, 2017]. Thus, it makes sense to analyze these three types of innovations differently. For instance, the 1993 CIS survey showed that process innovation was about 25%, which was lower than product innovation (35.9%; Arundel and Kabla, 1998).

The third important contribution to the literature from this article is the unique and representative dataset for the US data that are analyzed. Despite the high propensity for innovation activity to spatially cluster within close geographic proximity to the knowledge source, resulting in notable innovative clusters, such as Silicon Valley, no systematic, comprehensive, and large-scale survey on innovation activity had been created for the United States spanning the entire economy. In contrast, Europe has devoted considerable resources and effort in creating and analyzing systematic and comprehensive measurement of innovation activity. Most prominently are the Oslo Manuals, the European Union's Community Innovation Surveys (CIS) conducted in different European countries, the Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT), MEPIN, and SESSI, resulting in a number of important and influential scholarly and policy publications (e.g. Arundel and Kabla, 1998; Arundel, 2001; Arundel and Geuna, 2004; OECD/Eurostat, 2005, 2018; Frenz and Ietto-Gillies, 2009; Battisti and Stoneman, 2010; Bloch and Bugge, 2013).

The limited datasets measuring innovation in the United States (e.g. National Science Foundation's Survey of Industrial Research and Development, CompuStat, and 1994 Carnegie Mellon University survey of manufacturing innovation) suffer in that they are neither comprehensive nor representative of American companies, and do not reflect the diverse and heterogeneous nature of both knowledge sources or types of innovations (Cooper and Merrill, 1997). Data limitations have restricted the ability of scholars to undertake comprehensive and wide-ranging studies on innovation in the context of the United States. Thus, an additional key contribution of this study is to provide one of the first comprehensive, representative, and systematic analyses of innovation in the context of the United States by using the National Survey of Business Competitiveness (NSBC) data.

In particular, the novel contribution of this article to the literature is to compare three different types of innovations (product, process, and marketing) to show how five important knowledge sources (suppliers, customers, other people in industry, workers, and universities) are associated with these three innovation types as well as overall firm innovation activity differently. The main research question of this article thus is how do important sources of knowledge are associated with main innovation types and overall innovation activity? There are two sub-research questions in this study. First, how do suppliers, customers, and other business people in the industry, workers, and university as sources of innovation contribute to product, process, and marketing innovations? Second, how do these knowledge sources contribute to the overall firm innovation activity (the aggregate of all types of innovations)? This article is organized as follows. The following section will explain and discuss sources and types of innovations. Part three will introduce and explain the important and novel data used in this study along with the methodology. The results of this study will be discussed in Section 4. This article ends with a discussion, limitations, and conclusion.

2. Sources and types of innovation

2.1 Sources of innovations

Several studies and reports have addressed the issue of where ideas come from and the sources/actors that contribute to innovation (e.g. Arundel, 2001; Borins, 2001; Arundel and Geuna, 2004; OECD/Eurostat, 2005, 2018; Walker, 2006; Hüsig and Mann, 2010; APSC, 2011; Bloch and Bugge, 2013; Torugsa and Arundel, 2016b; Demircioglu and Audretsch, 2017b). For instance, Arundel (2001) classified sources of innovation as external (e.g. customers, other firms, and their parent firm) and internal (e.g. from in-house R&D activities) with using the 1992 Community Innovation Survey. Analyzing surveys from 1993 Policies, Appropriation, and Competitiveness in Europe (PACE) survey, 1994 Carnegie Mellon Survey, and 1997 Community Innovation Survey II, Arundel and Geuna (2004) have identified public research institutes and universities, affiliated firms, suppliers, and customers as important sources of innovation. However, these major studies did not analyze workers and as a source of innovation.

Additionally, although these studies and our study have some similarities because both focus on sources or types of innovations, many differences exist. First, our dependent variable is type of innovation and overall innovations, while most other studies focus on the amount of R&D expenditures, patent applications, location, and geographic proximity of knowledge sources. Second, data for major studies focusing on sources of innovation are mostly from the 1990s and are not current. Third, other studies' sample size is usually small [e.g. Arundel and Geuna's (2004) main dataset, PACE, has only 588 responses]. Fourth, these many studies cover only the largest R&D-performing firms, so they generally exclude smaller firms and non R&D firms, which is also true for the US Business R&D and the Innovation Survey of 2008. Our study, on the other hand, is not restricted to high-performing firms. Fifth, most of the studies on innovation focus on Europe, but the focus of this study is on the United States.

