Review of Economics & Finance
Submitted on 19/July/2012
Article ID: 1923-7529-2013-01-83-07 William R. DiPietro

Effects of Connectivity and Freedom on Innovation: An Empirical Test Using Different Data Sources

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Abstract: This paper uses cross country regression analysis on a large sample of countries to look at the hypothesized relationship between country innovation and country connectivity. Regressions are undertaken employing three different measures of innovation, using connectivity as the sole explanatory variable, and using connectivity adjusting for other variables. The analysis of the paper lends support to the proposition that greater connectivity between individuals within countries causes greater innovation within these countries. Regardless of the measure used to capture innovation, connectivity is found to be statistically relevant.

Keywords: Connectivity, Innovation, Determinants of innovation, Cross country analysis, Ideas and creativity

JEL Classifications: O31, O30, O57, O10

1. Introduction

Innovation has always been a major driver behind the enhancement of productivity necessary for improvement in the standard of living. In order to improve mankind's material well-being, finding ways to foster innovation is therefore of utmost importance. Effective innovation policy, however, depends on innovation knowledge. A greater understating of innovation, how innovation comes about, the innovative process, the determinants of innovation, is required for society to gain real insights on proper ways and means to successfully enhance innovation.

The purpose of this paper is to focus on one potential determinant of innovation-connectivity between people. Specifically, the paper hypothesizes that there exists a positive relationship between connectivity and innovation that is measurable and discernible between countries. In other words, the paper maintains that, as a general proposition, greater connectivity leads to increased innovation. To test the hypothesis, the paper employs cross country regression analysis.

Greater connectivity is likely to lead to higher innovation for a number of reasons. First, more contacts between individuals increases the chances that any given idea will be expressed and become part of the public domain and consciousness. The reason this occurs, is because, with greater connectivity, it is more likely an individual with any idea will be able to find at least one sympathetic listener or sympathetic group for which he is comfortable and willing to communicate the idea. This is very important because the ultimate foundation for innovation is ideas. If concepts stay in people's brains, then they are likely to go nowhere, to be sterile, and have little effect on innovation. Greater connectivity brings out more ideas, which, in turn, leads to greater innovation.

The second reason greater connectivity leads to increased innovation is that greater connectivity not only increases the number of ideas that are floating around, but it also encourages greater feedback and idea development. Just as the case with the number of ideas, the denser the

network of contacts, the greater is the likelihood of responses, of further interest, of further exchange, and of further development for any given idea.

The third reason that greater connectivity leads to higher innovation is that it exposes more people to completely unfamiliar ideas resulting in a jarring, unsettling, and stimulating effect that creates even more new thoughts and ideas. People need to really think and to really let their unconscious work to try to regain equilibrium once it is put out of balance due to some unusual new idea or new way of perception. It probably took more than a generation for humanity to come to grips with Darwin's notion of evolution.

Fourth, really strange, off-beat, or extremely unusual ideas are likely to have a greater possibility of development with greater connectivity, as there is a greater probability in a larger network that a least someone in the network sees possibilities in a strange idea that no one else would ever possibly see.

This paper is divided into five additional parts. The next section gives a quick brush stroke glance at some of the literature regarding innovation and connectivity to provide some context. The third section puts forth and discusses a simple model of innovation based on connectivity. Section four discusses the variables and the sources of the variables that are used in the empirical analysis. The fifth section shows the results of cross country regressions of three different measures of innovation on connectivity and on a few other selected variables. The sixth and final section concludes.

2. Brief Overview of Some Literature

Without proper governance, Baird fears that the internet, with its tremendous innovative potential, could become a cultural wasteland like television, which, at its inception, was also considered to be so very promising for human development (BAIRD 2003). He recommends widespread participation in internet governance, and that the internet is governed with the objective of providing universal and ubiquitous access at reasonable costs to all users.

