# University – Industry Collaboration in R&D: The Role of Labor Market Rigidity

Christopher Williams*
Durham University Business School,
Mill Hill Lane,
Durham, DH1 3LB
United Kingdom
Email: chris.williams@durham.ac.uk
Tel : +44-191-334-5314

Gayle Allard, Ph.D.
IE Business School
María de Molina 12-1
28006 Madrid, Spain
Tel.: +34 915-568-9600
gayle.allard@ie.edu

*Corresponding Author

# University – Industry Collaboration in R&D:
# The Role of Labor Market Rigidity


## ABSTRACT

We investigate how R&D university – industry collaboration (R&D UIC) is influenced by labor market rigidity. While it is well-established that an educated and skilled workforce will facilitate R&D UIC, another aspect of these alliances has been under-researched: the role of labor market rigidity, in particular the difficulties employers face in hiring and firing workers. We hypothesize that the size of the R&D labor pool in a country will encourage R&D UIC, and that the ease with which employers are legally allowed to hire and fire will directly and indirectly influence R&D UIC. Integrating data from various sources, we test our model on a sample of 73 countries for which information on the size of the R&D labor pool and labor market regulations are available. We also conduct a robustness test using a different proxy for R&D labor pool on a larger sample of 109 countries. Results confirm the strong link between a country's R&D labor pool and R&D UIC, as well as direct negative impacts of hiring and firing rigidity and an indirect negative impact of hiring rigidity. The findings have implications for managers, policy makers and researchers of R&D collaboration between universities and industry.



**Key Words:** University-industry collaboration, labor market rigidity, R&D labor market pool, national systems of innovation

## Introduction

Many countries of the world have become, or are in the process of shifting towards, a knowledge-based entrepreneurial economy (Audrestch and Thurik, 2001). Appropriate regulation, decentralization, private ownership and an increase in knowledge-based activity figure prominently among the characteristics of these economies (Archibugi and Iammarino, 2002; Audrestch and Thurik, 2001). In these contexts, universities have become increasingly conscious of the value of their intellectual assets, companies have gained awareness of the powerful synergies between their activities and the academic world, and university – industry relationships have become more widespread and diverse (Galán-Muros and Plewa, 2016; Perkmann and Walsh, 2007; Yoda, 2016). University – industry collaboration in R&D (R&D UIC) is a central feature of a national innovation system (Global Competitiveness Report 2010-2011).

While there exists a vast literature on R&D UIC (Freeman, 1991, 1995; Galán-Muros and Plewa, 2016; Hagedoorn, Link and Vonortas, 2000; Lundvall, Johnson, Andersen and Dalum, 2002; Van Looy, Debackere and Andries, 2003), the diverse nature of these collaborations within a changing innovation environment have prompted calls to re-examine their organizational dynamics (Ankrah and AL-Tabbaa, 2015; Perkmann and Walsh, 2007; Yoda, 2016). Given that these collaborations are highly dependent on the underlying human and social capital in the economy (Ankrah and AL-Tabbaa, 2015; Jacobsson, 2002), factors that influence the availability and mobility of skilled labor are key considerations for managers, policy makers and researchers in the field. These factors ultimately determine the sources and flows of knowledge in the economy, including tacit knowledge vital for innovation.

Unfortunately, there has been a noticeable lack of research on how labor market institutions, specifically the legal requirements faced by employers when hiring or firing, might influence R&D UIC. Zhou, Dekker and Kleinknecht (2011) noted that the "impact of flexible labor contracts on innovation or productivity growth is still under-researched" (Zhou, Dekker, Kleinknecht, 2011: 942). Simonen and McCann (2008) lamented that recent studies of innovation had been dominated by those emphasizing knowledge-spillovers instead of human capital and labor mobility explanations (Simonen and McCann, 2008: 183). We argue that, since both universities and industrial firms are important employers in a knowledge-based economy, the legal environment that surrounds and constrains them *as* employers will play a role in their propensity to collaborate in R&D. However, the literature gives little insight into how this potentially critical aspect of a national innovation system underpins R&D UIC.

