Innovation as Determinants of Economic Growth in U.S. Counties

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Although innovation has long been considered a key driver of economic growth, no commonly accepted standard exists by which to measure innovative activities. Therefore, this article adopted a comprehensive variable, Innovation Index 2.0, which includes most previously used measurements of innovative activities in the literature. By using this index and its sub-indexes, we are able to thoroughly examine how they are connected to total personal income and population growth as proxies of economic growth. Another contribution of this article is that it focuses on smaller economic entities, U.S. counties, which have not been popularly studied in the literature. The regression results show that innovation as well as most of its related measures contribute to U.S. counties' income and population growth rates.

INTRODUCTION

The theoretical and empirical research related to economic growth has been one of the most popularly studied topics in economics field. Early neoclassical growth models claimed that economic growth was driven by capital accumulation and labor or population growth (Solow, 1956; Swan, 1956). Although many extensions existed to the original Solow-Swan model later on, the accumulation of a 'knowledge stock' became a key addition in to the neoclassical models. Studies focused on the role of innovation in the growth progress can be classified into four arenas: technological progress and spillovers (Solow, 1957; Uzawa, 1965; Jaffe, 1986, Barrell & Pain, 1997), human capital (Nelson & Phelps, 1966; Mankiw et al., 1992; Ciccone, 2002; Papageorgiou, 2003; Caselli & Wilson, 2004), research and development (R&D) (Davidson & Segerstrom, 1998; Klenow & Rodriguez-Clare, 2005), and learning by doing (Arrow, 1971; Romer, 1986; Aghion & Howitt, 1992).

Building on the antecedent neoclassical theoretical models, more recent research has focused on empirical studies using the national data (Bassanini & Scarpetta, 2001; Glaeser et al., 2004; Klenow & Rodriguez-Clare, 2005; Pelinescu, 2015) or industrial data (Feldman & Audretsch, 1999; Glass & Saggi, 2002; Porter, 2003) in order to test how innovation and economic growth influence each other. To be more specific, at the national level, Cosar (2011) built a general equilibrium model to prove that the variation in the skilled labor share leads to income differences between countries. He, then, collected data from 58 market economies for the period between 1950 and 1985 in order to explain the cross-country and within-country income differences, as measured by GDP per worker. When comparing the cross-country data, the reason that developed countries, in general, have lower income levels than the U.S., which is the benchmark, is that too few scientists and engineers are in the workforce. He also calibrated the within-country income differences between skilled and unskilled workers, and asserted that skilled labor is potentially much more important to development. Instead of evaluating multiple countries, Fleisher et al. (2010) explained how China's economic growth was strongly tied to total factor productivity (TFP) growth. They found that human capital had both direct and indirect effects on TFP growth in which the direct effect came from domestic innovative activities and the indirect effect was a spillover effect of human capital on TFP growth.

At the industrial level, Xu (2000) demonstrated that the level of human capital was a key factor in explaining the level of technology diffusion from U.S. multinational enterprises (MNEs) to their host countries. He found the developed countries received more benefits from the technology transfers provided by the U.S. MNEs than the less developed countries because the less developed countries did not meet the minimum human capital threshold level. Falk (2007) estimated a dynamic empirical growth model using panel data for 58 manufacturing sectors from 19 OECD countries between 1970 and 2004. The results concluded that the ratio of a firm's R&D expenditures to GDP and its share of R&D investment in the high-tech sector had strong positive effects on GDP per capita and GDP per hour worked.

Although past literature has extensively studied this topic, no standard variable exists by which to gauge innovative activities on countries or states. Pelinescu (2015) used education expenditure in the GDP, the number of employees with secondary education, and the number of patents as proxies for innovation activity. Huggins (2004) used the number of people in R&D in the private sector as a proxy for human capital, while Baldwin (1971) and Outreville (1999) used as the share of university graduates in the workforce as their proxy. Fleisher et al. (2010) used census data to capture the proportion of population by different educational levels, varying from elementary school to college, as their proxy, while Feldman and Audretsch (1999) adopted the U.S. Small Business Administration's Innovation Data Base (SBIDB), which measures new product introductions and is compiled from new product announcements within more than 100 technology, engineering, and trade journals, to be used as their proxy. Falk (2007) considered at the share of investment in the high-tech sector as innovation activity, while Xu (2000) applied the technology transfer spending (e.g., royalties and license fees) of MNE affiliates as the proxy for innovation activity.