Several studies analyzing public sector organizations have found that employees, regardless of their rank is very important and provides a valuable source of innovation in the public sector (Borins, 2001, 2002; APSC, 2011; Bloch and Bugge, 2013; Torugsa and Arundel, 2016b; Bugge and Bloch, 2016; Demircioglu and Audretsch, 2018). However, one of the greatest limitations of these empirical and case studies is that the findings are limited only to public sector organizations and exclude private firms. Additionally, due to data limitations, studies using the Australian Public Service Commission (APSC) data have focused only on individual and group levels of analysis and have generally ignored the knowledge sources and types of innovation at the organizational level. In contrast, the data used in this article make it possible to include both workers and universities as sources of innovation at the firm level. This is a very important and highly valued contribution to the literature. As Nakamura has pointed out, workers provide important sources of creativity and knowledge fueling firm innovation in the United States on the basis of his findings that the professional creative workers accounted for 0.7% of all employment (0.2 million) in 1900 and 1.9% of all employment (1.1 million) in 1950, and increased to 5.7% in 1999 (7.6 million), suggesting that the number of workers involved in creative and innovation activities continues to increase (Nakamura, 2000).

Additionally, Arundel and Geuna (2004) summarized many studies on innovation and patent applications and found that in both North America and Western Europe, knowledge and ideas emanating from universities and research institutions increase the quality and quantity of innovations. When firms are located far away from universities and R&D laboratories, firm-university interactions are less frequent, and firms may receive fewer ideas, ultimately reducing their innovation activity (Adams, 2001). In a recent study, Richardson *et al.* (2016: 132) find that "both scholars and public policy makers have viewed investment in university research as a key component to generating innovation activity." Thus, the effects of universities on types of innovation and overall innovations are vital to analyze. As Audretsch and Stephan (1996) find, "companies can also learn about the research occurring in university labs through social contacts between employees and university scientists and by sending employees to participate in workshops and seminars at the university" (Audretsch and Stephan, 1996: 646). Furthermore, Demircioglu and Audretsch (2017b) find that ideas emanating from universities are positively associated with the quality of public services, employee job satisfaction, and interagency collaboration. Thus, we expect that ideas emanating from workers and universities are positively associated with types and overall innovations and the association is statistically significant and meaningful.

2.2 Types of innovations

As the Oslo Manual argues, "It is not enough to know whether firms are innovative or not; it is necessary to know how firms innovate and what types of innovations they implement" (OECD/Eurostat, 2005: 13). Innovations can be defined differently. Slaper *et al.*, use the following definitions: "According to the U.S. Department of Commerce (2008), innovation is 'the design, invention, development and/or implementation of new or altered products, services, processes, systems, organizational structures, or business models for the purpose of creating new value for customers and financial returns for the firm.' Other authors offer similar definitions, including the Federal Reserve Bank of St. Louis (2007), which defines innovation as 'taking something established and introducing a new idea, method or device that creates a new dimension of performanceã and adding value'" (Slaper *et al.*, 2011, 37). According to Arundel (2001: 614), a firm is "innovative if it introduced a product or process innovation... includes firms that only make minor improvements or introduce new products and processes developed by other firms. Many of these 'minor' innovators might not develop patentable innovations." Therefore, innovations are different than inventions and the focus of this study is innovation.

Innovation is typically multidimensional (Torugsa and Arundel, 2016a; Demircioglu and Audretsch, 2018), so that several types of innovation exist. There are a number of distinct types of innovation activity, such as product, process, and organizational innovation (OECD/Eurostat, 2005, 2018; Walker, 2006; Radicic *et al.*, 2016; Gault, 2018). The Oslo manual was developed by the OECD and Eurostat in an effort to measure and analyze the impact of innovation activity (OECD/Eurostat, 2005, 2018). According to the OECD, product innovation has two dimensions—goods and services innovation, both of which introduce a "good or service that is new or significantly improved with respect to its characteristics or intended uses" (OECD/Eurostat, 2005: 48). Process innovation is "the implementation of a new or significantly improved production or delivery method [e.g. techniques or software]" (OECD/Eurostat, 2005: 49), and marketing innovation is "the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing" (OECD/Eurostat, 2005: 49).