Our study addresses this gap. Integrating insights from academic literature on university – industry collaborations with studies on labor market institutions and their effects, we hypothesize difficulty in hiring and firing workers has direct effects on R&D UIC and indirect effects on the relationship between the R&D labor pool and R&D UIC. To test our hypotheses, we build a dataset comprising 73 countries for which R&D labor market pool and labor market rigidity data are available. We also run a robustness test using an alternative operationalization for R&D labor pool (n=109 countries). The results give broad support. In terms of direct effects, the R&D labor pool and labor market rigidity have statistically significant but *opposite* effects on R&D UIC. In terms of indirect effects, national laws that hinder employers' ability to hire decrease the positive relationship between the R&D labor pool and R&D UIC.

The study contributes to literature on university-industry collaboration by showing how labor market rigidities influence R&D collaboration between universities and industrial firms, a perspective largely overlooked in prior research. By demonstrating the direct and indirect effects of rigidity in hiring and firing laws, we provide insights that R&D managers and policy makers can draw on when interpreting and enacting labor market reform in countries that are, or aspire to be, knowledge-based economies.

## Background and model development

In the 'triple-helix model' of national innovation, universities, industry and governments coalesce around innovation, their inter-linkages and networked collaboration encouraged by institutions providing a basis for knowledge transfer and joint scientific exploration and commercialization (Etzkowitz, 2010). This national system of innovation (defined as a "well-articulated network of firms, research centers, universities and think tanks that work together to take advantage of global knowledge, assimilating and adapting it to local needs, thus creating new technology", World Bank, 2016), is constructed and influenced by a country's institutions (Etzkowitz, 2010; Freeman, 1995; Lundvall, Johnson, Andersen, and Dalum, 2002; Metcalfe, 1997; Whitley, 2002).

More specifically, collaboration between universities and industry is recognized as a critical component of the national innovation system (Acworth, 2008; Ankrah and AL-Tabbaa, 2015; Freeman, 1995; Galán-Muros and Plewa, 2016; Hagedoorn, Link and Vonortas, 2000; Perkmann and Walsh, 2007; Yoda, 2016). Nelson and Winter (1982) described the "interweaving" of basic research and market-focused R&D, and Freeman (1995) pointed out that features of a national innovation system include higher education and training institutions and research institutes as well as private sector companies. University-industry collaboration in R&D (R&D UIC) enables the needs of business and society to be incorporated into basic research activity by allowing new ideas to be put into practice in such a way that they are viable for commercialization and useful ultimately to end-users, whether they are individual consumers or organizations (Acworth, 2008).

R&D UIC provides a multitude of benefits. Technology transfer from universities to industry can improve firms' financial performance and develop the economy through successful spin-out companies (Lockett and Wright, 2005), developing a nationwide research capacity (Bozeman, 2000). R&D UIC also provides benefits to universities, including insights of user needs (Galán-Muros and Plewa, 2016; Freeman, 1991; Lundvall, Johnson, Andersen and Dalum, 2002). Such collaborations have been useful sources of revenue for universities, and universities have developed strategies to engage in technology transfer through industry collaborations (Bruneel, D'Este and Slater, 2010; Motohashi, 2005). R&D UIC also provides opportunities for students and enhances university prestige. Scholars have noted potential drawbacks for universities as well, including threats to academic freedom and research autonomy, and pressures for researchers to work on commercial projects at the expense of less lucrative basic research (Harman, 2001).

In addition to consequences of R&D UIC, scholars have also examined its determinants. In their synthesis of literature in the field of research partnerships, Hagedoorn, Link and Vonortas (2000) provide insights from three theoretical perspectives - transaction cost, strategic management and industrial organization - on incentives to engage in research collaboration. From the transaction cost perspective, organizations collaborate in R&D (as opposed to conducting all R&D in-house or through arms-length arrangements in the market) in order to minimize transaction costs involving technical knowledge and overcome problems relating to incomplete contracts. From the strategic management perspective, research collaborations allow firms to share R&D costs, pool risks and learn from one another in order to build new innovation capabilities. From an industrial organization perspective, in addition to sharing R&D costs and pooling risks, organizations increase market power and appropriate returns from their investment in the collaboration (for details see Hagedoorn, Link and Vonortas, 2000). While institutional determinants of R&D UIC do not feature strongly within these theories, Hagedoorn, Link and Vonortas (2000) also provided empirical evidence from the US, Europe and Japan on governmental role in promoting and supporting research partnerships. As noted above, institutions matter: they promote the circulation of individuals not only within, but across helices of the 'triple helix' model (Etzkowitz, 2010).

