Paper to be presented at the

35th DRUID Celebration Conference 2013, Barcelona, Spain, June 17-19

The Impact of Investments in Research and Innovation: A Literature Review

Margaret Dalziel
University of Waterloo
Conrad Business, Entrepreneurship and Technology Centre
mdalziel@uwaterloo.ca

Tanita Noor Tahmina
University of Ottawa
Telfer School of Management
ttahm082@uottawa.ca

Xiao (Mimosa) Zhao
University of Ottawa
Telfer School of Management
xzhao053@uottawa.ca

Abstract

We conduct a systematic review of the recent literature on the impact of government investments in university research, technology transfer offices, and industry research and innovation. We consider the research questions, findings, and methodologies of 50 studies published between 2000 and 2012, and find a diverse range of investigations that ask a complementary range of research questions, and that are sensitive to a multiplicity of investment objectives, circumstances, and outcomes. These studies employ 36 different measures of impact, and an average of 9.6 years of longitudinal data. Methodological rigour is generally high, notwithstanding the universal use of post-hoc analysis design. Many studies test multiple models or specifications. Of the 243 models presented, 65% find that the investment yields a positive impact. Of the 113 models that control for endogeneity, 63% report a positive impact. Overall, the evidence points to the importance context in achieving socio-economic benefits as a consequence of investments in research and innovation. With few exceptions, firm absorptive capacity, entrepreneurial behaviour, geographic proximity, and immersion in the national system of innovation are significant predictors of impact.

Jelcodes:O38,-

Governments around the world invest significant funds in research and innovation activities conducted by universities, innovation intermediaries, and firms. A recent estimate of total spending on R&D by governments, universities, and firms puts the figure at $1.4 trillion per year (Economist, 2013), approximately two-thirds of which is financed by governments (OECD, 2012). Not surprisingly, governments and their citizens seek reliable assessments of the impact of these investments, in part as a consequence of the desire for effectiveness, efficiency, and accountability in the spending of public funds, and in part as consequence of the importance of the hoped-for socio-economic benefits. Such investments have been shown to contribute to economic growth through increasing the stock of useful knowledge, developing highly qualified individuals, creating new scientific instrumentation and methodologies, forming networks and stimulating social interaction, increasing the capacity for scientific and technological problem-solving, and creating new firms (David, Mowery & Steinmueller, 1992; Salter & Martin, 2001).

Early attempts to measure research and innovation related phenomena at the National Science Foundation in the US and at the Organization for Economic Co-operation and Development in Europe focused on more easily measured inputs, activities, and outputs, rather than outcomes or impacts, which are harder to measure (Godin, 2003; Freeman & Soete, 2009; Pavitt, 2001). Early academic studies of the relationship between investments in innovation and socio-economic benefits include Griliches' (1957) analysis of the rate of adoption of hybrid corn in the US, Nelson's (1959) analysis of the economics of basic research, Mansfield's (1961) analysis of innovation diffusion rates in multiple industries, Rosenberg's (1983) analysis of the economics of technological change, and Jaffe's (1986) demonstration that investments in university R&D induce local commercial investments in R&D and patenting. Recent decades have seen a greatly expanded and diversified literature that includes reviews of the economic benefits of investments in basic research (Salter & Martin, 2001), and the literatures on technology transfer (Bozeman, 2000), science parks and incubators (Phan, Siegel & Wright, 2005), and business networks (Pittaway et al., 2004).

The increased focus on measurement has been accompanied by increased concerns regarding the unintended consequences of measurement activities. Most fundamental is the fact that once a social measure is declared to be important, people are likely to behave in such a way as to achieve a good rating on the measure, rather than in such a way as to address the problem or opportunity that was the motivation for identifying the target measure (Freeman & Soete, 2009; Paton, 2003). If patents are taken as an indicator of useful inventions, then people may focus on generating patents, rather than on generating useful inventions. A naïve focus on patents as a measure of inventiveness may, as a consequence, reduce inventiveness. A second concern is the poor selection of measures. Efforts to encourage and measure the commercialization of university technologies have been criticized for focusing on the superficial and the easily measured at the expense of the substantive (Langford et al., 2006; Litan, Mitchell & Reedy 2007; Mowery et al., 2001). Final concerns are that measurement may stifle experimentation (Pavitt, 2001) and may not lead to learning. A study of evaluations of US state-level economic development offices found that less than one quarter made recommendations for program changes (Eisinger, 1995).

Acknowledging the validity of these concerns, we conduct a systematic review of the recent literature on the impact of government investments in research and innovation. We consider 50 studies published between 2000 and 2012, and find a diverse range of investigations that ask a complementary range of research questions, and that are sensitive to a multiplicity of investment objectives, circumstances, and outcomes.

We begin by briefly describing our methodology. In the two main sections of the paper we present the research questions and findings, and analyze the empirical approaches. In both sections we group the studies into those that consider investments in university research, those that consider investments in university technology transfer, and those that consider investments in industrial research and innovation. In the final section we discuss the implications of our findings.

METHODOLOGY

We began our systematic review by creating a sample of articles published in journals that offer high quality studies of the impact of investments in research and innovation. While our sample of 50 papers is small and omits many outstanding contributions, it has the benefit of being an unbiased appraisal of the state of the art. We consider articles published in Research Policy, The American Economic Review, the Journal of Technology Transfer, or Management Science that had at least one of the following phrases in their title: HERD (Expenditure on R&D in the Higher Education Sector), innovation intermediaries, research institutes, research consortia, technology transfer, science parks, business incubators, business advice, chambers of commerce, industry associations, impact, or outcomes. We selected a final list of 50 articles published between January 2000 and February 2012 by scanning abstracts, and in some cases the full articles, and excluding articles that were not empirical studies of the impact of investments in research and innovation. We eliminated articles that were unrelated to our topic, articles that were based on literature reviews or conceptual arguments, and articles that described research or innovation activities without considering the outcomes or impacts of those activities. We began our analysis by summarizing the research questions, findings, and methodologies of each paper and noted the use of 36 different impact measures.

We conduct a detailed analysis of the choice of impact measure. Our approach for analyzing the literature based on the nature of the measure of impact can be contrasted with Bozeman's (2000) approach, which is based on the nature of the explanation for technology transfer effectiveness, and the approach of Salter and Martin (2001), who consider theoretical rationales and findings. In order to gain an understanding of the range and frequency of the alternative measures of impact used by the studies included in our review, we create a logic model-based characterization of the innovation process, and classified each measure according to its position in the process. Logic models are used to present theories of change and relate the inputs to the change process to activities, outputs, and impacts (Millar et al., 2001). The theory of change implied by our model is that investments in research and innovation activities conducted by universities and innovation intermediaries may yield direct private returns for the firms involved, and social returns for regions, societies, and economies.

RESEARCH QUESTIONS AND FINDINGS

University Research

While it is clear that investments in university research have had socio-economic benefits, the measurability of these impacts is less clear (David et al., 1992). The affected parties and the nature of impacts are diverse—ranging from knowledge impacts on individuals to widespread environmental impacts, and the transformation of discoveries from the scientific to the practical realm may involve long timeframes and may take many unforeseen and not easily traced paths. Accordingly, the 14 studies of the impact of investments in university research included in our review consider a variety of research questions related to the outcomes of investments in university research including impacts on firms (five papers), impacts on university researchers (two papers), and the predictors of university-industry engagement (seven papers).

Impacts on firms. Two ambitious studies seek to quantity the impact of university research on firms. Toole (2012) examines the effect of government investments in basic science on the introduction of new molecular entities and finds that, following a 17-24 year time lag, each dollar invested in basic research yields an annuity of $0.43 in annual revenues, with cost-benefit ratios highly dependent on interest rate assumptions. Vincett (2010) assesses the economic impacts of investments in basic research by estimating the contributions to GDP and tax revenues of university spin-offs. He reports that while spin-offs are not the most important impact of university research, the economic impact of spin-offs alone exceeds the government investments in university research by a wide margin. Audretsch & Lehmann (2005) examine the impact of knowledge spillovers from university research on firm growth and find that university proximity and productivity has a significant effect on firm growth.