All of these three types of innovations are crucial for organizations. For example, product innovation leads to an increase in firm profitability, as buyers tend to buy a new or updated product with more cost and process innovations usually leads improvement of methods and reduce costs (Fritsch and Meschede, 2001). Process innovations can create competitive advantage, efficiency improvements, and product growth to firms, justify government support for innovations, and help for economic growth (Terjesen and Patel, 2017). Marketing innovations can increase organizational survival particularly during economic crises and will increase their competitive advantage (e.g. reducing costs of their products, increasing differentiation, and increasing their focus; Naidoo, 2010; see also Gault, 2018; OECD/Eurostat, 2018).

Examples of a product innovation include "robotic vacuum-cleaners in nursing homes for the elderly; environmentally friendly ambulances; and the use of the 'PARO seal' in residential homes (the PARO seal is a robot shaped like a seal, which is able to move its eyes and make sounds)" (Bugge and Bloch, 2016: 286). Examples of process innovations include "a new IT solution for joint login to public services, which enabled switching between services without new logins for each service; and self-service in the personnel and payroll system" (Bugge and Bloch, 2016: 286) and "to cut down decision layers from five to just two, reducing approval time by 80 per cent" (Van der Wal, 2017: 170). An example of a marketing innovation is the creation of online stores, even while retail companies continue doing their regular business at their psychical location, such as Amazon.com's "one-click" ordering process at online (Chen, 2006).

3. Data and methods

3.1 Data and sample

Data come from the National Survey of Business Competitiveness (NSBC), which was conducted by the Social & Economic Sciences Research Center (SESRC) at Washington State University for the United States Department of Agriculture's Economic Research Service. Before distributing the questionnaire, pilot study data collection started in November 2013 and December 2013. After the pilot study, over 53,000 respondents were invited to complete the surveys via (i) online, (ii) phone interview, or (iii) mail from April through November 2014. All respondents received an invitation letter, questionnaire, reminder (by a postcard), questionnaire again, and phone and email reminders, respectively. About 10,952 respondents (22.4%) at least partially completed the survey. There are no statistical differences between respondents and nonrespondents (USDA, no date, Part C). In addition, no significant differences exist among different types of survey completion methods. Finally, the final sample size was reduced to 4845 due to missing variables and incomplete parts of the responses. There are no systematic differences between missing and without missing variables.

The population for this study is business establishments in the United States; businesses were selected randomly from strata based on industry codes (NAICS), location (metropolitan vs. nonmetropolitan area), and establishment size. The sample of this survey has been chosen from the business establishment list maintained by the Bureau of Labor Statistics. Washington DC and 46 out of 50 states have participated to the survey (Wojan and Parker, 2017). Additionally, NSBC is the first national and representative survey on innovation in the United States.[1]

Some of the questions of NSBC, particularly types of innovation, come from the European Union's Community Innovation Survey (EU-CIS), with the hope that future researchers compare innovation activities between European countries and the United States (USDA, no date, Part A). Although the first national level surveys on innovation in the United States was Business R&D and the Innovation Survey of 2008, these data are limited to only larger firms,

1 "The confidentiality of the Rural Establishment Innovation Survey data is protected under the statutes of US Code Title 18, Section 1905, US Code Title 7, Section 2276, and Title V of the E-Government Act, Confidential Information Protection and Statistical Efficiency Act of 2002 (CIPSEA; Public Law 107-347). A full statement is provided in mail questionnaires and web surveys confirming that answers to the survey will be kept confidential, and that under no circumstances will identifying information about individuals or their organizations be released to any unauthorized individuals, agencies, or institutions. It will assure respondents that only aggregated statistics will be reported, and that providing answers to any or all questions is strictly voluntary. Detailed disclosures regarding confidentiality will be provided in an advance letter to respondents (see Attachment D), and enumerators will check to ensure that respondents have received and read the letter and disclosures prior to conducting the survey. Economic Research Service will use established procedures for survey storage and disposal to ensure that individual identifiers are protected from disclosure. ERS will also use statistical disclosure limitation methods to ensure that individual identifying information does not appear in any public data product" (United States Department of Agriculture, 2014, Part A: 14).