Using social network analysis, Bjork and Magnusson find that for individuals, greater connectivity, greater interactivity with other individuals, linearly increases the quality of innovative ideas, and, that for groups, the relationship is nonlinear, with greater interactivity between groups increasing the quality of innovative ideas up to a point, beyond which increases in interactivity between groups have a negative effect on the quality of innovative ideas (Bjork and Magnusson 2009).

Looking at a cross section of one hundred and forty four developing countries, Meso, Musa, Straub, and Mbarika find support, using partial least squares statistical analysis, for the hypothesis that national information infrastructure positively influences both the quality of governance and the quality of socio-economic development (Meso, Musa, Straub, and Mbarika 2009).

Crespi reviews the explanations on the potential determinants of innovation in the areas of intellectual property rights, market structure, financial structure, corporate governance, market demand, human capital, geographic concentration, and governmental policy from the three major theoretical perspectives on innovation existing in the literature (Crespi 2004).

Ding employs sensitivity analysis and instrumental variables estimation on a sample of forty-three countries from 1998 through 2002 to examine six potential determinants of educational innovation and industrial innovation (achievement in education, participation in education, input to education, input to research and development, the extent of rule of law, and international trade openness) (Ding 2006). His analysis suggests that intellectual property rights protection may be a possible innovation determinant for both educational and industrial innovation, but that educational

participation may only be relevant for educational innovation. His work also indicates, contrary to the findings of some others, that neither educational achievement nor openness to international trade appears to be statistically significant determinants of innovation.

Griffiths and Kickul classify members of European Union countries into four groups, innovative leaders, innovative followers, innovative trailers, and innovative catcher-uppers, and try to uncover some socioeconomic reasons for differences in innovative behavior between the different groups (Griffiths and Kickul 2008). Their investigation shows that the leader group of countries has a statistically higher mean percentage of high tech workers and a statistical higher mean early stage funding of venture capital as a percentage of GDP compared to the follower group of countries.

Weinhold and Nair-Reichert look at the possibility that the share of income going to the middle class may be a source of differences in innovation across countries (Weinhold and Nair-Richert 2009). They hypothesize that a larger middle class income share may increase innovation both directly through demand and supply effects, and indirectly by improving institutional quality. Looking at a specification with innovation as a function of intellectual property rights, institutional quality, the share of income of the middle class, and other variables, they find evidence in their cross country regressions using ordinary least squares and instrumental variables estimation that domestic innovation is positively related to both intellectual property rights and to the income share of the middle class.

The management literature is a good source for defining innovation and trying to understand the entire innovative process with the ultimate aim of effectively managing innovation. A few examples of articles in this mold are Reid and DeBrentani (Reid and De Brentani 2004) and Francis and Bessant (Francis and Bessant 2005). A sociological theory theorizing on how good ideas are formed can be found in Burt (Burt 2004).

3. The Model

The model consists of a single equation and a set of partial derivatives. The equation, with its associated partial derivatives, is as follows

$$I = f(C, D, S, Y) \text{ with } \partial I/\partial C > 0,\ \partial I/\partial D > 0,\ \partial I/\partial S > 0 \text{ and } \partial I/\partial Y > 0$$

In the equation, I stands for country innovation, C for connectivity, D for democracy, S for the amount of scientists and engineers, and Y for the level of economic development. Country innovation is expected to be positively related to connectivity, and to each of the other three variables on the right hand side of the equation.

As already discussed in the introduction, since connectivity increases idea creation, idea dissemination, and idea development, innovation is expected to be positively related to connectivity.

In addition to connectivity, innovation is also predicted to be positively related to the amount of freedom and democracy in a country. Free speech, the absence of fear of torture or death from what you say, little censorship and minimal control of information are favorable to the generation, nourishment, and free flow of ideas necessary for creativity and innovation. Democratized knowledge that is widely available to users, knowledge not restricted to a select few, horizontal knowledge that is not hierarchy controlled, channeled, and manipulated, provides an environment for innovation to flourish.

In a world in which production processes require more and more sophisticated and intricate knowledge, technical human capital is bound to be a key supply determinant of country innovation.

Thus, it is anticipated that innovation will be positively related to technical human capital in the form of the number of available scientists and engineers.