These variables can capture some, but not all, aspects of innovative activities. As such, one of the contributions of this paper is to adopt a comprehensive variable to comprise most kinds of innovative activities as mentioned above. This variable, the Innovation Index 2.0, is developed by the Indiana Business Research Center at the Kelley School of Business at Indiana University[1] and is calculated based on five major categorical index: Human Capital with a weight of 20%, Business Dynamics with a weight of 20%, Business Profile with a weight of 20%, Productivity and Employment with a weight of 30%, and Economic Well-Being with a weight of 10%. Human Capital, Business Dynamics, and Business Profile are based on innovation inputs, including educational attainment, young adult population growth rate, high-tech employment, venture capital, broadband penetration, and investment in R&D. While, Employment and Productivity and Economic Well-Being are based on innovation outputs, including job growth, employment in high-tech firms, industry clusters, new patent creations, poverty rate, unemployment rate, and dependency ratio. Therefore, the Innovation Index 2.0 is a one-stop shop that employs all possible innovation measurements used in the literature and provides an all-around measure for innovative activities. A full description of the Innovation Index 2.0 can be found on the Indiana Business Research Center's website[2].

Another advantage of the Innovation Index 2.0 is the availability of innovation data for more than 3,000 U.S. counties. To date, past research has mostly focused on the national level of economic growth and ignored smaller scale economies (e.g., counties, smaller cities, and rural areas) since it is difficult to gather such data. With the availability of county data in the Innovation Index 2.0, this paper can extend past research so that it encompasses a little studied area (i.e., U.S. counties) and can test to determine whether innovative activities really matter to a county's economic growth.

The next section contains information on the data and methodology used for this study, and will be followed by the statistical results and a discussion. Final remarks on the study will be presented at the end of the paper.

DATA AND METHDOLOGY

In this section, we will test the relationship between innovation factors and the economic growth of U.S. counties. The dependent variables are the measurements of economic growth. The common conceptualization of economic growth is the growth of the GDP. However, GDP data is only available for the U.S. as a whole, states, and some metropolitan areas. As many of counties in this analysis are not a part of metropolitan areas, GDP growth data becomes an infeasible conceptualization. A common alternative of GDP is total personal income (Hubbard & O'Brien, 2016). Since the data on total personal income is available at the county level from the U.S. Bureau of Economic Analysis, we used the growth rate of total personal income as a measurement of a county's economic growth.

Economic growth is not only measured by GDP, but can also be measured by other economic and social indicators, such as population. The well-known classic growth theory has firmly explained the positive nexus between population and growth (Smith, 1776; Malthus, 1798; Ricardo, 1817) to some extent. Therefore, the second conceptualization of economic growth in this analysis is the growth of population. The data for total personal income and population was retrieved from the Bureau of Economic Analysis' Regional Fact Sheets (BEARFACTS). Based on the data from 2006 to 2015, we calculated the average compound annual growth rates of total personal income and population as proxies of economic growth for each county.

The independent variables in this analysis are related to measures of innovative activities. As described previously, the primary measure of innovation activity is the Innovation Index 2.0, which is comprised of five major categorical indexes. These major indexes are also created from several sub-indexes that are also organized thematically along more precisely defined concepts. For instance, the Human Capital index contains 12 measures: population growth rate for individuals between the ages of 25 and 44, high school attainment for individuals between the ages of 18 and 24, individuals with some college education who are at least 25, individuals who have attained an associate degree and are at least 25, individuals who have attained a bachelor's degree and are at least 25, individuals who have attained a graduate degree and are at least 25, patent technology diffusion, university-based knowledge spillovers, business incubator spillovers, STEM degree creation, technology-based knowledge occupation clusters, and high-tech industry employment share. Therefore, each major index offers crucial insights into each county's innovation assets. We also estimated each of the major categorical indexes in the models in order to determine how important it was in regard to contributing to the economic growth in each county.