Table 1. Descriptive statistics

Variable	Mean	SD	Min.	Max.
Product innovation	0.58	0.41	0	1
Process innovation	0.45	0.39	0	1
Marketing innovation	0.46	0.50	0	1
Source 1: Suppliers	2.26	0.64	1	3
Source 2: Customers	2.40	0.64	1	3
Source 3: Others in industry	2.38	0.63	1	3
Source 4: Workers	2.35	0.63	1	3
Source 5: Universities	1.55	0.65	1	3
Establishment years[a]	9.22	3.32	1	14
Number of employees[b]	8.33	4.11	1	15
Rurality index (Beale13)	4.87	2.28	1	9
Industry Classification (Naics2)				
21: Mining	0.26	0.16	0	1
31: Food manufacturing	0.08	0.27	0	1
32: Wood, paper manufacturing	0.13	0.33	0	1
33: Metal, machinery, electronic, hardware	0.21	0.40	0	1
42: Wholesale trade	0.20	0.40	0	1
48: Transportation	0.06	0.24	0	1
51: Information	0.07	0.25	0	1
52: Finance and insurance	0.02	0.15	0	1
54: Professional	0.17	0.37	0	1
55: Management of companies	0.02	0.15	0	1
71: Arts, entertainment	0.02	0.14	0	1
$n = 4845$				

[a]Years categories: 1800–1871 = 1, 18721896 = 2, 1897–1921 = 3, 1922–1946 = 4, 1947–1962 = 5, 1963–1972 = 6, 1973–1977 = 7, 1978–1982 = 8, 1983–1987 = 9, 1988–1992 = 10, 1993–1997 = 11, 1998–2002 = 12, 2003–2007 = 13, 2008–2012 = 14.

[b]Employment categories: Between 1 and 4 employees = 1, 5 = 2, 6 = 3, 7 = 4, 8 = 5, 9 = 6, 10 = 7, 11–12 = 8, 1–15 = 9 16–19 = 10 20–29 = 11, 30–49 = 12, 50–99 = 13, 100–249 = 14, 250–499 = 15, 500–14,000 = 15.

so they have a very limited focus. NSBC, on the other hand, is very unique in its broad representation. This project is consistent with the White House's emphasis on innovation. For instance, President Obama's 2011 State of the Union focused on innovation in America, including both urban and rural areas, as they key to national prosperity in the United States (USDA, no date, Part A).

3.2 Dependent variables

Four different dependent variables are used in this article. The first three dependent variables reflect the type of innovation, namely whether the business participated in (i) product (including goods and service innovations), (ii) process, and (iii) marketing innovations. All variables used in this study come from the respondents who represent their organizations. Thus, the levels of analysis are the firm. The first dependent variable asks whether an organization produced any new or significantly improved products. Two survey items capture the product innovation—whether the business has involved goods and service innovation (OECD/Eurostat, 2005, 2018). Appendix 1 (Table A1) shows all the operationalization used in this study.

The second dependent variable asked whether the firm introduced new or significantly improved methods of manufacturing or producing goods or services, introduced new or significantly improved logistics, delivery, or distribution methods for the firm's inputs, goods, or services, and introduced new or significantly improved support activities for the firm's processes. These three items capture process innovations. The third dependent variable asks whether new or significant improvements in the firm's marketing methods were implemented to measure marketing innovations. One survey item reflects marketing innovations. Finally, the last dependent variable is firm innovation activity, which includes all six indicators (including product, process, and marketing innovation).

3.3 Independent variables

Five main sources of knowledge, or innovation sources are used as independent variables. Important sources or new information identified by the National Survey of Business Competitiveness (2014) are: (i) suppliers, (ii) customers, (iii) other people in industry, (iv) workers, and (v) universities. Respondents were asked to evaluate how those sources of new information are valuable for the firm. The response categories are "not at all valuable," "somewhat valuable," and "very valuable." These identified sources are mostly consistent with Australian Public Service Commission's 2011 data which important sources are identified (APSC, 2011), Borins's analysis of sources of innovation (2011), the Oslo Manual (2018), and Terjesen and Patels' research on process innovations (2017).

3.4 Control variables

Because type, size, location, and establishment year of firm have been consistently identified in the extant literature as influencing innovation activity (e.g. Damanpour, 1991), they need to be included in the regression analysis as control variables. For example, analyzing the innovation activities of Europe's major industrial organizations of CIS, Arundel and Kabla found that, on average, firm product innovation rates in the pharmaceutical industry is approximately 80%, while in textiles it is only 8%. Similarly, Ballot *et al.* (2015) found that the particular types of industry (e.g. food manufacturing, heavy machine manufacturing, transportation, information, and finance and insurance companies) can affect innovation activity.