Finally, innovative activity is projected to be positively related to the level of economic development. Higher levels of economic development enable countries to provide for more education, greater educational quality, and more free time, free time that is necessary for idea generation and innovation. In addition, higher levels of development perpetuate a more innovative mind-set, replacing a traditional status quo perpetuating consciousness, so that innovation becomes more an integral part of the intellectual fabric and physical processes of society.

In sum, the model, the single equation and its associated partial derivatives, simply states that country innovation depends positively on country connectivity, as well as, the extent of democracy in a country, the quantity of country's scientists and engineers, and the country's level of economic development.

4. Data Sources and Variables

Three different measures of innovation are employed in the paper. The first measure of innovation is taken from the Global Competitiveness Report of the World Economic Forum (Word Economic Forum 2009). The Forum's computes an index entitled the capacity for innovation based on the question, "In your country how do you obtain technology?" The possible answers to the question range from one to seven, with an answer of one indicating exclusively from licensing or imitating foreign companies, and an answer of seven by conducting formal research and pioneering their own new product and processes. The index is a weighted average based on answers to the question for the years 2008 and 2009.

The second measure of innovation is the global innovation index for 2009 of the Boston Consulting Group (Andrew, DeRocco and Taylor 2009). The Boston Consulting Group index of innovation is based on surveys and interviews with executives. It is constructed for one hundred and ten countries, and ranges in value from a low value of -1.63 for Zimbabwe to a high value of 2.45 for Singapore.

The third measure of innovation is the 2008 global innovation index created by the Confederation of Indian Industry and INSTEAD (Confederation of Indian Industry and INSTEAD 2010). The Confederation of Indian Industry index ranges between one and seven. For 2008, it is available for one hundred and thirty countries. This Confederation of Indian industry index of innovation is very comprehensive, taking into consideration a whole multitude of variables in its construction.

The measure of country connectivity is the number of internet users as a percentage of the population for 2010. The variable is identified with the variable name PERINTERNETUSERS. The data on the number of internet users as a percentage of the population come from Wikipedia (Wikipedia 2012). Wikipedia's numbers are, in turn, based on data taken from the International Telecommunication Union and the U.S. Census Bureau.

The technical human capital variable, the availability of scientists and engineers, just like the second measure of innovation, comes from the Global Competitiveness Report of the World Economic Forum (Word Economic Forum 2009). For the years 2008 through 2009, it is the weighted average of answers to the question of the extent that scientists and engineers are available in the country. The variable ranges from one to seven with a one indicating that scientists and engineers are not available at all and a seven that they are widely available. The variable is identified with the variable name AVAILSCIENTISTS.

The Economist's Intelligence unit produces a democracy index with a range between zero and ten with higher values indicating greater democracy. The index for 2008 is used as a measure of democracy. It is given the variable name DEMOCRACY.

The level of economic development and is measured by per capita real GDP in 2000 U.S. dollars for the year 2005. The data for per capita real GDP comes from the World Bank (World Bank 2009). It is identified with the variable name GDPPC2000.

5. Cross Country Regression Findings

Table 1 shows cross country regressions of innovation as measured by the first measure on innovation, the World Economic Forum Innovation Index, on connectivity, and on connectivity adjusting for other variables. The first equation is the equation of innovation on the index of connectivity, the percentage of internet users to the population (PERINTERNETUSERS), by itself. The remaining three equations cumulatively add additional explanatory variables to the first equation. The second adds the freedom measure, the Economist's intelligence unit's democracy index (DEMOCRACY). The third adds, in addition to the freedom measure, the human capital variable, the availability of scientists and engineers (AVAILSCIENTISTS). Finally, the fourth equation adds the measure of the extent of economic development, real GDP per capita for the year 2005 (GDPPC2000).