Two studies examine the impact of university research, complemented by incubators, on venture performance. Rothaermel & Thursby (2005) find that venture absorptive capacity (as measured by backward citations to university research on venture patent applications) affects positively venture performance when measured by venture capital financing, but not when measured by venture revenues. Salvador (2011) compares the revenues of university spinoffs and other startups and finds that when measured by revenues, university spinoffs perform worse.

Impacts on university researchers. Two papers examine the impacts of researcher characteristics and behaviors on academic publishing. Crespi et al., (2011) examine the impact of academic patenting on publishing rates and find that patenting complements publishing up to approximately 10 patents, after which additional patents reduce publishing outputs. Similarly, patenting complements other knowledge transfer activities up to approximately eight patents, after which there is a substitution effect. Gonzalez-Brambila & Veloso (2007) consider the effects of age and reputation on academic publishing and citation rates and find that publishing peaks at age 53, while citation rates peak at age 56.

University-industry engagement. Eom & Lee (2010) investigate the antecedents and impact of cooperation between industry and public sector researchers and find that firm innovativeness and R&D subsidies predict cooperation. Cooperation has no significant impact on firm patenting, sales, or labor productivity, but when the sample is restricted to innovative firms, cooperation has a positive impact on patents for new products. Woerter (2011) and Santoro & Gopalakrishnan (2001) examine the determinants of university-industry technology transfer. Woerter finds that technological proximity increases the likelihood of transfer, and Santoro and Gopalakrishnan find that trust, geographic proximity, and flexible university intellectual property policies are associated with more extensive engagement.

Cohen et al. (2003) and Arvanitis et al. (2008) investigate the channels through which impact is achieved. Based on the Carnegie Mellon Survey, Cohen et al. find that public sector research contributes both to the generation of new projects and to the completion of ongoing projects through many channels, including publications, events, informal exchanges, and consulting. Arvanitis et al. find consistent econometric evidence of impact for research, mixed evidence for education and infrastructure, and no evidence for consulting.

Hussler & Rondé (2007) consider the effect of the composition and knowledge orientation of inventing teams on the geographic breath of their research network. They find no effect for team heterogeneity, and that collaboration among university researchers is more local among epistemic communities (inventors of knowledge-based patents) than among communities of practice (inventors of patented tools). Roelofsen et al. (2011) examine the impact of structured meetings on the identification of possible matches between the demand for research outputs and their supply, and find that dialogue design facilitates learning but has no impact on action.

Overall these studies find that investments in university research may have quantifiable impacts on firms, including university spin-offs, although the discernability of such impacts depends on a number of methodological choices. Predictors of university-industry engagement include geographic and technological proximity, trust, university policies, and subsidies.

Technology Transfer

In this section we present the research questions and findings of the 13 papers that focus on university technology transfer offices (TTOs) as agents of university-industry engagement in the interests of knowledge dissemination and deployment, university fundraising, and economic development. In terms of research questions, three of the papers consider the antecedents to engagement, four papers consider the efficiency of TTOs, three papers examine the predictors of university spin-offs, and the final three papers consider changes in the efficiency of TTOs over time.

Antecedents to technology transfer. Hulsbeck at al. (2011) and Owen-Smith and Powell (2001) consider the predictors of invention disclosure to TTOs with a view to understanding variations in the number of disclosures by institution, and the considerations of faculty in the decision to disclose. Hulsbeck et al. show that faculty quality, medical school presence, and TTO specialization are positively related to the number of disclosures, while industrial concentration is negatively related. Owen-Smith and Powell find that the faculty member's conception of the benefits of patenting and the costs of engaging with TTO personnel, shaped by the institutional culture and history, explain qualitative variations in the propensity of university faculty to disclose inventions. Van den Berghe and Pries consider the firm perspective and show that positive perceptions of the strategic value of a technology make an exclusive license agreement more likely.

Measuring and explaining TTO efficiency. Four studies examine TTO efficiency using activity and output measures. Thursby et al. (2001) and Siegel et al. (2003) use data collected by the Association of University Technology Managers to consider the efficiency of US TTOs while Chapple et al., (2005) and Caldera et al. (2011) consider UK and Spanish TTOs, respectively.

Thursby et al. find correlations between the number of invention disclosures and university patents, the amount of sponsored research and the number of licenses. They also find that technology licensed at an early stage of development is likely to be associated with sponsored research, while technology licensed at a late stage of development yields higher royalties. Siegel et al. examine the relative efficiency of US TTOs and find constant returns to scale and that TTOs in regions with high levels of industrial R&D are more productive.

Chapple et al. (2005) examine the relative efficiency of UK TTOs and find high levels of heterogeneity in performance as measured by the number of licenses and the amount of licensing revenues. They find negative returns to scale with older, larger TTOs exhibiting lower levels of efficiency than their younger, smaller counterparts. They also find that the presence of a medical school has a negative effect but the regional R&D and GDP has a positive effect. Caldera and Debande (2010) consider the impact of Spanish TTO policies and characteristics on outcomes and find positive effects for clear policies, and that the capabilities of TTO personnel have a positive effect on the number of R&D contracts, but no effect on contract revenues, licensing outcomes, or the number of spin-offs. University quality has a positive effect on contract outcomes and the number of licenses but no effect on licensing revenues or the number of spin-offs.

Spin-offs. The number of university spin-offs launched has emerged as an alternative measure of TTO performance. Clarysse et al. (2011) develop a model of the likelihood that a university faculty member will launch a spin-off and find that the individual's self-assessed capacity for opportunity recognition, entrepreneurial experience, and tenure status are significant positive predictors of the likelihood entrepreneurial activity, but that the likelihood of the presence of a TTO, as measured by the year of the faculty member's university appointment, had no effect. Algieri et al. (2011) examine the predictors of university spin-offs in Italy and find that TTO size, TTO employee specialization, and university financial resources are positive predictors of spin-off launch. O'Shea et al. (2005) consider the US case and find that the significant predictors of spin-off launch in the US are the quality of university faculty, and scientific and industrial research funding, and TTO size.

Changes in TTO efficiency. Two studies use AUTM data to evaluate changes in the efficiency of TTOs over time. Kim (2011) computes eight years of average total factor productivity scores for 90 US TTOs and finds that technology transfer productivity has increased over the 1999 to 2007 time period. In contrast, Cardozo et al. (2011) compare TTO cohorts and find that the efficiency of TTOs founded prior to 1990 has increased, but that TTOs founded after 1990 are less efficient than older offices. Both Cardozo et al. and Kim find a positive effect for the presence of a medical school, although Kim reports a very modest effect. Cardozo et al. report that it is likely that over half of the TTOs in their sample are economically viable only as a consequence of being subsidized by their host universities. Cardozo et al., like Chapple et al. (2005), advise the regional amalgamation of small TTOs. Debackere and Veugelers (2005) present a case study of a TTO in Belgium and based on this, call for TTO personnel with entrepreneurial and scientific capabilities, TTO autonomy, and incentive alignment.

Definitive results regarding the effectiveness of TTOs are elusive because results vary according to the measures and predictors of effectiveness employed and study methodologies. In the consideration of TTO outcomes, TTO capabilities have been found to have a positive effect (Algieri et al., 2011), no effect (Clarysse et al., 2011), and mixed effects (Caldera & Debande, 2010). The impacts of other factors of TTO effectiveness have been similarly mixed. University quality has been found to have a positive effect (Clarysse et al., 2011; Hulsbeck et al., 2011; O'Shea et al., 2005) and mixed effects (Caldera & Debande, 2010; Thursby et al., 2001), regional characteristics have been found to have a positive effect (Algieri et al., 2011; Chapple et al., 2005; Siegel et al., 2003) and a negative effect (Hulsbeck et al., 2011), the presence of a medical school has been found to have positive effect (Cardozo et al., 2011; Hulsbeck et al., 2011; Kim, 2011), a negative effect (Chapple et al., 2005), and mixed effects (Caldera & Debande, 2010; Thursby et al., 2001), and the presence of an incubator has been found to have a positive effect (Caldera & Debande, 2010) and no effect (O'Shea et al., 2005).