Formal government legislation provides structure in which individuals and organizations (including universities and industrial firms) act and interact (North, 1990). Research shows that regulative institutions matter to R&D UIC: they influence the availability of skilled labor and the circulation of labor in the economy, such labor embodying the tacit knowledge vital for innovation (Ankrah and AL-Tabbaa, 2015; Perkmann and Walsh, 2007). For example, Colyvas, Crow, Gelijns, Mazzoleni, Nelson, Rosenberg and Sampat (2002) showed how the Bayh-Dole Act of 1980 made it easier for universities to set up technology transfer offices and increase R&D collaborations with industry. Audretsch and Thurik (2001) insightfully noted how "the central role of government policy in the entrepreneurial economy is enabling in nature….government policy in the entrepreneurial economy targets education, increasing the skills and human capital of workers, and *facilitating the mobility of workers*…" (p. 307, emphasis added). Thus two elements are at play here: (1) the stock of human capital in a country, and (2) the mobility of that human capital.

Firstly, in terms of human capital stock, the R&D labor pool in a country (i.e., the nation's technological competence as embodied in its body of scientists and engineers and how it is accessed, developed and utilized) is vital to the functioning of an innovation system (Ankrah and AL-Tabbaa, 2015; Lawton Smith, 2006; Taplin, 2007). However, no two countries have the same endowments of human capital (Archibugi and CoCo, 2005). Each country has its own distinctive heritage in terms of universities and resources for industrial development (Lockett, Siegel, Wright and Ensley, 2005; Trumbull, 2004; Wilson, 2012). Key to generating and perpetuating university-industry collaboration is a critical mass of skilled R&D workers who can engage in this activity from either the university or the business side. Without this mass, collaboration is less likely; there are lower numbers of scientists and engineers to utilize in collaboration. Actors are more likely to seek R&D competence outside the country, or by importing technology through inward FDI. The larger the R&D labor pool, the more likely knowledge will be generated, shared and applied through collaborative links, both in the scientific exploration stage as well as later stage commercialization (Ankrah and AL-Tabbaa, 2015). This leads to our baseline hypothesis:

*Hypothesis 1: Ceteris paribus, the size of the R&D labor pool will have a positive influence on the extent of a country's university – industry collaboration in R&D.*

Secondly, in terms of mobility of human capital in a country, given universities and firms both are important employers in a knowledge-based economy, the regulative environment that constrains them as employers will play a crucial role in how they collaborate in R&D. For decades, researchers have argued that labor market institutions affecting mobility are key determinants of economic success. Some have tested the impact of labor market institutions on broad macroeconomic outcomes such as productivity, innovation, foreign investment flows, or employment and unemployment levels (see Blanchard, 2005 or Eichhorst, Feil and Braun, 2008). These studies tended to focus on developed countries, and a consensus view emerged that labor-market rigidity led to less desirable macroeconomic outcomes. Stiffer regulations on hiring and firing, for instance, were associated with higher unemployment rates (Blanchard and

Wolfer, 2000), reduced productivity (Allard and Lindert, 2006) and higher unemployment rates for "outsiders" such as women and youth (Bertola, Blau and Kahn, 2007).

Research relating economic outcomes to labor market institutions of developing countries is less common. Botero, Djankov, La Porta, Lopez de Silanes and Shleifer (2004) found a link between rigid labor regulations and negative macroeconomic outcomes. Freeman (2009) examined employment protection in a large sample of countries and found that it shifted employment to informal sectors and reduced labor mobility, while Campos and Nugent (2012) found that rigid labor market regulation was associated with lower GDP per capita and greater income inequality. Hence the conventional view held that more flexible labor markets were needed for better economic performance.