In addition, the size of a firm affects innovative performance in that large organizations tend to perform better thanks to their larger budgets and personnel (Arundel, 2001; Lægreid *et al.*, 2011; Ballot *et al.*, 2015). Moreover, the location of the firms (e.g. their location in either an urban or rural area) and the number of employees can similarly effect innovation (Arundel and Kabla, 1998; Carlino, 2001). In this study, we have used Beale codes, which is a Rural-Urban Continuum Code (between 1 = more urban and 9 = more rural) developed by the United States Department of Agriculture (USDA) to reflect the geographic location. This nine-scale variable is better than a binary metro versus non-metro variable. Finally, firm age affects innovations because on the one hand, older firms may have more established innovation routines, so they are more innovative (Terjesen and Patel, 2017). On the other hand, new organizations "will have less fixed identities, norms and values, enabling them to think 'outside the box,'" and thus they tend to be more innovative (Lægreid, *et al.*, 2011: 1328). Thus, we have also controlled these factors. Table 1 shows descriptive statistics of all the variables used in this study Appendix 2 also reports correlation coefficients.

3.5 Estimation

As explained in the above section, the set of dependent variables reflects the type of innovation, namely product, process, and marketing innovation. Because these three dependent variables are correlated with each other (error terms are correlated), using ordinary least square (OLS) or ordinal logit models cause inefficient results, since the latter models assume that the errors are not correlated with each other (Zellner, 1962; Fiebig, 2001; Martin and Smith, 2005). For instance, the correlation between product and process innovation is 0.56, the correlation between product and marketing innovation is 0.43, and the correlation between process and marketing innovation is 0.8, indicating that the errors are somewhat correlated. To compensate for this problem, seemingly unrelated regressions (SUR) are used (Zellner, 1962; Fiebig, 2001; Martin and Smith, 2005). Stata software program can provide results of the SUR precisely and efficiently. OLS is used for the fourth and last dependent variable—overall firm innovation activity as this variable is a summated scale of six indicators. The next section will report and summarize the results.

4. Results

Table 1 reports the descriptive statistics. On average, 58% of companies reported to have implemented product innovation, 46% of companies reported to have implemented marketing innovation, and 45% of companies reported to have implemented process innovation. The highest mean value of the knowledge sources is customers, suggesting that customers involve many of the innovation activities. There is considerable variance in establishment year in the survey, so both very new and old firms exist, which also confirms the representativeness of the survey. Results of

Table 2. Regression results

Variable	Product innovation	Process innovation	Marketing innovation	All innovations
Source 1: Suppliers	0.023*	0.013	0.006	0.014
Source 2: Customers	0.061***	0.053***	0.054***	0.056***
Source 3: Others in industry	−0.01	0.020*	0.033**	0.015
Source 4: Workers	0.043***	0.052***	0.053***	0.049***
Source 5: Universities	0.074***	0.076***	0.096***	0.082***
Establishment years	0.010***	0.009***	0.010***	0.010***
Number of employees	0.010***	0.015***	0.018***	0.014***
Rurality index (Beale13)	−0.009***	−0.009***	−0.011***	−0.010***
Industry classification (Naics2)Base: 21: mining				
31: Food manufacturing	0.194***	0.098**	0.037	0.110**
32: Wood, paper manufacturing	0.133***	0.067	0.025	0.075*
33: Metal, machinery, electronic, hardware	0.239***	0.117***	0.089*	0.149***
42: Wholesale trade	0.140***	0.080*	0.121**	0.113***
48: Transportation	−0.052	−0.015	0.001	−0.022
51: Information	0.306***	0.175***	0.183***	0.221***
52: Finance and insurance	0.176***	0.087	0.216***	0.160***
54: Professional	0.125***	0.048	0.117*	0.096**
55: Management of companies	0.071	−0.016	0.065	0.04
71: Arts, entertainment	0.283***	0.098*	0.166*	0.183***
Constant	−0.102	−0.237***	−0.319***	−0.219***
R^2	0.11	0.1	0.08	0.12

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; $n = 4845$.

the industry classification (Naics2) show that most of the firms in the sample are in the following two-digit sectors: 21: mining, 33: metal, machinery, electronic, and hardware, and 42: wholesale trade, followed by 54: professional jobs and 32: wood and paper manufacturing.

Table 2 reports the results of the unstandardized SUR models. Accordingly, ideas emanating from customers, workers, and universities are positively associated with all types of innovations ($P < 0.001$). For instance, ideas emanating from customers are positively associated with namely product ($B = 0.06$, $P < 0.001$), process ($B = 0.05$, $P < 0.001$), and marketing innovations ($B = 0.05$, $P < 0.001$), holding other variables constant. Ideas emanating from suppliers are moderately and positively associated with only product innovation ($B = 0.02$, $P < 0.05$), but suppliers do not have any statistical relationship to other types of innovations. Ideas emanating from other business people in the firm's industry are positively associated with process and marketing innovations ($P < 0.05$), holding other variables constant, although the magnitude of the effect is small. Ideas emanating from workers are positively associated with all types of innovations (product, process, and marketing), holding other variables constant ($B = 0.04$, 0.05, and 0.05, respectively; $P < 0.001$). Finally, the universities as sources of innovation are also positively and statistically associated with both types of innovations ($P < 0.001$). In fact, the university as a source of innovation has higher coefficients ($B = 0.07$, 0.08, and 0.1, respectively), suggesting that universities are important sources of innovation.

