Investments in R&D and innovative behavior: an exploratory cross-country study

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Abstract:

The relationship between investments in research and development (R&D) and innovative behavior, measured in terms of new products or services being delivered to the market, is well documented in the literature. This paper departs from the extant literature in that the unit of observation is a country rather than a firm. Using World Bank aggregate data, this level of analysis thus allows for a systematic study of cross-country observations on an *R&D* ➔ *Innovation* relationship.

Keywords: R&D | innovation | developed economy | transition economy | developing economy

Article:

Introduction

The relationship between investments in research and development (R&D) and innovative behavior, measured in terms of new products or services being delivered to the market, is well documented in the literature (Audretsch and Link, 2018a, 2018b; Bednar et al., 2019; Boles and Link, 2017; Gicheva and Link, 2016; Link et al., 2020; Link and Ruhm, 2009; Link and Scott, 2009, 2010; Protogerou et al. 2017). In fact, as Link and Cunningham (forthcoming) argue, the key technology policy target variable, and technology policy is at the root of policies to foster innovation, is investments in R&D.

In this paper, I depart from the extant literature in that the unit of observation is a country rather than a firm. This level of aggregation thus allows for a systematic study of cross-country observations, by the extent of their development, on an *R&D* ➔ *Innovation* relationship.

The data that I use for this study comes from the World Bank Enterprise Surveys of countries[1]:

[1] See https://www.enterprisesurveys.org/en/about-us (accessed October 14, 2020). The aggregated country statistics are based on a stratified random sample of firms within the country.

> An Enterprise Survey is a firm-level survey of a representative sample of an economy's private sector. The surveys cover a broad range of business environment topics including access to finance, corruption, infrastructure, crime, competition, and performance measures. Since 2005-06, nearly all data collection efforts have been centralized within the Enterprise Analysis Unit, where a Global Methodology was developed and applied ever since. To date, over 164,000 interviews in 144 countries have taken place …

More specifically, I rely on the population of 40 country reports in which information is aggregated and summarized on variables related to each country's investments in R&D and dimensions of innovation behavior.[2] The dimensions of innovative behavior that I consider are per se innovation, referring to the introduction of a new-to-the-firm product/service and the introduction of a new-to-the-market product/service. Other scholars have studied, using the World Bank firm-level data, new-to-the-firm innovative behavior within a country (e.g., Sharma, 2019) as well as across countries (e.g., Barasa et al., 2017; Goel and Nelson, 2018), but yet to be studied is the more nuanced measure of new-to-the-market innovative behavior.

My cross-country focus, using aggregated data, not only allows me to highlight differences in the *R&D* ➔ *Innovation* relationship by country but also by level of development of the country. The latter facilitates a prospective view about the role of R&D in a country's technology policy.

The World Bank's interpretation of the term *innovation* coincides with most interpretations by researchers in the fields of entrepreneurship. As Audretsch, Link, and Wright (2019, p. 2) point out, different academic disciplines view the concept of innovation differently. These three authors offered the following generalizations. In the area of finance, innovation is viewed in terms of the "allocation by firms of financial resources to innovative activities and the accessing by those firms of funds to finance innovation." In the area of entrepreneurship, innovation is characterized as follows: "Innovation-driven firms and entrepreneurs engage with a variety of knowledge providers (collaborations, spillovers) while also investing in research and development to disrupt the market equilibrium by introducing new ideas, products and services."[3] In the area of management, innovation is viewed in terms of the "access and development of the capacity, skills and resources to identify, pursue and coordinate innovation in processes, products, management and business models." Finally, in the area of marketing, innovation captures the "creation of a steady stream of new products and services that meets the needs of customers."

The remainder of the paper is outlined as follows. In Section II, I present descriptive information on the variables that I use to explore empirically the strength of the *R&D* ➔ *Innovation* relationship across countries. My empirical findings are presented in Section III, and I conclude the paper in Section IV with summary policy remarks and a brief suggested agenda for future research on this topic.

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[2] Forty-three (43) country reports present aggregated information on the R&D and innovation variables relevant to this study, but 3 of those reports do not contain information on a key independent variable and thus they are dropped from the analyses that follow.

[3] Schumpeter (1939, p. 62) defined innovation with reference to the production process which "describes the way in which quantity of product varies if quantities of factors vary. If instead of quantities of factors, we vary the form of the function, we have an innovation."