Industrial Research and Innovation

The remaining 23 papers included in our review assess the impact of interventions designed to help firms succeed and policies that may or may not have an impact on firm success. In the following we summarize the findings of the papers that consider the impact of support for new ventures, science parks, research institutes, support for collaborative R&D, foreign government investments in R&D, and government policies.

Support for new ventures. Cumming & Fischer (2012) assess the impact of advisory services on entrepreneurial ventures and find that the hours of advice received has a significant impact on revenues and venture capital financing, but no impact on patenting or strategic alliances. These findings are noteworthy because previous studies have found no impact of advisory services on SMEs. Cumming & Fischer argue that the growth orientation of the entrepreneur will affect the likelihood that business support services will have an impact on the venture, and distinguish their sample of entrepreneurial ventures from the general samples of SMEs used in earlier studies. The findings of Soetanto & Jack (2011) also point to the importance of the entrepreneur's growth orientation. In their examination of the networks of firms in a UK incubator, Soetanto & Jack show that highly innovative firms are more proactive in building internal and external networks, and that their networks have a greater impact on their performance than the networks of less innovative firms. Hackett and Dilts (2008) propose scales to be used in describing and measuring the impact of incubator processes.

Science parks. Three studies examine the impact of science parks on new technology-based firms. Two papers consider the impact of Swedish science parks and find significant effects on networking, technological innovation, and new product development (Lindelof & Lofsten, 2004), and on employment and revenues, but not profitability (Lofsten & Lindelof, 2002). Yang et al., (2009) examine the impact of the Hsinchu Science Park in Taiwan on the research efficiency of new, technology-based firms and find that changes in R&D investments have a greater effect on the revenues of on-park firms than on the revenues of off-park firms.

Research institutes. Izushi (2003) examines relationships between research institutes and SMEs in Japan and finds a positive relationship between the duration of the relationship and the likelihood that the SME will access 'high information gap' services. This result is echoed by Barge-Gil & Modrego (2009) who examine the impact of Spanish R&D institutes and find that the duration and intensity of the firm-institute relationship is a significant predictor of impact. Coccia (2008) finds that the distance between firms and research institutes in Italy is inversely related to the likelihood of technology transfer.

Government-supported collaborative R&D. Barajas et al., (2011) examine the impact of collaborative research supported by the European Union on the labour productivity of participating firms. They find that collaborative research has a direct effect on technological capabilities, and thereby an indirect effect on labour productivity. Branstetter & Sakakibara (2002) examine the impact of participation in government-sponsored research consortia on Japanese firms, and find that outcomes are positively associated with technological complementarities amongst consortium members, but negatively associated with product market competition. Busom & Fern'andez-Ribas (2008) find that government support for R&D increases the likelihood of collaboration, both with other firms and with public research institutes.

Foreign government investments in R&D. Three studies report on the impact of foreign government investments in R&D on UK manufacturing firms, finding effects where the UK firms have operations or inventors located in the foreign countries. Frenz & Ietto-Gillies (2009) examine the impact of internally, externally, and collaboratively generated knowledge on innovation sales, and find that in-house R&D, bought-in R&D, and the reach of international, intra-firm knowledge networks have a positive impact on innovation sales, but that collaboration, including international collaboration, has no effect. Añón Higón (2007) examines R&D spillovers finding evidence of intra-industry and inter-industry spillovers, but no evidence of spillovers from the R&D investments of foreign countries. Griffith et al. (2006) examine the effect of US investments in R&D on UK firms, and find that benefits are proportional to the firm's level of inventive activity in the US (patents of employee-inventors located in the US).

Government policies. Czarnitzki et al., (2011) consider the impact of R&D tax credits and report a positive effect on measures of firm innovation, but no effect on firm performance in the market. Varsakelis (2001) examines the impact of culture, openness, and patent policy on R&D investments, and finds support for all three effects. Gans et al., (2008) examine the impact of patent allowance on the likelihood of licensing and find a significant effect, suggesting that patents increase the efficiency of the 'market for ideas'.

Impacts on regional and national economies. The final two papers examine impacts on regional and national economies. Choi et al. (2009) consider the impact of firm investments in technology and operations on national economic performance and Roessner et al. (2010) estimate the regional and national economic impacts of three US-based engineering research centers.

Our review makes four conclusions. First, the findings of studies that examine the impact of business advisory services and incubators on ventures are extremely sensitive to the choice of dependent variable. Cumming and Fischer (2012) find impact on revenues and venture capital financing, but not on patenting or strategic alliances. Lofsten & Lindelof (2002) find impact on employment and revenues, but not on profitability. In the section on investment in university research we reported that Rothaermel & Thursby (2005) found impact on venture capital financing, but not on revenues. Second, the impacts of venture-targeted investments are also sensitive to the behavior of the entrepreneur. Studies report that the duration (Izushi, 2003) and intensity (Barge-Gil & Modrego, 2009) of the relationship with the entrepreneur has an effect on the choice of services accessed, and their impact, respectively. Soetanto & Jack (2011) report that innovative entrepreneurs create more effective networks than non-innovative entrepreneurs, and Cumming & Fischer (2012) find that the coachability ranking assigned to the entrepreneur is a significant predictor of the impact of the business advisory services.

Third, the importance of the firm's absorptive capacity is evident. Firm investments in basic research are associated with the effectiveness of engineering research centres (Feller et al., 2002), research consortia investments in basic research are associated with consortia effectiveness (Branstetter & Sakakibara, 2002), and the presence of patents increases the effect of public support for R&D on the propensity to collaborate (Busom & Fern'andez-Ribas, 2008). The signaling value of patents may also be important, as ventures that have patents are more likely to receive advisory services (Cumming & Fischer, 2012). The final conclusion concerns the importance of immersion in the national system of innovation. Firms are only able to benefit from foreign investments if they have substantial activities in the foreign country (Anon Higon, 2007; Frenz & Ietto-Gillies, 2009; Griffith et al., 2006).

EMPIRICAL APPROACHES

In this section we examine the data sources, measures, and statistical methodologies employed by the studies included in our review with a view to understanding the range of empirical approaches.

Data

As shown in Figure 1, below, most of the studies included in our review are set in a single country, and in all but four cases it is the country of residence of at least one of the authors, reflecting the requirement for an understanding of the system of innovation in which investments are made. A total of 16 mostly advanced countries are involved, and approximately half the studies are conducted in the US, the UK, or Canada.

The studies included in our review employ up to 51 years of data, with the average study employing 9.6 years of data. The span of data used is proportional to the distance between the nature of the investment and the commercial realm; data for studies of the impact of investments in university research, TTOs, and industrial research and innovation span 13.5, 9.1, and 7.3 years, respectively.

****
Insert Figure 1 here.
****

Measures

We make sense of the huge diversity of measures employed by the studies included in our review by classifying them according to their nature. We base our classification on a compound logic model that characterizes the innovation process into sequential phases of research and innovation facilitation, and impact. We recognize and allow for the fact that innovation processes are not sequential, but may be iterative, and that all innovation-related activities potentially employ inputs from and yield outputs to all other innovation-related activities (Kline & Rosenburg, 1986). We accommodate the non-sequential nature of innovation activities within our sequential framework by allowing measures used as dependent variables to be classified earlier in the sequence than measures classified as independent variables, where this is appropriate.

As in the previous section, we first consider papers that examine the impacts of investments in university research, technology transfer, and industrial research and innovation. In each case we present a table that classifies the dependent and independent variables of interest according to their nature. In the first column we identify the paper and in the remaining columns we distinguish between measures that pertain to research and innovation facilitation in non-firm organizations including universities, government organizations, and non-profit research institutes (Columns 2-4), firm impact measures (Columns 5-6), and society or economy level impact measures (Column 7). For non-firm organizations we distinguish between input measures, which are typically investments; activity measures, which are typically measures of university-industry engagement; and output measures, which include publications, patents, licenses, contracts, and spin-offs. For firms, we distinguish between input measures of firm resources and capabilities, and output measures of firm performance. The measures of firm activities that were employed by sample studies are largely confined to measures of inter-organizational collaboration. These are listed in Column 3 if they measure engagement with universities or public sector researchers, and in Column 5 if they measure inter-firm collaboration.