Table 1 provides an overview of the data and some sample statistics, including the means, standard deviations, and minimums and maximums for the following variables: total personal income (TPI) growth rate, population (Pop) growth rate, innovation index, Human Capital index, Business Dynamics index, Business Profile index, Employment and Productivity index, and Economic Well-Being index. As shown by the data presented in Table 1, a large variation exists in regard to county-specific characteristics for the sample. For example, McKenzie County (ND) had the highest average compounded personal income growth rate at 19.8%, while Carroll County (KY) had the lowest rate at -4.2%. For population growth, St. Bernard County (LA) gained the most population at 11.9%, while Alexander County (IL) lost the most at -2.8%. For the innovation index, San Mateo County (CA) led the nation at 133.4, while Issaquena County (MS) ranked at the bottom at 54.8. Wake County (NC) had the most intensive human capital at 166.7, while Issaquena County (MS) had the least human capital at 37.5. San Francisco County (CA) had the highest Business Dynamic index at 159.1, while King County (TX) had the lowest Business Dynamic index at zero. Tunica County (MS) had the most diverse business profile at 126.4, while Echols County (GA) had the least diverse business profile at 38.4. Greenlee County (AZ) led the Employment and Productivity index at 152.7, while Owsley County (KY) had the lowest Employment and Productivity index at 45.5. In terms of economic well-being, Stark County (ND) was highest at 187.8, while Jefferson County (MS) was last with 59.6. In total, the data pool contained 3,106 observations.

TABLE 1
SUMMARY STATISTICS

	TPI. growth	*Pop. growth*	*Innovation Index*	*Human Capital*	*Bus. Dynamics*	*Bus. Profile*	*Emp.& Produc.*	*Econ. Well-Being*
Count	3106	3106	3106	3106	3106	3106	3106	3106
Mean	0.037	0.002	85.558	94.466	55.489	75.200	97.889	111.617
Std. Dev.	0.017	0.009	13.130	24.382	19.396	14.309	15.925	22.239
Min.	-0.042	-0.028	54.800	37.500	0	38.4	45.5	59.6
Max.	0.198	0.119	133.400	166.700	159.1	126.4	152.7	187.8

The regression specifications are as follows:

$$\text{Growth Rate}_i \text{ (TPI or Pop)} = \beta_0 + \beta_1 \text{Innovation\_Index}_i + \mu_i \qquad \text{(for Model 1)}$$

$$\text{Growth Rate}_i \text{ (TPI or Pop)} = \beta_0 + \beta_2 \text{Human\_Capital}_i + \beta_3 \text{Business\_Dynamics}_i + \beta_4 \text{Business\_Profile}_i + \beta_5 \text{E\&P}_i + \beta_6 \text{Econ\_Well-Being}_i + \mu_i \qquad \text{(for Models 2 to 7)}$$

In Model 1, we regressed the growth rate of total personal income or population on the overall innovation index for all U.S. counties. Since the Innovation Index is a composition of five major innovation-related categories, in Models 2 to 7, we specifically examined the relationships between economic growth and these five major categorical indexes individually and aggregately.

RESULTS AND DISCUSSIONS

Table 2 presents the seven OLS models that analyzed the impact of the innovation index and its related sub-indexes on economic growth as measured by total personal income growth. Not surprisingly, the models presented the innovation index as having a positive and statistically significant association with total personal income. A one-point increase in the innovation index would increase total personal income by about 0.03 percent.

By breaking the innovation index down into the five major categorical indexes, we were able to identify how each innovation-related factor contributed economic growth. The negative results of human capital were unexpected, but insignificant in Models 2 and 7. Business dynamics showed a positive and significant impact on total personal income growth in Models 3 and 7. Approximately, a one-point change in the business dynamics factor was associated with a 0.01 percent change in total personal income growth. Like the human capital factor, the coefficient of the business profile factor was also negative, but insignificant. Employment and productivity and economic well-being were also significantly important to total personal income growth.