Scholars recently have studied links between labor market institutions and other indicators of economic success, with often contradictory conclusions. While some found higher dismissal costs (i.e., more rigidity) reduces productivity, others discovered that a higher share of temporary contracts (i.e., more flexibility) reduced firm productivity, while longer job tenure raised it (Autor, Kerr and Kugler, 2007; Lucidi and Kleinknecht, 2009; Ortega and Marchante, 2010). Others showed that firms with higher shares of temporary workers (indicating greater flexibility) performed less innovation, sold fewer innovative products (Boeri and Garibaldi, 2007; Michie and Sheehan, 2003; Zhou, Dekker, Kleinknecht, 2011) and had lower patenting (Pieroni and Pompei, 2007).

*Hiring and firing: direct and indirect effects*

Difficulty in hiring occurs where the regulative environment makes it challenging for employers to hire employees at will. In the World Bank´s Employing Workers indicator[i], the difficulty of hiring index measures whether fixed-term (temporary) contracts are prohibited for permanent tasks, what the maximum duration of fixed-term contracts is, and the ratio of the minimum wage to value-added per worker. We argue that, if organizations are to build human capital and a highly skilled workforce critical for developing cutting-edge R&D (Ankrah and AL-Tabbaa, 2015), they need flexibility to hire temporarily, particularly in areas that are highly exploratory and technologically early-stage. Even though permanent contracts may give workers more security in which to innovate, the uncertainty surrounding exploratory research (March, 1991) makes it difficult for employers to assess precisely the resource requirements for longer-term research activities in advance (Tidd, 2001). Furthermore, R&D UIC may be based on formal agreements with equity stakes in new ventures (more long-term) or on informal, undefined arrangements which are often more short-term (Hagedoorn, Link and Vonortas, 2000). The formal, equity types are likely to require some degree of employee mobility, particularly when recruiting during the establishment phase. As Hagedoorn, Link and Vonortas (2000) note, informal arrangements inevitably involve the university acting as project-specific research "sub-contractor". Even though the collaboration may not involve the need for employees to be recruited into a new venture, or even change employment from industry to university (or vice-versa), it is likely the university will need flexibility in employment options in order to staff these types of projects. Without this flexibility, this type of sub-contracting role may be unviable. Under these circumstances, actors will benefit from a flexible hiring environment that tolerates temporary contracts and flexibility in the limits to fixed time contracts. These considerations lead us to posit the following:

*Hypothesis 2a: Ceteris paribus, rigid hiring laws will have a negative influence on the extent of a country's university – industry collaboration in R&D.*

*Hypothesis 2b: Ceteris paribus, rigid hiring laws will have a negative influence on the relationship between the size of the R&D labor pool within a country and university – industry collaboration in R&D in that country.*

Difficulty of firing in the World Bank indicator reflects whether redundancy is grounds for job termination, whether worker pre-notification or third-party approval are required for dismissal, and whether the employer is required to reassign or retrain workers or follow seniority rules before dismissing them. In competitive environments, organizations need to continually upgrade their capabilities in order to deal with change, remain competitive, and avoid organizational inertia. Technological change can force companies to make resource adjustments. Employers will sometimes need to reassign or remove workers whose skills have not evolved with emerging R&D requirements. Should formal (equity) ventures between universities and firms need to downsize or terminate, employers will need flexibility to do this. Organizations that are legally allowed to fire workers without complex and costly procedures and approval processes will be able to retain their most productive workers and dismiss the least suitable. Flexibility in firing, from the employer's perspective, means they can fine tune resource allocations in line with new trends in science and technology. Restrictive firing regulations are a constraint for employers, inducing firms to retain their most senior workers rather than keeping the most innovative or productive. Rigid firing rules could weaken incentives for learning and creativity and hinder firms' development of human capital. The burden of maintaining a workforce not fully appropriate for leading-edge R&D, will mean employers will be less efficient in R&D and less able to participate in collaboration with universities. They may also be less attractive to others seeking collaborations in R&D. We therefore posit:

*Hypothesis 3a: Ceteris paribus, rigid firing laws will have a negative influence on the extent of a country's university – industry collaboration in R&D.*

*Hypothesis 3b: Ceteris paribus, rigid firing laws will have a negative influence on the relationship between the size of the R&D labor pool within a country and university – industry collaboration in R&D in that country.*