We identify dependent variables and important independent variables of theoretical interest, indicating the former with the letters DV in parentheses. For example, Paper 4 (Crespi et al., 2011) considers the effect of academic patenting (an independent variable which we classify as a research output) on publishing (a dependent variable which we classify as a research output), and on university-industry knowledge transfer (a dependent variable which we classify as a research activity). Note that in this example, the dependent variables are classified in the same category as the independent variable, or in the preceding category. This is consistent with our recognition that neither innovation processes, nor studies of innovation processes, adhere to the sequential view of innovation that may be implied by our framework.

University research. As shown in Table 1, six of the 14 papers that consider the impacts of investments in university research employ measures of activities and outputs as measures of impact, considering relationships such as the impact of funding on publications. These papers confine their consideration of impact to scientific impacts. The remaining eight papers consider the impacts of investments in university research on firms or economies, considering the link between investments in the scientific realm and impacts in the economic realm. Six papers consider the impact of investments in university research on firms, either the impact on firm knowledge, resources, or capabilities (inputs) or the impact on firm performance (outputs). One paper considers both firm and non-firm impacts (Eom & Lee, 2010) and one paper considers both impacts on firms and economy level impacts (Vincett, 2010).

Our framework helps us identify two papers that are remarkable for the spread between the phenomena they measure. Both Toole (2012) and Vincett (2010) consider the impacts of investments in the scientific realm on economic outcomes. Toole is able to trace National Science Foundation investments in biomedical research to the likelihood of the commercial deployment of new molecular entities by pharmaceutical firms, while Vincett is able to trace investments in physics research to the taxes paid by physics-based university spin-offs. Both studies rely on approximately 50 years of data and attribute their findings to the significance of the scientific discoveries.

****
Insert Table 1 here.
****

Technology transfer. Our analysis of the measures classified in Table 2 shows that only two of the TTO studies consider the perspective of the industrial partner to the engagement. Van den Berghe and Guild (2008) consider the firm perspective on the value of university IP on licensing behaviors, and Siegel et al. (2003) compare the perspectives of industry partners, TTO personnel, and university faculty on the barriers to engagement. The remaining studies focus exclusively on the university perspective with the studies that consider university spin-offs only considering explanations of the number of spin-offs, not the effect of spin-off status on venture success.

It is likely that the institutionalization of TTO outputs as measures of TTO effectiveness has had an effect on research in this area (Langford et al., 2006; Mowery et al., 2001). Since the early 1990s the US-based Association of University Technology Managers (AUTM) has been collecting data on university expenditures, invention disclosures, patents, licenses, contract research, and spin-offs (AUTM, 2012). The availability of this TTO output data has reduced the incentives to conduct surveys of firms in the interests of collecting TTO impact data. In the few cases where researchers have conducted surveys of firms with a view to assessing the impact of university research on firms (Cohen et al., 2002), they have not included in their surveys questions regarding the impact of TTOs. Nor have researchers used econometrics to tease out the impact of TTOs on firms from secondary data. Such an attempt would likely be futile as it is extremely difficult to tease out the impact of university research from secondary data on firm performance, let alone the impact of the university TTO. Toole (2012) accomplished this only by using a measure of firm performance that was highly sensitive to the impact of university research: the introduction of new molecular entities.

The focus of university TTOs on the generation of countable outputs and the maximization of revenues at the expense of the dissemination and deployment of new knowledge and technology has come under criticism (Langford et al., 2006; Mowery et al., 2001). Some authors have advocated the elimination of the TTO monopoly on the commercialization of university-generated intellectual property in the interests of allowing university researchers to engage the best qualified individuals in their efforts to deploy their findings (Litan, Mitchell & Reedy, 2007). Others report that in spite of the focus on the generation of revenues, most university TTOs do not generate enough revenues to sustain their existence (Cardozo et al., 2011).

****
Insert Table 2 here.
****

Industrial research and innovation. Like the studies of the impact of investments in university research, the studies of the impact of investments in industrial research and innovation employ a wide range of measures. But as might be expected, measures of firm performance are the most frequently employed type of measure. Of the 23 studies in this section, 14 employ (usually multiple) measures of firm performance such as patents, revenues, profitability, employment, productivity, and survival as their dependent variables. Measures of firm performance benefit from high levels of validity and objectivity, and the availability of secondary data including administrative data collected by governments. Of these 14 studies, three also employ firm input measures such as learning, intangible assets, capabilities, and collaborative networks as alternative dependent variables. Such measures are usually obtained through special purpose surveys.

As shown in Table 3, moving from left to right across our framework, the dependent variables employed by the remaining studies include national R&D expenditures, engagement with research institutes or other firms, firm input measures, and economy level measures. One study (Soetanto & Jack, 2011) was restricted to analyzing correlations.

****
Insert Table 3 here.
****

Measures by model. To present a more fine-grained consideration of the measures used by the studies included in our review we shift our level of analysis to that of the model. Several of the papers included in our review present multiple models or specifications in order to consider multiple dependent variables, alternative explanatory variables, or alternative statistical methodologies. Of the 50 papers included in our review, 44 papers present one or more quantitative models, with the remaining papers presenting descriptive statistics or conducting qualitative data analysis. The 44 papers present a total of 243 models.

As shown in Figure 2, below, these 243 models employ a total of 36 different dependent variables. The most frequently employed dependent variables are measures of university-industry collaboration, measures of inter-firm collaboration, counts of new products, patents, new product revenues, revenues, and measures of regional growth. It is also interesting to consider variations in dependent variables by investment type as indicated by the shading of the bars in Figure 2. For example, the impact of investments in university research is most frequently measured by the number of new products introduced, whereas the impact of investments in industrial research and innovation is most frequently measured by new product revenues. While the introduction of a new product may be sufficient to demonstrate the socio-economic impact of investments in university research, the revenues earned by the new product is a better measure of investments seeking to produce commercial impact.

****
Insert Figure 2 here.
****

Statistical Methodologies

Researchers that conduct assessments of the impact of government investments in research and innovation must address the selectivity problem, the need to distinguish between the impact of the investment and other causes of superior performance. The selection bias may be serious because high performing researchers or firms are likely to continue exhibiting high performance, regardless of whether or not they benefit from government investments. So evaluators must distinguish between performance that is endogenous to the investee, and performance that is a consequence of the intervention.

Jaffe (2002) identifies two fundamental approaches for addressing the selectivity problem. Where evaluations of impact are conducted after investments have been made, 'after-the-fact' evaluations are the only option. In such cases researchers have four alternatives (in order of increasing reliability with citations to exemplar studies included in our review): control variables (Barge-Gil & Modrego, 2009), paired samples of treated and untreated entities (Löfsten & Lindelöf, 2002), difference-in-differences approaches where pre-treatment performance is compared to post-treatment performance (Branstetter & Sakakibara, 2002), and finally the use of selection models with instrumental variables (Cumming & Fisher, 2012).

The second approach involves designing the investment program in such a way as to facilitate rigorous evaluation. Here there are two alternatives. The first involves distributing funding randomly amongst entities that meet basic criteria, essentially conducting a randomized trial, as is common in the evaluation of medications. And the second involves ranking program applicants according to quality prior to making investments and employing this information in regression discontinuity design.

All four of the post-hoc approaches to evaluation are employed by the studies included in our review, but neither of the two more rigorous approaches. Jaffe does not identify a study that employs randomization, but the UK's innovation foundation Nesta has recently conducted such an experiment (Bakhshi et al., 2012). The applicability of randomization is limited because randomly distributing funding or other resources is politically difficult, and infeasible where the resources or services in question are highly specialized and therefore suitable only to a small number of candidates. To our knowledge, regression discontinuity design has yet to be applied to the analysis of the impact of research or innovation investments (Lee & Lemieux, 2009).

It has been said that the more rigorous the econometrics, the less likely it is that the study will find a positive impact (Roodman, 2009). Of the 243 models included in our review, 157 (65%) find a positive impact. In some cases the selection issue does not arise, because the independent variable of interest is an output count measure that is uncorrelated with the error term (41 models). Of the remaining 202 models, 113 control for endogeneity using selection models or difference-in-differences approaches and 89 do not. In many of the cases where selection is not addressed, it is because authors are purposefully comparing the results of ordinary least squares regressions without instrumental variables, with the results of multiple stage regressions that use instrumental variables. Of the 113 models that control for endogeneity, 63% (71/113) find a positive impact. Of the 89 models that do not control for endogeneity, 66% (59/89) find a positive impact. The small difference between the two proportions challenges the adage concerning the inverse relationship between rigor and the likelihood of finding a positive effect. It is important to note that the finding of a positive impact is a consequence of many design decisions in addition to the choice of econometric methodology, including, importantly, the choice of impact measure.