TABLE 2
OLS MODEL OF TOTAL PERSONAL INCOME GROWTH

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	0.0138 *** (7.14)	0.0409 *** (34.11)	0.0311 *** (34.45)	0.0403 *** (25.14)	0.0037 *** (2.11)	-0.007 *** (-5.38)	-0.0068 *** (-3.54)
Innovation Index	0.00027 *** (12.16)						
Human Capital		-4.1E-05 (-3.33)					-0.0002 (-15.29)
Business Dynamics			0.00011 *** (6.97)				0.00014 *** (8.72)
Business Profile				-4.4E-05 (-2.10)			-3.3E-05 (-1.75)
Employment and Productivity					0.00034 *** (19.08)		0.00019 *** (10.21)
Economic Welling-Being						0.00039 *** (34.37)	0.00035 *** (27.98)
N	3106	3106	3106	3106	3106	3106	3106
R^2	0.045	0.004	0.015	0.001	0.105	0.276	0.34

Note: *t* statistics in parentheses. * p<.1, ** p<.05, *** p<.01

The statistical results are more robust when we used population growth as proxy of economic growth, as shown in Table 3. All of the indexes, including human capital and business profile that were insignificant in Table 2, were significantly and positively associated with population growth. The Innovation index had a bigger impact on population growth (0.04 percent) than on total persona income growth (0.03 percent). Indeed, most previous studies have only explained how innovation leads to job growth, which, in turn, affects income and subsequent economic growth (Acs & Armington, 2004; Atkinson & Stewart, 2012). Our findings directly explain how the impact of innovation goes beyond employment growth to overall population growth. It not only creates jobs, but also attracts more people to innovation intensive areas and seek new employment and start-up opportunities. Thus, innovative activities create a positive externality impact to a county's economy.

TABLE 3
OLS MODEL OF POPULATION GROWTH

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	-0.0306 *** (-32.81)	-0.01454 *** (-24.43)	-0.00886 *** (-19.18)	-0.01158 *** (-13.42)	-0.02009 *** (-20.83)	-0.00821 *** (-9.80)	-0.02838 *** (-25.36)
Innovation Index	0.00039 *** (35.86)						
Human Capital		0.00018 *** (29.49)					9.64E-05 *** (12.62)
Business Dynamics			0.00020 *** (25.93)				8.52E-05 *** (9.32)
Business Profile				0.00019 *** (16.56)			4.94E-05 *** (4.47)
Employment and Productivity					0.00023 *** (23.68)		9.87E-05 *** (8.96)
Economic Welling-Being						9.56E-05 *** (12.97)	3.24E-05 *** (4.51)
N	3106	3106	3106	3106	3106	3106	3106
R^2	0.293	0.219	0.178	0.081	0.153	0.296	0.34

Note: *t* statistics in parentheses. * p<.1, ** p<.05, *** p<.01

Regressions prove that innovative activity conduces the county's economic growth. A one-point increase in the innovation index increased total personal income by 0.03 percent and population by 0.04 percent annually. This result is close to previous findings in the literature. For example, Cameron (1996) stated that a 1 percent increase in R&D capital stock increased output between 0.05 percent and 0.1 percent. Falk (2007) found that the elasticity of the GDP per capita with respect to business sector R&D expenditures was 0.024 in the short run.

The results of this paper are a good addition to the literature. In the past, innovative activity has mostly been attested to be important to the nation's economic growth. For the county's economic growth, instead of innovation, most research regarded factors such as tax policies (Carlino & Mills, 1987), natural resource amenities (Deller et al., 2001), social and institutional factors (Rupasingha et al., 2002), infrastructure spending (Fan et al., 2000), and metropolitan spillover effect (Zhong, 2016). Our findings confirmed that innovative activities also provide contributions to a county's economic growth.