**Method and Results**

To test the hypotheses, we ran two sets of regression models. Firstly, we used a sample of 73 countries for which reliable data were available for a count-based operationalization of R&D labor pool, i.e., the number of R&D researchers per million population per country. This sample covers the lion's share of the world's R&D: these 73 countries contained 195 out of the world's top 200 universities as defined by *The Times Higher Education World University Rankings*; had a combined population of 4.84 billion people; and, on average, filed 40.69 utility patents per million population. Secondly, we ran a robustness test using a larger sample of 109 countries using an alternative operationalization of R&D labor pool – availability of scientists and engineers in a country. This sample also contained 195 of the world's top 200 universities, had a combined population of 5.38 billion people and, on average, filed 29.62 utility patents per million population. Table 1 summarizes the operationalization of all the variables, definitions, measurements, and sources. We apply at least a one-year lag to independent variables to capture the lead-lag effect of explanatory variables.

-----------------------------------------
Insert Table 1 about here
-----------------------------------------

*Variables*

We used the World Economic Forum's Global Competitiveness Report (GCR 2010-2011) to operationalize *university - industry collaboration in R&D*. The GCR asked in its Executive Opinion Survey: To what extent do businesses and universities collaborate on research and development in your country? Responses ranged from 1 to 7, with 1 denoting no collaboration and 7 extensive collaboration.

For the operationalization of the size of the *R&D labor pool* in a country, we used the World Bank's indicators for number of R&D researchers per million population combined with the number of R&D technicians per million population. For the second operationalization in the robustness test, we used item 12.06 from the World Economic Forum's GCR report, namely, the availability of scientists and engineers. The question asked here was: In your country, to what extent are scientists and engineers available? Responses ranged from 1 to 7, with 7 denoting widely available. We note a strong positive bi-variate correlation between R&D researchers and availability of scientists and engineers sourced from the GCR (r=0.67, n=73), suggesting this as an appropriate alternative proxy. *Difficulty of hiring and firing* employees was taken from the World Bank's 2010 Doing Business project. Since 2006 this project tracked the regulation of employment in most countries, measuring the rigidity of national legislation as it applies to hiring, firing, work schedules, and the cost of redundancy. It was measured on a scale of 0-100, with higher numbers denoting greater rigidity.

To account for alternative explanations for the variation in university – industry R&D collaborations, we include four control variables: population (log transformed), GDP growth, the Human Development Index (HDI) and expenditure on tertiary education as a per cent of total education spending.

*Model and Results*

We used a cross-sectional, time-lagged model, with the independent and control variables captured between 2009-2010, and the dependent variables captured in 2011. Interaction terms were calculated as the product using standardized scores. We tested the model using an Ordinary Least Squares test (OLS) and conducted tests for heteroskedasticity and multicollinearity. Table 2 reports descriptive statistics and Table 3 provides pairwise correlations for all variables.

-----------------------------------------
Insert Tables 2 and 3 about here
------------------------------------------

As expected, university - industry collaboration in R&D is positively correlated with the R&D labor pool (r=0.66, p<0.001) and with the HDI (r=0.58, p<0.001). The dependent variable is negatively correlated to difficulty in hiring (r=-0.37, p<0.001) and difficulty in firing (r=-0.32, p<0.01). A country's R&D labor pool and its HDI are negatively related to GDP growth (r=-0.41, p<0.001 and r=-0.38, p<0.001 respectively), which is a reflection of emerging markets with higher GDP growth rates in our dataset.

Regression results are shown in Table 4. Variance inflation factors (VIF) were well under commonly accepted limits of 10 for multiple regression models (Neter, Wasserman and Kutner, 1985). The greatest variance explained occurs in Model 4, with all interaction terms included. We find support for Hypothesis 1: the R&D labor pool has a positive and significant impact on R&D UIC in all models. We also find support for Hypotheses H2a and H3a: difficulty in hiring and firing have negative impacts (p<0.1) on R&D UIC in Models 3 and 4. Finally, we find support for Hypothesis 2b (negative moderating effect of difficulty hiring) but not for Hypothesis 3b (negative moderating effect of difficulty firing). The results of the robustness test using availability of scientists and engineers as a proxy for the R&D labor pool in a country are shown in Table 5. This shows broadly similar results. Hypothesis 1 finds support across all models. In terms of direct effects of labor market rigidity, we see negative signs on all coefficients. However, the coefficient for the direct effect of difficulty in hiring loses significance. Nevertheless, we find support for H2b (negative moderating effect of difficulty hiring) and H3a (direct negative effect of difficulty firing).