IMPLICATIONS

In the following we describe the implications of our review for researchers and policy makers seeking to learn from past assessments or to make informed decisions regarding future evaluations.

Diversity of impact measures. Our first observation is the wide variety of measures of the effects of investments. Consistent with the multidimensional nature of success in innovation and business performance, we identify 36 different dependent variables, and observe that the likelihood of finding of an effect is highly sensitive to the choice of measure. Many studies report significant impacts on some measures, and no impacts on other measures. The implication is that it is not possible to identify a single standard measure of return on investment as the appropriate measure of impact, as impact will vary according to the nature of the intervention, the nature of the recipient, and the time lag between investment and impact assessment.

Assessment timelines. Assessment timelines are lengthy. We note that the average study in our sample uses 9.6 years of data with some studies using up to 50 years of data. Rigorous impact assessment requires access to fine-grained longitudinal data and is therefore expensive.

As a consequence, some have suggested that rigorous evaluation is best reserved for programs that are reasonably mature and large, and that have demonstrated effectiveness in non-randomized studies (Epstein & Klerman, 2012).

Importance of firm characteristics. Many of the studies included in our review have shown that the characteristics of the firm and the entrepreneur are important predictors of impact. Firms with high absorptive capacity are more likely to collaborate (Busom & Fer'andez-Ribas, 2008; Eom & Lee, 2010), to receive advisory services (Cumming & Fischer, 2012), and to perform better (Rothaermel & Thursby, 2005). Innovative (Soetanto & Jack, 2011) and coachable (Cumming & Fischer, 2012) entrepreneurs experience greater impact. This confounds impact assessment because it is difficult to measure and control for firm or entrepreneurial capabilities.

Importance of contextualized knowledge. We also observe the importance of contextualized knowledge. This shows up in the importance of geographic proximity (Algieri et al., 2011; Audretsch & Lehmann, 2004; Chapple et al., 2005; Coccia, 2008; Siegel et al., 2003), the significance of relationship duration (Izushi, 2003) and intensity (Barge-Gil & Modrego, 2009) on the impact of research institutes, and the fact that firms find it difficult to extract the benefits of investments in innovation if they are not active in the national system of innovation in which investments are made (Añón Higón, 2007; Frenz & Ietto-Gillies, 2009; Griffith et al., 2006). This has implications for the design of interventions. Policymakers should refrain from copying interventions without a full understanding of local conditions (Mowery et al., 2001).

Evolution in assessment methodologies. Overall we note high levels of methodological rigor, notwithstanding the universal use of post-hoc evaluation designs. It is noteworthy that none of the studies in our sample used experimental designs that involve random sampling or regression discontinuity analysis. Random sampling requires a population of agents that are all potential candidates for treatment. Such a population may be available where the treatment involves the dispersion of funds or very generic services, as was the case in the Nesta experiment (Bakhshi et al., 2012), but given the importance of the entrepreneur's behavior on the impact of venture support programs, and the importance of the firm's absorptive capacity on the impact of R&D support programs, it would likely be highly inefficient to disperse such services randomly. As Jaffe (2002) notes, regression discontinuity design is a more viable methodological option. Researchers and policymakers designing assessment strategies, and employing assessment results in innovation strategies, require a high level of expertise.

Political courage. Rigorous evaluation requires political courage. Even given the bias towards the publication of positive results, only 65% of the models we reviewed reported positive results. Given the very possibility of learning that an intervention has failed to yield the desired outcome, compounded by the long timelines and expense of rigorous assessment, it is easy to understand why many policy makers hesitate to undertake rigorous evaluations. Those that do however, may be rewarded with knowledge of the effectiveness of interventions, reduced expenditures as a consequence of the cancellation of ineffective programs, and most importantly, effective programs.

The innovation impact assessment literature is diverse and evolving, commensurate the divergent and evolving nature of the objectives of investments in research and innovation. In the future we expect continued experimentation, leading to the adoption of a range of assessment methodologies designed to address alternative evaluation objectives, circumstances, and resources.

REFERENCES

Algieri, B., Aquino, A., & Succurro, M. 2011. Technology transfer offices and academic spin-off creation: The case of Italy. ***Journal of Technology Transfer,*** (Article in Press): 1-19.

Añón Higón, D. 2007. The impact of R&D spillovers on UK manufacturing TFP: A dynamic panel approach. ***Research Policy,*** 36(7): 964-979.

Arvanitis, S., Sydow, N., & Woerter, M. 2008. Do specific forms of university-industry knowledge transfer have different impacts on the performance of private enterprises? An empirical analysis based on Swiss firm data. ***Journal of Technology Transfer,*** 33(5): 504-533.

Audretsch, D. B., & Lehmann, E. E. 2004. Mansfield's missing link: The impact of knowledge spillovers on firm growth. ***Journal of Technology Transfer,*** 30(1-2), 207-210.

Autio, E., Kanninen, S., & Gustafsson, R. 2008. First- and second-order additionality and learning outcomes in collaborative R&D programs. ***Research Policy,*** 37(1): 59-76.

AUTM. 2012. AUTM STATT Database. http://www.autm.net/source/STATT/index.cfm?section=STATT

Bakhshi, H., Edwards, J., Roper, S., Scully, J., Shaw, D., & Morley, L. 2012. Creative credits: A randomized controlled industrial policy experiment. Nesta. Available at: http://www.nesta.org.uk/

Barajas, A., Huergo, E., & Moreno, L. 2012. Measuring the economic impact of research joint ventures supported by the EU framework programme. ***Journal of Technology Transfer,*** 37(6): 917-942.

Barge-Gil, A., & Modrego, A. 2011. The impact of research and technology organizations on firm competitiveness. measurement and determinants. ***Journal of Technology Transfer,*** 36(1): 61-83.

Bozeman, B. 2000. Technology transfer and public policy: A review of research and theory. ***Research Policy,*** 29(4-5): 627-655.

Branstetter, L. G., & Sakakibara, M. 2002. When do research consortia work well and why? Evidence from Japanese panel data. ***American Economic Review,*** 92(1): 143-159.

Busom, I., & Fernández-Ribas, A. 2008. The impact of firm participation in R&D programmes on R&D partnerships. ***Research Policy,*** 37(2): 240-257.

Caldera, A., & Debande, O. 2010. Performance of Spanish universities in technology transfer: An empirical analysis. ***Research Policy,*** 39(9):1160-1173.

Cardozo, R., Ardichvili, A., & Strauss, A. 2011. Effectiveness of university technology transfer: An organizational population ecology view of a maturing supplier industry. ***Journal of Technology Transfer,*** 36(2):173-202.

Chapple, W., Lockett, A., Siegel, D., & Wright, M. 2005. Assessing the relative performance of U.K. university technology transfer offices: Parametric and non-parametric evidence. ***Research Policy,*** 34(3): 369-384.

Choi, J. Y., Lee, J. H., & Sohn, S. Y. 2009. Impact analysis for national R&D funding in science and technology using quantification method II. ***Research Policy,*** 38(10): 1534-1544.

Clarysse, B., Tartari, V., & Salter, A. 2011. The impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship. ***Research Policy,*** 40(8): 1084-1093.

Coccia, M. 2008. Spatial mobility of knowledge transfer and absorptive capacity: Analysis and measurement of the impact within the geoeconomic space. ***Journal of Technology Transfer,*** 33(1): 105-122.

Cohen, W.M., Nelson, R.R., & Walsh, J.P. 2002. Links and impacts: The influence of public research on industrial R&D. ***Management Science,*** 48(1): 1-23.

Crespi, G., D'Este, P., Fontana, R., & Geuna, A. 2011. The impact of academic patenting on university research and its transfer. ***Research Policy,*** 40(1): 55-68.