Description of the data

The 40 countries considered in this paper are listed in Table 1. From the World Bank's country reports, the key R&D variable comes from reported values of the percent of firms in the country that spend on R&D.[4] The key innovation variables come from the reported values of the percent of firms in the country that introduced a new-to-the-firm product/service, and, the percent of firms in the country whose new product/service is also new to the market. The product of responses to these two innovation variables approximates the percent of firms in the country that innovated by introducing a new-to-the-market product/service. Table 2 shows descriptive statistics on these four focal variables.

Table 1. List of Countries ($n = 40$)

Country	Year of the World Bank Report
Albania	2019
Armenia	2020
Azerbaijan	2019
Belarus	2018
Bosnia and Herzegovina	2019
Bulgaria	2019
Croatia	2019
Cyprus	2019
Czech Republic	2019
Egypt, Arab Republic	2020
Estonia	2019
Georgia	2019
Greece	2018
Hungary	2019
Italy	2019
Jordan	2019
Kazakhstan	2019
Kosovo	2019
Kyrgyz Republic	2019
Latvia	2019
Lithuania	2019
Malta	2019
Moldova	2019
Mongolia	2019
Montenegro	2019
Morocco	2019
North Macedonia	2019
Poland	2019
Portugal	2019
Russian Federation	2019
Rwanda	2019
Serbia	2019

[4] The World Bank uses the word *enterprise* when referring to these studies although the survey questions use the word *firm*.

Country	Year of the World Bank Report
Slovak Republic	2019
Slovenia	2019
Tajikistan	2019
Turkey	2019
Ukraine	2019
Uzbekistan	2019
West Bank and Gaza	2019
Zambia	2019

Note: It appears that information on the variables of interest in this paper were aggregated and included in the country reports beginning sometime in 2018

Table 2. Descriptive Statistics on the R&D and the Innovation Variables (n = 40)

Variable	Mean	Standard Deviation	Minimum	Maximum
Percent of firms that spend on R&D	41.81	17.346	8.1	70.2
Percent of firms that introduced a new product/service	28.03	14.073	1.6	60.2
Percent of firms whose new product/service is also new to the main market	65.17	14.235	26.9	91.2
Percent of firms that introduced a new product/service that is new to the main market	18.48	10.358	1.4	40.6

Note: The innovation variables are not clustered at either end of the percent spectrum

The 40 countries in the sampling population can be divided into those that are developed economies, those that are transition economies, and those that are developing economies. Counties within these three categories have been pre-defined by the United Nations (2020).[5] The mean values of the four variables in Table 2 are disaggregated and presented in Table 3 by these United Nations' categories.

Table 3. Mean Values of the R&D and Innovation Variables by United Nations' Categories

Categories	Developed Economy (*n* = 15)	Transition Economy (*n* = 16)	Developing Economy (*n* = 9)
Percent of firms that spend on R&D	53.78	35.20	33.62
Percent of firms that introduced a new product/service	29.12	32.65	17.98
Percent of firms whose new product/service is also new to the main market	61.25	65.27	71.52
Percent of firms that introduced a new product/service that is new to the main market	17.91	21.71	13.70

Note: Two of the World Bank countries were not considered in the United Nations' categorizations. For illustrative purposes, those two countries are placed in the developing economy category in this table. In the regression analysis below, categorical control variables are for developed economies, transitional economies, and all other economies

[5] "Since there is no established convention for the designation of "developed" and "developing" countries or areas in the United Nations system, this distinction is made for the purposes of statistical analysis only." See United Nations (2005, p. 43). "In the World Development Indicators database (and most other time series datasets), all 189 World Bank member countries, plus 28 other economies with populations of more than 30,000, are classified so that data users can aggregate, group, and compare statistical data of interest, and for the presentation of key statistics. The main classifications provided are by geographic region, by income group, and by the operational lending categories of the World Bank Group." See https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries (accessed October 15, 2020).

Several generalizations might be suggested from the data pattern in Table 3, and these generalizations are offered given that the classification of economies into the three categories are not standardized (see footnote 5 above). Thus, my comparison is only between the two extremes: developed economies and developing economies. Firms within countries within the category of being a developed economy compared to firms in countries with the category of a developing economy have (1) a larger percent of firms involved in R&D, (2) a larger percent of firms that introduced a new-to-the-firm product/service, and (3) have a larger percent of firms that introduced a new product/service that is new to the market.

Other variables that are included as controls in the regression analysis described in the following section of this paper are the mean age of firms within the country, the mean years of top manager's experience working in the firm's sector, and the mean level of employment (a proxy for firm size) of firms within the country. These variables approximate dimensions of the knowledge base or experiential base of firms. Thus, each of these controls should be positively related to innovative activity. Descriptive statistics on these control variables are presented in Table 4. The mean values for each of the first two variables are larger among the countries in the category of developed economies.[6] The mean number of employees is smaller among firms in the category Developed Economy perhaps due to a greater capital intensity in firms in that category.