Regarding the control variables, on average, the younger firms, firms with more employees, and firms located in urban areas exhibit a greater degree of innovation activity for all types of innovations—product, process, and marketing innovations. All of these results are statistically significant at the 0.01% level. In addition, compared with other industry types, companies in information (Naics = 51), metal, machinery, electronic, hardware (Naics = 33), and arts and entertainment (Naics = 71) are more innovative than are other companies. Moreover, on average, companies tend to generate more product innovations compared with process innovations. Finally, the results show that transportation firms and management of companies do not exhibit a significant amount of innovation activity suggesting that the particular type of organization matters for innovation.

5. Discussion

Innovation, which is one of the most important topics in the studies of business, economics, and management can contribute to organizational performance, in that is conducive to organizational survival, success such as increasing competitiveness, productivity, and performance (e.g. Burns and Stalker, 1961; OECD/Eurostat, 2005, 2018; Pianta, 2006; Damanpour *et al.*, 2009; Frenz and Ietto-Gillies, 2009; Thompson, 2010; Stojčić and Hashi, 2014; Demircioglu and Audretsch, 2017a; Wojan *et al.*, 2018). The extent, scale, and scope of the studies on innovation and innovation activities reflect the prominence of innovation (e.g. Mohr, 1969; Kimberly and Evanisko, 1981; Damanpour, 1991; Greenhalgh *et al.*, 2004; Smith, 2006; Ballot *et al.*, 2015; Torugsa and Arundel, 2016a, 2016b; –>Demircioglu and Audretsch, 2018; Kattel and Mazzucato, 2018; Mazzucato, 2018). Analyzing how five important sources of innovation (i.e. suppliers, customers, others in industry, workers, and university) are associated with types of innovation (i.e. product, process, and marketing), we have found that universities, workers, and customers are important sources of innovation positively associated with all of innovation types. This article has made several unique and important contributions that are discussed in below.

This main focus of this article is sources of innovation. Although identifying sources of innovation goes back to the late 19th century (Carlino, 2001), testing for the effects of different knowledge sources and relating them to different outcomes is a relatively recent topic. Using ideas from different knowledge sources are crucial for generating different types of innovations and outcomes (Audretsch and Stephan, 1996; Arundel and Geuna, 2004; Frenz and Ietto-Gillies, 2009). Terjesen and Patel (2017: 1422) suggest that organizational managers must recognize and take advantage of ideas emanating from a broad spectrum of knowledge sources (e.g. universities) because “this knowledge is subsequently stored in the organization’s memory (i.e., equipment, systems, procedures, routines, and managers) and becomes ‘organizational knowledge’ that can be harnessed to enhance a firm’s innovation activities… [which are] imperative to innovation.” The empirical results of this article show that particular knowledge, such as customers, workers, and universities can enable firms to generate product, process, and marking innovations. Knowledge and ideas emanating from customers positively associated all types of innovation, which is consistent with the hypothesis that feedback and ideas generated by customers enable organizations to become more innovative.

While workers provide internal sources of knowledge within the organization or firm, universities and customers provide external sources of innovations. The results imply that both internal and external sources are necessary to develop different types of innovations. Moreover, as the positive and statistically significant coefficients of variables measuring universities and workers indicate, the results support the view that universities and workers are key sources of ideas and innovations. This is particularly important from the perspective of organizational managers, who should encourage their workers to express their views and facilitate their feedback to enhance innovation activity. Future studies may focus on analyzing how workers in the organizational context of universities specifically influence different types of innovations.