Cumming, D.J., & Fischer, E. 2012. Publicly funded business advisory services and entrepreneurial outcomes. ***Research Policy,*** 41(2): 467-481.

Czarnitzki, D., Hanel, P., & Rosa, J. M. 2011. Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms. ***Research Policy,*** 40(2): 217-229.

David, P.A., Mowery, D., & Steinmueller, W.E. 1992. Analysing the economic payoffs from basic research. ***Economics of Innovation and New Technology,*** 2(1): 73-90.

Debackere, K., & Veugelers, R. 2005. The role of academic technology transfer organizations in improving industry science links. ***Research Policy,*** 34(3): 321-342.

Economist. 2013. The great innovation debate: Fears that innovation is slowing are exaggerated, but governments need to help it along. http://www.economist.com/news/leaders/21569393-fears-innovation-slowing-are-exaggerated-governments-need-help-it-along-great. Accessed January 12th, 2013.

Eisinger, P. 1995. State economic development in the 1990s: Politics and policy learning. ***Economic Development Quarterly,*** 9(2): 146-158.

Eom, B.Y., & Lee, K. 2010. Determinants of industry-academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. ***Research Policy,*** 39(5): 625-639.

Feller, I., Ailes, C.P., & Roessner, J.D. 2002. Impacts of research universities on technological innovation in industry: Evidence from engineering research centers. ***Research Policy,*** 31(3): 457-474.

Freeman, C., & Soete, L. 2009. Developing science, technology and innovation indicators: What we can learn from the past. ***Research Policy,*** 38(4): 583-589

Frenz, M., & Ietto-Gillies, G. 2009. The impact on innovation performance of different sources of knowledge: Evidence from the UK community innovation survey. ***Research Policy,*** 38(7): 1125-1135.

Gans, J.S., Hsu, D.H., & Stern, S. 2008. The impact of uncertain intellectual property rights on the market for ideas: Evidence from patent grant delays. ***Management Science,*** 54(5): 982-997.

Godin, B. 2003. The emergence of S&T indicators: why did governments supplement statistics with indicators? ***Research Policy,*** 32(4): 679-691.

Gonzalez-Brambila, C., & Veloso, F.M. 2007. The determinants of research output and impact: A study of Mexican researchers. ***Research Policy,*** 36(7): 1035-1051.

Griffith, R., Harrison, R., & Van Reenen, J. 2006. How special is the special relationship? Using the impact of U.S. R&D spillovers on U.K. firms as a test of technology sourcing. ***American Economic Review,*** 96(5): 1859-1875.

Griliches, Z. 1957. Hybrid corn: An exploration in the economics of technological change. ***Econometrica,*** 25(4): 501-522.

Hackett, S.M., & Dilts, D.M. 2008. Inside the black box of business incubation: Study B - scale assessment, model refinement, and incubation outcomes. ***Journal of Technology Transfer,*** 33(5): 439-471.

Hartmann, G.B., & Masten, J. 2000. Profiles of state technological transfer structure and its impact on small manufacturers. ***Journal of Technology Transfer,*** 25(1): 83-88.

Hülsbeck, M., Lehmann, E.E., & Starnecker, A. 2011. Performance of technology transfer offices in Germany. ***Journal of Technology Transfer,*** (Article in press): 1-17.

Hussler, C., & Rondé, P. 2007. The impact of cognitive communities on the diffusion of academic knowledge: Evidence from the networks of inventors of a French university. ***Research Policy,*** 36(2): 288-302.

Izushi, H. 2003. Impact of the length of relationships upon the use of research institutes by SMEs. ***Research Policy,*** 32(5): 771-788.

Jaffe, A.B. 1986. Technological opportunity and spillovers of R & D: Evidence from firms' patents, profits, and market value. ***The American Economic Review,*** 76(5): 984-1001.

Jaffe, A.B. 2002. Building programme evaluation into the design of public Research-Support programmes. ***Oxford Review of Economic Policy,*** 18(1): 22-34.

Kim, Y. 2011. The ivory tower approach to entrepreneurial linkage: Productivity changes in university technology transfer. ***Journal of Technology Transfer,*** (Article in Press): 1-18.

Kline, S.J., & N. Rosenberg. 1986. An Overview of Innovation. In R. Landau and N. Rosenberg (eds), ***The Positive Sum Strategy: Harnessing Technology for Economic Growth*** (pp. 275-305). Washington, DC: National Academy Press.

Langford, C.H., Hall, J., Josty, P., Matos, S., & Jacobson, A. 2006. Indicators and outcomes of Canadian university research: Proxies becoming goals? ***Research Policy,*** 35(10): 1586-1598.

Lee, D.S., & Lemieux, T. 2010. Regression Discontinuity Designs in Economics. ***Journal of Economic Literature,*** 48(2): 281-355.

Lindelöf, P., & Löfsten, H. 2004. Proximity as a resource base for competitive advantage: University-industry links for technology transfer. ***Journal of Technology Transfer,*** 29(3-4): 311-326.

Litan, R. E., Mitchell, L., & Reedy, E. J. 2007. Commercializing university innovations: Alternative approaches. ***Innovation Policy and the Economy,*** 8: 31-57.

Löfsten, H., & Lindelöf, P. 2002. Science parks and the growth of new technology-based firms - academic-industry links, innovation and markets. ***Research Policy,*** 31(6): 859-876.

Mansfield, E. 1961. Technical change and the rate of imitation. ***Econometrica,*** 29(4): 741-766.

Millar, A., Simeone, R.S., & Carnevale, J.T. 2001. Logic models: A systems tool for performance management. ***Evaluation and Program Planning,*** 24(1): 73-81.
Mowery, D.C., Nelson, R.R., Sampat, B.N., & Ziedonis, A.A. 2001. The growth of patenting and licensing by U.S. universities: An assessment of the effects of the Bayh–Dole act of 1980. ***Research Policy,*** 30(1): 99-119.
Mowery, D., & Rosenberg, N. 1979. The influence of market demand upon innovation: A critical review of some recent empirical studies. ***Research Policy,*** 8(2): 102-153.
Nelson, R.R. 1959. The simple economics of basic scientific research. ***The Journal of Political Economy,*** 67(3): 297-306.
OECD. 2012. ***Main Science and Technology Indicators.*** OECD Publishing. http://dx.doi.org/10.1787/msti-v2011-2-en-fr.
O'Shea, R.P., Allen, T.J., Chevalier, A., & Roche, F. 2005. Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities. ***Research Policy,*** 34(7): 994-1009.
Owen-Smith, J., & Powell, W.W. 2001. To patent or not: Faculty decisions and institutional success at technology transfer. ***Journal of Technology Transfer,*** 26(1-2): 99-114.
Paton, R. 2003. ***Managing and measuring social enterprises*** (pp. 192). London: Sage Publications.
Pavitt, K. 2001. Public policies to support basic research: What can the rest of the world learn from US theory and practice? (And what they should not learn). ***Industrial and Corporate Change,*** 10(3): 761-779.
Phan, P. H., Siegel, D.S., & Wright, M. 2005. Science parks and incubators: Observations, synthesis and future research. ***Journal of Business Venturing,*** 20(2): 165-182.
Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. 2004. Networking and innovation: A systematic review of the evidence. ***International Journal of Management Reviews,*** 5-6(3-4): 137-168.
Roelofsen, A., Boon, W.P.C., Kloet, R.R., & Broerse, J.E.W. 2011. Stakeholder interaction within research consortia on emerging technologies: Learning how and what? ***Research Policy,*** 40(3): 341-354.
Roessner, D., Manrique, L., & Park, J. 2010. The economic impact of engineering research centers: Preliminary results of a pilot study. ***Journal of Technology Transfer,*** 35(5): 475-493.
Roodman, D. 2009. Rossi's Rules. Centre for Global Research. http://blogs.cgdev.org/open_book/2009/07/rossis-rules.php. Accessed July 20th, 2012
Rosenberg, N. 1983. ***Inside the black box: technology and economics.*** Cambridge: University Press.
Rothaermel, F.T., & Thursby, M. 2005. University-incubator firm knowledge flows: Assessing their impact on incubator firm performance. ***Research Policy,*** 34(3): 305-320.
Salter, A.J., & Martin, B.R. 2001. The economic benefits of publicly funded basic research: A critical review. ***Research Policy,*** 30(3): 509-532.
Salvador, E. 2011. Are science parks and incubators good "brand names" for spin-offs? The case study of Turin. ***Journal of Technology Transfer,*** 36(2): 203-232.
Santoro, M.D., & Gopalakrishnan, S. 2001. Relationship dynamics between university research centers and industrial firms: Their impact on technology transfer activities. ***Journal of Technology Transfer,*** 26(1-2): 163-171.