Table 4. Mean Values of the Age and Experience Variables Used as Controls in the Regression Analysis ($n = 40$)

Control Variable	Full Sample ($n = 40$)	Developed Economy ($n = 15$)	Transition Economy ($n = 16$)	Developing Economy ($n = 9$)
Age of firms in years	17.87	20.60	15.45	17.63
Years of top manager's experience working in the firm's sector	19.47	22.75	17.24	17.96
Employees in firms	31.61	26.35	37.19	30.48

Empirical findings

The model that I consider in this paper is:

1. *Innovation* = f (*R&D*, **X**)

where the variable *Innovation* in eq. (1) is measured from two of the survey variables: Percent of firms that introduced a new-to-the-firm product/service (*PctInnovProdSer*) and Percent of firms that introduced a new-to-the-market product/service (*PctInnovProdSerNewMkt*). The variable R&D in eq. (1) is measured from the survey variable: Percent of firms that spend on R&D (*PctR&D*).

[6] In cross-firm studies one might also control for the industry(ies) in which the firm produces. While it would be useful to have had data from the World Bank on the major industry or industries in which firms produce, such information is not available in the country reports. See Goel (1990).

Also included in the specification of eq. (1) are interaction terms between binary variables that control for the category of the country (*CatD* refers to developed economy and *CatT* to a transition economy), the mean age of the firms in years in the country (*Age*), the mean age of the year of top manager's experience working the firm's sector (*MgtExper*), and the mean number of employees (*Emp*).

The correlation coefficient between *Age* and *MgtExper* is 0.838 ($\rho < 0.0001$). Thus, each of these variables enters a specification of eq. (1) separately. Each enters the statistical model in logarithmic terms to account for nonlinearities. The correlation coefficient between *lnAge* and *lnMgtExper* is 0.847 ($\rho < 0.0001$).

All of the variables considered in the estimation of eq. (1) are defined in Table 5 and the regression results are shown in Table 6.

Table 5. Definition of Variables Used to Estimate Specifications of Eq. (1)

Dependent Variable	**Definition**
PctInnovProdSer	Percent of firms that introduced a new product/service
PctInnovProdSerNewMkt	Percent of firms that introduced a new product/service that is new to the main market
Independent Variable	
PctR&D	Percent of firms that spend on R&D
CatD	Binary variable equal to 1 if the country is classified as a developed economy; 0 otherwise
CatT	Binary variable equal to 1 if the country is classified as a transition economy; 0 otherwise
PctR&DCatD	Interaction term between *PctR&D* and *CatD*
PctR&DCatT	Interaction term between *PctR&D* and *CatT*
Age	Age of firms in years
MgtExper	Years of top manager's experience working in the firm's sector
Emp	Number of firm employees
lnAge	Natural logarithm of *Age*
lnMgtExper	Natural logarithm of *MgtExper*
lnEmp	Natural logarithm of *Emp*

Table 6. Regression Results (standard errors in parentheses, n = 40)

	Dependent Variable *PctInnovProdSer*			**Dependent Variable *PctInnovProdSerNewMkt***		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
PctR&D	−0.5014***	−0.6129***	−0.2261	−0.3546**	−0.3998**	−0.2133
	(0.2231)	(0.2561)	(0.2400)	(0.1821)	(0.2062)	(0.1909)
PctR&DCatD	0.9019***	0.8978***	0.6721*	0.6465**	0.6429**	0.5289*
	(0.3977)	(0.4082)	(0.4266)	(0.3245)	(0.3288)	(0.3393)
PctR&DCatT	0.5877**	0.6978***	0.3833	0.3290	0.3766*	0.2224
	(0.2917)	(0.3109)	(0.3144)	(0.2380)	(0.2504)	(0.2500)
lnAge	22.4922***	–	–	11.0739	–	–
	(9.5705)			(7.8089)		
lnMgtExper	–	25.1761**	–	–	11.3867	–
		(13.3037)			(10.7136)	
lnEmp	–	–	11.5391**	–	–	6.1449
			(6.8822)			(5.4730)
CatD	−30.7166*	−31.0571*	−19.2921	−25.1110*	−25.1363*	−19.1550
	(20.0494)	(20.6125)	(21.3175)	(16.3591)	(16.5994)	(16.9526)