In addition, rather than focusing only on a sole type of innovation or aggregated innovation activity, the present study provides and compares across three different types of innovations—product, process, and marketing innovations. Distinguishing among product, process, and marketing innovations is essential because each type of innovation has distinct and different characteristics (e.g. process innovations are less tangible), may be influenced by different knowledge sources (e.g. different external sources are associated with different types of innovations differently), may require different resources (e.g. process innovations may be more costly in terms of monetary sources), and may lead to different organizational outcomes (e.g. product innovations may lead to patents compared with other types of innovations; Fritsch and Meschede, 2001; OECD/Eurostat, 2005, 2018; Chen, 2006; Naidoo, 2010; Stojčić and Hashi, 2014; Radicic *et al.*, 2016; Terjesen and Patel, 2017; Van der Wal, 2017; Gault, 2018). The results of this study suggest that different types of knowledge sources are associated with distinct types of innovations differently. Therefore, future studies would be wise to extend and build on this study by comparing different types of innovations.

Moreover, this study uses a recent (2014), comprehensive (both rural and urban area with almost all states in the United States), and large-scale survey ($n = 10{,}952$ firms) on firm innovation in the United States. Despite many datasets in Europe [e.g. Community Innovation Surveys (CIS)], fewer datasets on firms' innovation activities are available for the United States. This is unfortunate because many large and innovative companies such as Apple, Uber, Amazon, Netflix, and Microsoft are located in the United States. Furthermore, the United States ranks among the large advanced countries in the world, with a population of over 320 million. Therefore, a key contribution of this study is analyzing survey responses from the National Survey of Business Competitiveness (NSBC) which is sponsored by the United States Department of Agriculture. The findings provide interesting results, such as the more robust innovation activity exhibited by firms in the urban areas, but also both the extent and heterogeneity of innovation activity exhibited by firms in rural areas. This article also shows that on average, certain types of industries (e.g. IT, metal, machinery, electronic, and arts) are more innovative than other industries. Additionally, both firm age and size are positively associated with innovation types. All of these findings made possible by analyzing these new and unique data provide insights that will be instructive and enlightening for decision makers in both business and policy.

Several important limitations inherent in this study need to be emphasized. Like most of survey research, this article is based on a cross-sectional data (United States Department of Agriculture (USDA), Economic Research Service, 2014). Therefore, lack of panel data, or quasi-experimental design does not permit scholars to make causal claims about findings. In other words, the study is correlational, not causal. In addition, due to data limitations, we could not measure which particular innovations are more important and effective than others. For example, data does not provide information about the quality of innovations such as which innovations lead huge savings, sales, or patents. Similarly, the outcomes variables are only probably to innovate in a given, so the outcome is same if a given firm introduces only one innovation versus five innovations in the previous three years. This limitation (both quality—the significance of innovation—and the quantity—the number of innovations–) was also acknowledged from the USDA as it was stated as "a noted weaknesses of this set of questions is their inability to differentiate highly innovative from nominally innovative establishments" (USDA, Part A: 4). Thus, future research may focus on the quality and quantity of innovation with using more questionnaires. Future research may also use qualitative methods (e.g. cases, in-depth interviews, and ethnographic research) to examine how and why certain sources of innovative ideas lead major innovations because qualitative research are important to explain how and why a particular relationship occurs, not occurs, or occur in different intensity (Corbin and Strauss, 2008; Maxwell, 2012; Bryman, 2016).

Despite the limitations of this study, it offers insights and practical implications about how sources of innovations are associated with types of innovations, the importance of workers, customers, and universities as innovation sources, the importance of product, process, and marketing innovations. We recommend future studies to focus on the link of sources and types of innovation in other context with qualitative research. Future research may also focus on how and why universities, customers, and employees influence innovation activities and benefits of innovations (e.g. whether innovation from particular sources reduces cost and increases quality of produce and services) in public, nonprofit, and private settings. Future research may also explore the effects of other sources of knowledge such as the Federal government's role for innovation activities of companies and public organizations.

6. Conclusion

Innovation has emerged not just as an important force driving the performance of firms and other organizations, but also entire regions and countries. Despite its prominence, there are not many quantitative studies analyzing how different knowledge sources are associated with different types of innovations as well as overall innovation activity. Using United States National Survey of Business Competitiveness (NSBC) conducted in 2014, this study has contributed to the innovation literature by analyzing how the following knowledge sources are associated with product, process, and marketing innovation as well as overall innovation activity by the following important innovation sources: (i) suppliers, (ii) customers, (iii) other people in industry, (iv) workers, and (v) university. The most important findings of this article are that universities, customers, and workers are crucial knowledge sources, positively associated with product, process, marketing, and overall innovation activity. Suppliers and others in industry have either little or no statistical effect for innovation activities.