Siegel, D.S., Waldman, D., & Link, A. 2003. Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. ***Research Policy,*** 32(1): 27-48.

Soetanto, D.P., & Jack, S.L. 2011. Business incubators and the networks of technology-based firms. ***Journal of Technology Transfer,*** (Article in Press): 1-22.

Thursby, J.G., Jensen, R., & Thursby, M.C. 2001. Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities. ***Journal of Technology Transfer,*** 26(1-2): 59-72.

Toole, A.A. 2012. The impact of public basic research on industrial innovation: Evidence from the pharmaceutical industry. Research Policy, 41(1): 1-12.

van den Berghe, L., & Guild, P.D. 2008. The strategic value of new university technology and its impact on exclusivity of licensing transactions: An empirical study. ***Journal of Technology Transfer,*** 33(1): 91-103.

Varsakelis, N. C. 2001. The impact of patent protection, economy openness and national culture on R&D investment: A cross-country empirical investigation. ***Research Policy,*** 30(7): 1059-1068.

Vincett, P. S. 2010. The economic impacts of academic spin-off companies, and their implications for public policy. ***Research Policy,*** 39(6): 736-747.

Woerter, M. 2012. Technology proximity between firms and universities and technology transfer. ***Journal of Technology Transfer,*** 37(6): 828-866.

Yang, C.H., Motohashi, K., & Chen, J.R. 2009. Are new technology-based firms located on science parks really more innovative? Evidence from Taiwan. ***Research Policy,*** 38(1): 77-85.

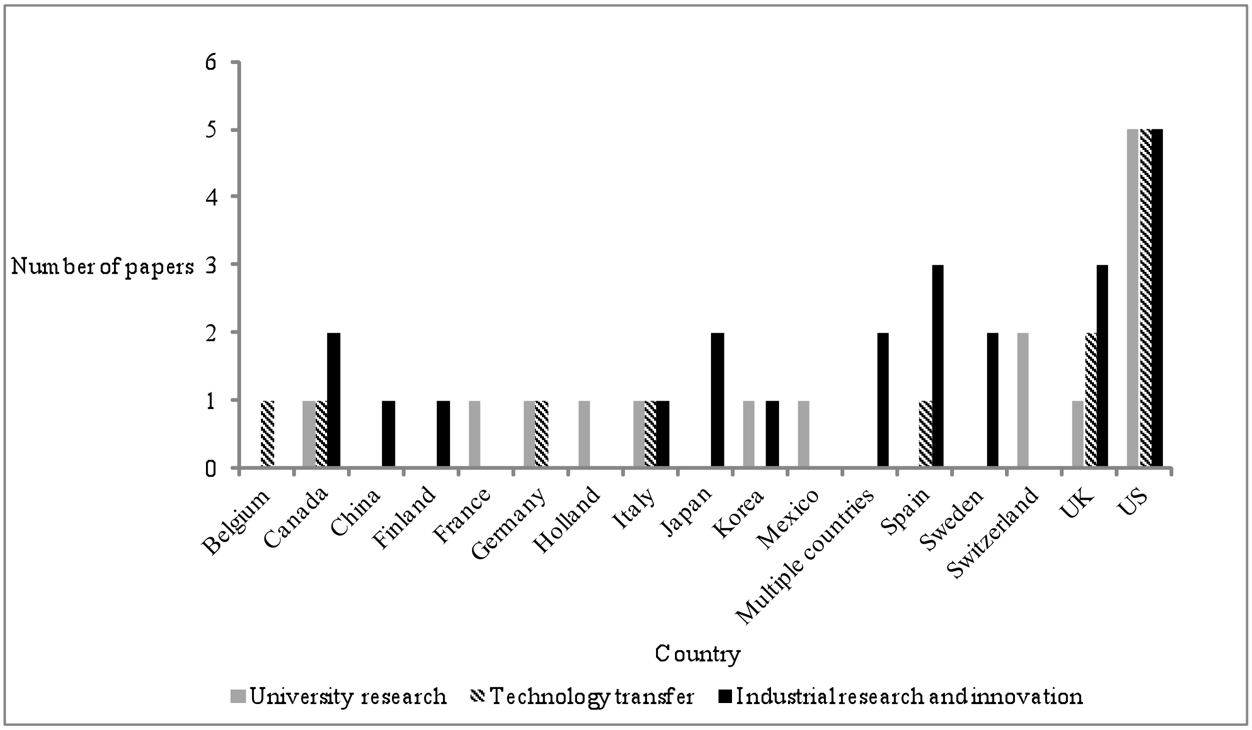

Figure 1: Data samples by country

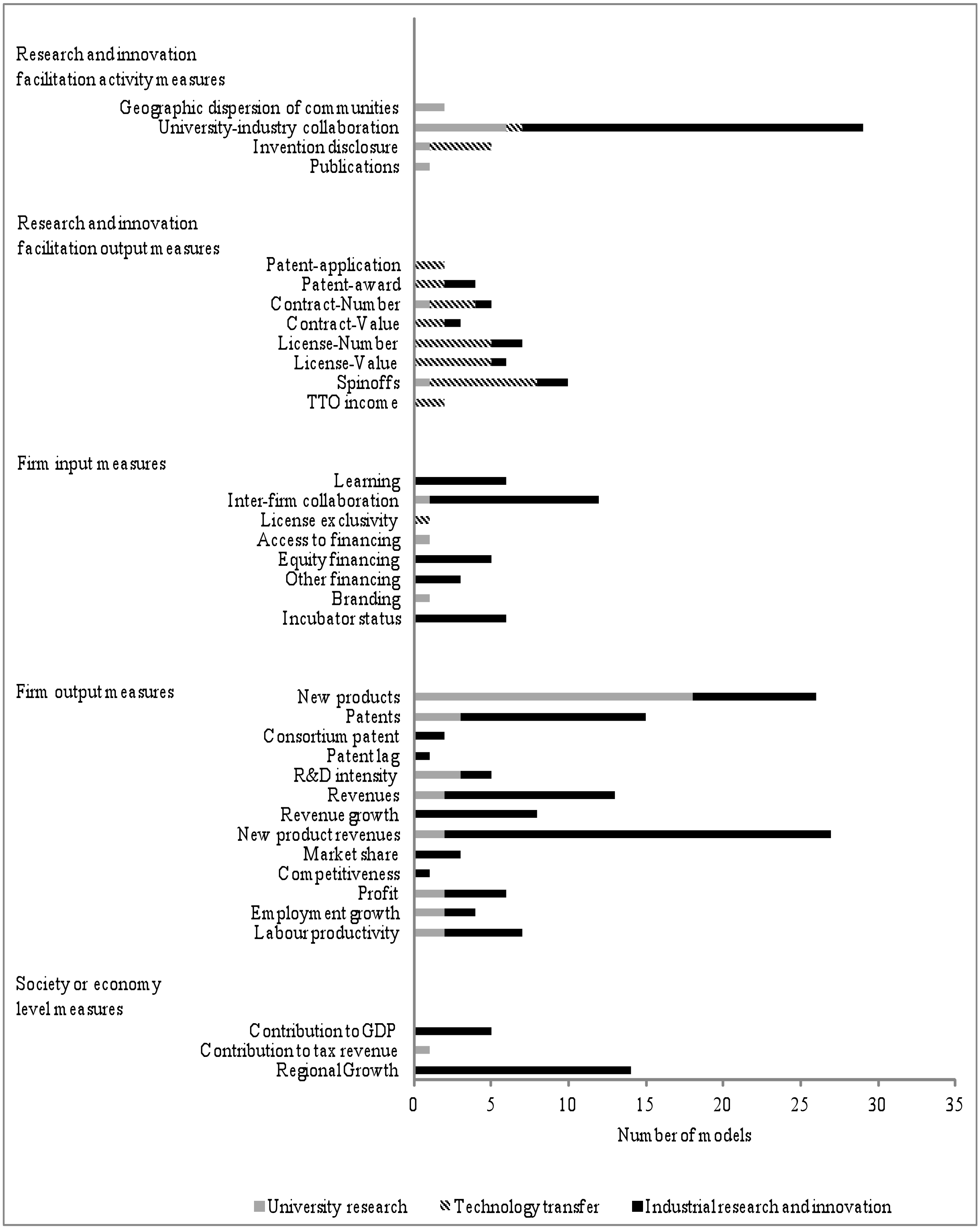

Figure 2: Frequency of measures at the model level by investment type

Table 1: University research, main independent and dependant variables classified by nature