	Dependent Variable *PctInnovProdSer*			Dependent Variable *PctInnovProdSerNewMkt*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
CatT	−2.0363	−8.2242	−1.0659	−1.4464	−4.3032	−0.8710
	(11.1961)	(11.7420)	(11.6845)	(9.1354)	(−4.3032)	(9.2921)
Intercept	−29.3255	−33.4744	−12.9694	−5.9665	−5.4493	0.3360
	(26.7467)	(34.8259)	(27.2850)	(21.8237)	(28.0455)	(21.6982)
R^2	0.377	0.344	0.3301	0.235	0.215	0.218
F-level	3.33***	2.89***	2.71***	1.69	1.51	1.53

Note: **** significant at .01-level, *** significant at .05-level, ** significant at .10-level, * significant at .15-level

The empirical findings presented in Table 6 support the relationship between investments in R&D and innovative behavior at the country level. The empirical strength of that relationship varies across countries based on the United Nations classification of economies as developed, in transition, or developing. For example, consider the regression results in column (1) in Table 6. Among the countries in the category Developed Economy (*CatD* = 1), a 10%age point increase in the percent of firms that invest in R&D is associated with a 4.01 (9.019–5.014) percentage point increase in the percent of firms that innovate as measured in terms of the percent of firms that introduce a new-to-the-firm product/service in the market. Among the countries in the category Transition Economy (*CatT* = 1), a 10 percent point increase in the percent of firms that invest in R&D is associated with a 0.86 (5.877–5.014) percentage point increase in the percent of firms that innovate as measured in terms of the percent of firms that introduce a new-to-the-firm product/service in the market.

There is not a positive relationship between investments in R&D and innovation, as measured here, among the countries in the classification Developing Economy (*CatD* = 0 and *CatT* = 0). The calculated strength of these relationships is slightly smaller in the specification of eq. (1) presented in column (2) in Table 6.

Holding constant mean firm size as measured in terms of number of employees (*lnEmp*) does not yield informative information. The relationship between R&D and innovation among firms in the classification Developed Economy is positive and marginally significant. See the regression results in column (3) in Table 6.

Consider the regression results in column (4) in Table 6. The dependent variable reflects the introduction of a new product/service that is new to the main market. As shown in Table 3, the introduction of a new product/service that is also new to the main market occurs less frequently, among all of the countries, than the per se introduction of a new-to-the-firm product/service. Thus, one should expect, based on regression results, a smaller calculated relationship between the percent of firms that invest in R&D and the percent of firms that innovate in this latter way. In fact, as shown in column (4), among the countries in the category Developed Economy, a 10 percentage point increase in the percent of firms that invest in R&D is associated with a 2.92 (6.465–3.546) percentage point increase in the percent of firms that innovate as measured in terms of the percent of firms that introduce a new product/service that is new to the main market. This relationship among countries in the category Transition Economy is weaker, and it is not relevant (i.e., in a statistical sense) among countries in the category Developing Economy. The regression results presented in columns (5) and (6) tell a similar, but statistically weaker, story.

Finally, the strength of the relationship between the age of a firm and the introduction of a new product/service is positive and slightly stronger, from a statistical significance perspective, than the relationship between the years of management experience in the relevant sector and the introduction of a new product/service; but, from an numerically quantitative perspective, the strength of these relationships is just the opposite. Compare the regression results in columns (2) and (3) in Table 6.

Summary remarks

This paper offers exploratory insight into the *R&D* ➔ *Innovation* relationship among firms in countries that cover the spectrum of being developed, in transition, and developing economies. Differences between the strength of the *R&D* ➔ *Innovation* relationship by category of economic development offers insight into the importance of investments in R&D and to the importance of an economy being able to move from one category to another through innovation. Policy makers need to pay attention to the prospective role of investments in R&D (Link, 2020). Link and Cunningham (forthcoming) write that a bellwether of how successful government technology policies will be (and the success of a technology policy is a necessary condition for the success of a subsequent innovation policy) is determined in large part by the earlier levels of investments in private-sector R&D.

However, additional research on this topic is needed. For example, one might investigate other covariates associated with the *R&D* ➔ *Innovation* relationship such as the composition of the labor force (e.g., skilled versus technical versus unskilled workers) and the availability of external financial sources to support internal R&D investments. And, little is known about comparative innovative behavior among countries/firms in developing economies, and that remains an area in need of additional study.[7]

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[7] Some country-specific technology studies have been done using the World Bank's data. See https://www.enterprisesurveys.org/en/enterprise-research (accessed October 16, 2020).

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