Just as knowledge sources are heterogeneous, so too are the manifestations of innovation activity highly heterogeneous. Yet, the literature on innovation activity has generally ignored the heterogeneity inherent in both knowledge sources and manifestations of innovation. If there is an innovation, there should be a knowledge source(s), other than the skies to which Solow eluded driving innovation activity. Our study is original and important to the literature as it has found that universities, workers, and customers are crucial sources for innovations. With using qualitative or quantitative research, future studies may analyze other sources (e.g. governments' role for innovation), other types of innovations (e.g. organizational), or the benefits of innovation (e.g. whether a particular innovation increases efficiency) in other context both in terms of different region (e.g. in Asia) and in different sector (e.g. public and nonprofit).

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Appendix 1

Table A1. Operationalization of variables

Dependent variables	The response categories are following: 0 = No, 1 = Yes.
Product innovation (alpha = 0.53)	– In the past 3 years, did this business produce any new or significantly improved services?
	– In the past 3 years, did this business provide any new or significantly improved services?
Process innovation (alpha = 0.68)	– In the past 3 years, did this business introduce new or significantly improved methods of manufacturing or producing goods or services?
	– In the past 3 years, did this business introduce new or significantly improved logistics, delivery, or distribution methods for your inputs, goods, or services?
	– In the past 3 years, did this business introduce new or significantly improved support activities for your processes?
Marketing innovation	– In the past 3 years, did this business introduce new or significant improvements in your marketing methods?
Overall innovation (alpha = 0.81)	Factor score for all three types of innovations.
Independent variables	The response categories are following: 1 = Not at all valuable, 2 = Somewhat valuable, and 3 = Very valuable.
Source 1	Suppliers
Source 2	Customers
Source 3	Other business people in your industry
Source 4	Workers
Source 5	University extension, community colleges, business schools
Control variables	
Location-Beale13	1: Counties in metro areas of 1 million population or more
	2: Counties in metro areas of 250,000 to 1 million population
	3: Counties in metro areas of fewer than 250,000 population
	4: Urban population of 20,000 or more, adjacent to a metro area
	5: Urban population of 20,000 or more, not adjacent to a metro area
	6: Urban population of 2500 to 19,999, adjacent to a metro area
	7: Urban population of 2500 to 19,999, not adjacent to a metro area
	8: Completely rural or less than 2500 urban population, adjacent to a metro area
	9: Completely rural or less than 2500 urban population, not adjacent to a metro area
Establishment years	1800–1871 = 1, 1872–1896 = 2, 1897–1921 = 3, 1922–1946 = 4, 1947–1962 = 5, 1963–1972 = 6, 1973–1977 = 7, 1978–1982 = 8, 1983–1987 = 9, 1988–1992 = 10, 1993–1997 = 11, 1998–2002 = 12, 2003–2007 = 13, 2008–2012 = 14
Employment categories	Between 1–4 employees = 1, 5 = 2, 6 = 3, 7 = 4, 8 = 5, 9 = 6, 10 = 7, 11–12 = 8, 13–15 = 9, 16–19 = 10, 20–29 = 11, 30–49 = 12, 50–99 = 13, 100–249 = 14,250–499 = 15, Over 500 = 15.
Industry classification (Naics2)	21: Mining, 31 = Food manufacturing, 32 = Wood and paper manufacturing, 33 = Metal, machinery, electronic, and hardware manufacturing, 42 = Wholesale trade, 48 = Transportation, 51 = Information, 52 = Finance and insurance, 54 = Professional, 55 = Management of companies, 71 = Arts and entertainment.

Appendix 2

Table A2. Correlations

		1	2	3	4	5	6	7	8	9	10	11
1	Product innovation	1										
2	Process innovation	0.56	1									
3	Marketing innovation	0.43	0.80	1								
4	Source 1: Suppliers	0.09	0.09	0.07	1							
5	Source 2: Customers	0.15	0.16	0.12	0.28	1						
6	Source 3: Others in industry	0.04	0.09	0.10	0.20	0.20	1					
7	Source 4: Workers	0.12	0.15	0.13	0.16	0.28	0.19	1				
8	Source 5: Universities	0.15	0.17	0.16	0.14	0.08	0.17	0.18	1			
9	Establishment years	0.05	0.04	0.03	−0.01	0.06	−0.03	0.02	−0.07	1		
10	Number of employees	0.12	0.17	0.14	0.04	0.07	0.01	0.02	0.08	−0.16	1	
11	Rurality index (Beale13)	−0.07	−0.07	−0.07	0.02	−0.07	0.00	−0.02	0.06	−0.11	−0.05	1