Article	Research and innovation facilitation input measures	Research and innovation facilitation activity measures	Research and innovation facilitation output measures	Firm input measures	Firm output measures	Society or economy level measures
Arvanitis, Sydow & Woerter (2008)		- Knowledge transfer activities		- Firm's resource endowments - Firm's affiliations	- Innovation sales of modified or new products (DV)	
Audrestech & Lehmann (2005)		- Publications and grants			- Employment growth (DV)	
Cohen, Nelson & Walsh (2002)		- Public meetings, conferences, consulting	-Publications patents, graduates, licenses, contracts	- Project ideas, completion (DVs) - R&D intensity (DV)		
Crespi et al. (2011)		- Knowledge transfer (DV)	- Patents -Publication counts (DV)			
Eom & Lee (2010)		- Participation in R&D projects - Risk/cost sharing - University-industry collaboration (DV1/IV2)			- New products (DV2) - Firm patents (DV2) - Innovation sales (DV2) - Labor productivity (DV2)	
Gonzalez-Brambila & Veloso (2007)	- Researcher age, gender, reputation - PhD location		-Publications (DV) - Citations (DV)			
Hussler & Ronde (2007)		- Academic collaboration versus university-industry collaboration - Co-location of inventing teams (DV)				
Roelofsen et al. (2011)		- Stakeholder dialogues - Learning about shared, complementary demands (DV)				
Rothaermel & Thursby (2005)		- Patent backward citations		- Licenses	- Revenues (DV) - VC and other investments (DVs) - Incubator status (DV)	
Salvador (2011)			- Spin-off vs. start-up status		- Net income (DV)	
Santoro &	- Trust	- Technology				

Gopala-krishnan (2001)	- Geographic proximity -University policies	transfer activities (DV)				
Toole (2012)	- Investments in biomedical research			- Industry funded R&D	- New products: molecular entities (DV)	
Vincett (2010)	- Federal funding		- Spin-offs		- Revenues (DV)	- Contribution to tax revenues (DV)
Woerter (2011)		- Intensity of transfer (DV)	- Patent classes			

Table 2: Technology transfer, main independent and dependant variables classified by nature

Article	Research and innovation facilitation input measures	Research and innovation facilitation activity measures	Research and innovation facilitation output measures	Firm input measures	Firm output measures	Society or economy level measures
Algieri, Aquino & Succuro (2011)	- Annual budget	- TTO age -Number of full time TTO employees	- Spin-offs (DV)			
Caldera & Debande (2010)	- TTO age and size - Science park presence	-TT policies -TTO specialization	- Contracts (DV) - Licenses (DV) - Spin-offs (DV)			
Cardozo, Ardichvili & Strauss (2011)	- Research expenditures	- TTO age	- TTO income, invention disclosures, patents, licenses (DVs)			
Chapple et al. (2005)	- University research income - TTO staff - Legal expenditures	-Invention disclosures	- Licenses (DV)			
Clarysse, Tartari & Salter (2011)	- Academics' entrepreneurial attributes and experience	- TTO efficiency	- Spin-offs (DV)			
Debackere & Veugelers (2005)	- TTO centralization - Incentive measures	- University-industry collaborations				
Hulsbeck, Lehmann & Starnecker (2011)	- TTO number of employees, qualifications, specialization	- Invention disclosures (DV)				
Kim (2011)	- TTO employees - R&D expenditures	- Invention disclosures	- Patents (DV) - Licenses (DV)			
O'Shea et al. (2005)	- TTO employees - Spinoff stock - Funding		- Spin-offs (DV)			
Owen-Smith & Powell (2001)	- Institutional culture - Perceived costs and benefits of patenting	- Invention disclosures (DV)				

Siegel, Waldman & Link (2003)	- TTO age and employees - Institutional culture and compensation practices	- Invention disclosures - External legal expenditures	- Licenses (DV)			
Thursby, Jensen & Thursby (2001)	- TTO objectives - Type and stage of invention	- Income splits between licensor, TTO and inventor - Sponsored research (DV)	- Patents (DV) - Licenses (DV)			
Van de Berghe & Guild (2008)			- Perceived strategic values - Product innovation novelty	- License exclusivity (DV)		

Table 3: Industrial research and innovation, main independent and dependant variables classified by nature

Article	Research and innovation facilitation input measures	Research and innovation facilitation activity measures	Research and innovation facilitation output measures	Firm input measures	Firm output measures	Society or economy level measures
Anon Higon (2007)						- Contribution to GDP (DV) - R&D stock, inter-industry R&D stock, foreign R&D stock
Autio, Kanninen & Gustafsson (2008)		- Program management support - Interaction frequency		- Learning (DV) - R&D subsidy - Identification with community of practice		
Barajas, Huergo & Moreno (2011)		- Participation in sponsored collaborative R&D		- Intangible fixed assets over employment (DV)	- Labor productivity (DV)	
Barge-gil & Modrego (2011)		- Public sector-industry collaboration		- Impacts on investment behaviour and capabilities (DV)	- Technical and economic impacts (DV)	
Branstetter & Sakakibara (2002)		- Participation in research consortia - Technological proximity - Product market proximity			- Firm patent lags (DV) - Firms patents (DV) - Consortium patents (DV)	
Busom & Fern'andez-Ribas (2008)		- Participation in national R&D Programs - Cooperation (DV)				
Choi, Lee & Sohn (2009)				- Government support for R&D	- Manufacturing and management performance improvement (DV)	- S&T and economic impacts (DV)
Coccia (2008)	- Spatial distance	- Number of technology contacts (DV)				
Cumming & Fischer (2012)		- Advisory hours		- Equity finance (DV) - Inter-firm collaboration (DV)	- Revenue growth (DV) - Firm patents (DV)	
Czarnitzki, Hanel & Rosa (2011)				- R&D tax credits	- Innovation outputs (DV) - Profitability	

				(DV) - Market share (DV)	
Feller, Ailes & Roessner (2002)		- Facilitating factors - Barriers	- Range of benefits		
Frenz & letto-Gillies (2009)			- In-house and external R&D - Intra-company international knowledge sources	-Innovation sales (DV)	
Gans, Hsu & Stern (2008)				- License timing (DV)	- Intellectual property policy
Griffith, Harrison & VanReenen (2006)			- US R&D stocks - Employees-inventors located in US	- Output of UK firms (DV)	
Hackett & Dilts (2008)				- Venture survival and profitability (DV)	
Hartmann & Masten (2000)	- State higher education expenditures				- Small firm growth (DV)
Izushi (2003)	- Geographical proximity	- Duration of relationship - Use of 'high information gap' services (DV)			
Lindelof & Lofsten (2004)		- Presence in science park - Cooperation and proximity to universities	- Time lapse before new products	- New products (DV)	
Lofsten & Lindelof (2002)		- Presence in science park - University-industry collaboration		- Revenues (DV) - Employment growth (DV) - Profitability (DV)	
Roessner, Manrique & Park (2010)		- Engineering Research Center investments			- Economic impact (DV)
Soetanto & Jack (2011)			- Networks	- Employment growth (DV)	
Varsakelis (2001)	- National R&D expenditures (DV)				- Patent policy - Culture - Market openness
Yang, Motohashi & Chen (2009)		- Presence in science park	- R&D spending	- Revenues (DV)	