Table 1 Cross country regressions of innovation (Using World Economic Forum Innovation Index) on the percentage of Internet users, democracy and other variables

	(1)	(2)	(3)	(4)
CONSTANT	2.218*** (24.89)	1.851*** (11.49)	.0844 (.274)	.5126 (1.66)
PERINTERNETUSERS	.0245*** (13.10)	.0215*** (9.48)	.0124*** (5.22)	.0058** (2.11)
DEMOCRACY		.0825*** (2.67)	.0927*** (3.39)	.0794*** (3.046)
AVAILSCIENTISTS			.5036*** (6.50)	.4294*** (5.69)
GDPPC2000				.000026*** (4.01)
Adjusted R^2	.555	.590	.693	.726
N	138	134	127	127

The results are consistent with the hypothesis that increased connectivity leads to greater country innovation. The percentage of internet users is positive in each of the four equations in table 1. The variable is significant at the one percent level or better in three of the four equations (equation 1, 2, & 3), and is significant at the five percent level or better in the remaining equation (equation 4). On its own, connectivity, as represented by PERINTERNETUSERS, explains over fifty five percent of the cross country variation in the World Economic Forum measure of innovation (equation 1).

Each of the three other variables also behaves very well. Democracy is positive and significant at the one percent level of significance in the three equations it appears (equation 2, 3, & 4). The technical human capital variable, AVAILSCIENTISTS, is positive and significant at the one percent level or better in the two equations it enters (equation 3 & 4), and the level of development variable, GDPPC2000, is positive and significant at the one percent level of significance or better in the sole equation it enters (equation 4).

The same four regression in Table I were re-run using the two other measures of country innovation, the Boston consulting Group innovation index and the Confederation of Indian Industry innovation index. The results for the Boston Consulting Group index are given in table 2 and the results for the Confederation of Indian industry index are shown in table 3.

Table2 Cross country regressions of innovation (Using Boston Consulting Group Innovation Index) on the percentage of Internet users, democracy and other variables

	(1)	(2)	(3)	(4)
CONSTANT	-1.272*** (-13.13)	-1.571*** (-9.22)	-2.990*** (-9.46)	-2.524*** (-8.07)
PERINTERNETUSERS	.0298*** (15.61)	.0265*** (11.44)	.0198*** (8.12)	.0127*** (4.50)
DEMOCRACY		.0682** (2.14)	.0654** (2.30)	.0467* (1.75)
AVAILSCIENTISTS			.4090*** (5.13)	.3392*** (4.49)
GDPPC2000				.000027*** (4.25)
Adjusted R^2	.692	.702	.763	.797
N	109	108	107	107

Table 3 Cross country regressions of innovation (Using Confederation of Indian Industry Innovation Index) on the percentage of Internet users, democracy and other variables

	(1)	(2)	(3)	(4)
CONSTANT	2.348*** (46.00)	2.054*** (22.80)	1.191*** (7.05)	1.738*** (12.21)
PERINTERNETUSERS	.0219*** (20.64)	.0194*** (15.82)	.0150*** (11.33)	.0083*** (6.62)
DEMOCRACY		.0651*** (3.85)	.0663*** (4.41)	.0533*** (4.59)
AVAILSCIENTISTS			.2487*** (5.81)	.1411*** (4.05)
GDPPC2000				.00003*** (9.31)
Adjusted R^2	.767	.795	.838	.904
N	130	127	127	127

The results in tables 2 and 3 are similar to the findings in table 1. Once again, the connectivity variable is positive and highly significant in each of the four equations. Once again, each of the other variables behaves extremely well in the equations in which they appear.

6. Conclusion

This paper provides empirical support for the hypothesis that a country innovation is positively related to country's connectivity as measured by the percent of the country's population that are internet users. Whether or not different measures of innovation are used, whether connectivity is used alone as an single explanatory variable in a cross country regressions to explain innovation, or whether connectivity is used in combination with other variables to adjust for the effect of other

relevant variables on innovation, the results indicate that connectivity has a statistically significant positive effect on innovation.

The obvious policy implication is that one way to promote innovation, the engine of economic growth, is to foster connectivity. At present, a promising inexpensive means to move toward greater connectivity is the encouragement of the dissemination of cell phones with internet capability.

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