The constituent five major categorical indexes outlined more specific targets through which counties could develop their economies. Human capital has long been deemed a prerequisite determinant of economic growth. However, in this study, it showed a negative link with total personal income growth. Such a result can also be found in Benhabib and Spiegel (1994), Nonnemen and Vanhoudt (1996), and Pelinescu (2015). As Pelinescu (1995) explained, the heterogeneity of countries caused this negative relationship in her paper. As such, we believe that the heterogeneous group of U.S. counties analyzed in this paper could explain our negative result. The relationship between human capital and population growth showed the expected positive, significant sign.

Business dynamics is the mechanism through which counties replaced outdated ideas, jobs, and practices with new and/or revolutionary ones. A thriving and dynamic economy needs to cultivate new industries, firms, and jobs, which, in turn, bolster further economic growth (Reynolds, 1994; Armington & Acs, 2002). All of our regression results showed that both total personal income and population growth were positively associated with business dynamics in U.S. counties. The county government needs to establish policies and procedures to encourage entrepreneurship and startups that are more adept at new technology and innovation.

Business Profile gauges local business conditions and the resources available to entrepreneurs and companies, both of which can lead to growth and, subsequent, innovation. These resources can be found in the form of capital (i.e., domestic or foreign investments), connectivity within and with other regions, the dynamism of the region, and entrepreneurship. This index had a negative and insignificant impact on total personal income growth, but a positive and significant impact on population growth.

Previous studies have mentioned the importance of several of the Business Profile measures in regard to economic growth. For example, Borensztein et al. (1998) suggested that FDI is an important vehicle for the transfer of technology, contributing relatively more to growth than domestic investment. Czernich et al. (2011) verified that a 10 percent increase in broadband penetration raises annual per capita growth by 0.9 percent to 1.5 percent. Adelino et al. (2014) measured the availability of financial resources, such as the share of local bank deposits relative to all deposits in a particular geographic area, to small- and medium-sized enterprises (SMEs). Given that local banks are more likely to lend to smaller firms, startups, and SMEs, regions with higher concentrations of local bank deposits were more likely to exhibit greater rates of entrepreneurship, SME activity, innovation, and growth in comparison to regions where little to no local banking activity existed. Our results confirmed these statements.

The measures in the Employment and Productivity index suggest that the share of high-tech employment in total employment (Kolko, 1999), the degree of industry cluster (Saxenian, 1994; Porter, 2000; Delgado et al., 2010), and patent activity (Agrawai & Henderson, 2002; Bilbao-Osorio & Rodriguez-Pose, 2004; Bode, 2004; Barkley, 2006) were also important for innovation because they facilitated the growth of startup firms, which are considered key agents of innovation. Our findings strongly support such a conclusion.

Finally, innovative activities improve economic well-being because residents earn more and have a higher standard of living, which is a reflection of economic growth. The results of this study affirm that economic well-being, as an outcome of innovation activity, strongly and positively leads to economic growth.

CONCLUSION

This paper uses a newly developed index, the Innovation Index 2.0 created by the Indiana Business Research Center at the Kelley School of Business at Indiana University, to capture the overall innovative activities in more than 3,000 U.S. counties. This index also offers more sophisticated measurements within five major categorical indexes. This paper highlighted the importance of innovation in ensuring economic growth as expressed as total personal income and population growth. The model reveals a positive and significant relationship among income, population growth, and innovation as well as with most of the five major categorical indexes, as was expected according to growth theory. This paper presents a variety of innovative activities that local policymakers can utilize in order to improve their local economies, including related to adult education, workforce training, new firm establishments, broadband connections, availability of local and foreign capital to businesses, industry clusters, patenting, and poverty rates. Implementations within these areas will help build thriving and innovative communities, which, in turn, will benefit long-run economic growth.

ENDNOTES

1. Slaper, T. et al, *Driving regional innovation: The innovation index 2.0*. (2016). Retrieved from http://statsamerica.org/ii2/reports/Driving-Regional-Innovation.pdf.
2. Ibid

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