-----------------------------------------
Insert Tables 4 and 5 about here
------------------------------------------

**Discussion**

A country's institutions are central to the functioning of its national innovation system (Etzkowitz, 2010; Freeman, 1995; Lundvall, Johnson, Andersen and Dalum, 2002; Whitley, 2002). R&D collaboration between universities and industrial firms (i.e., R&D UIC) has also been shown to be an integral part of a national innovation system (Ankrah and AL-Tabbaa, 2015; Galán-Muros and Plewa, 2016; Hagedoorn, Link and Vonortas, 2000; Perkmann and Walsh, 2007). Our approach is to examine the link between labor market institutional determinants and R&D UIC, with a specific focus on labor market rigidity. We believe labor market regulations are important because they influence how human capital circulates among universities and firms, making them essential, more broadly, to our understanding of institutional determinants of national innovation systems. While it is acknowledged that university - industry collaborations are highly dependent on the underlying human and social capital in the economy (Ankrah and AL-Tabbaa, 2015), our literature review revealed that no research had been conducted on the role of labor market rigidity on this specific issue.

Our analysis shows that R&D collaboration between universities and industry is negatively affected, both directly and indirectly, by the rigidity of a country´s labor laws. Rules that make it more onerous to fire workers have a statistically significant, negative direct impact on university – industry collaboration in R&D in all models, and rigidity of rules relating to hiring also has a negative direct effect when we operationalize the R&D labor pool using a count-based measure. We also find empirical support for a negative moderating influence of rigid hiring rules on the relationship between the R&D labor pool and the degree of R&D UIC in a country. We see this in both of our tests, covering 73 and 109 countries respectively. These results suggest that national laws that hinder employers' ability to hire dampen the expected positive relationship between the R&D labor pool and R&D UIC. Figures 1 and 2 give a visual representation of this moderating effect using the count-based and perception-based measures of the R&D labor pool in a country.

-----------------------------------------
Insert Figures 1 and 2 about here
-----------------------------------------

The current study contributes to the literature on university-industry collaboration by putting forward, and empirically testing, an argument related to the role of labor market rigidities in national systems of innovation. This perspective has been largely overlooked in empirical research that has examined the effects of other institutional factors. In relation to previous studies, our analysis makes some interesting points. For instance, we add to Hagedoorn, Link and Vonortas' (2000) perspective on incentives to engage in collaboration by including the role of labor market institutions on top of minimization of transaction costs, sharing R&D costs, pooling risks, and increasing market power (Hagedoorn, Link and Vonortas, 2000). We provide support to Audretsch and Thurik's (2001) comment about the role of government policy in an entrepreneurial economy facilitating the mobility of workers. In relation to specific work on labour market rigidity, we provide support to the 'conventional' view that flexibility will lead to more desirable outcomes, in our case: R&D UIC (Blanchard, 2005; Eichhorst, Feil and Braun, 2008). However, our findings are not in line with studies showing a negative association between innovative outcomes and flexibility (Michie and Sheehan 2003, Boeri and Garibaldi, 2007; Pieroni and Pompei, 2007). Our analysis provides an alternative perspective and shows empirically that institutional forces that may prevent the flow of individuals between different types of employers within an economy have an important role to play. This has been overlooked in much of the previous work on R&D UIC.

Despite the need for some measures to make jobs sufficiently secure so that both industry and universities could attract and retain valuable human capital, formal laws making both hiring and firing more difficult hamper university-industry collaboration. Rigid labor market rules affect firms as they seek to accumulate the highly skilled human capital that can lead to high-tech collaborations with universities on R&D initiatives. Rules that make hiring a more onerous or complex process reduce the positive association between a country´s abundance of skilled R&D workers and its level of university-industry collaboration in R&D.

Government policymakers concentrating efforts on promoting national technological competence and science and technology capabilities should be cognizant of the impact that their labor market laws will have on circulation of skilled workers and the resulting knowledge and resource exchange between two of the most important types of actors in the national innovation system: universities and industrial firms. The need for worker security, a key element in the accumulation of human capital, appears to be less significant than the need for firms to remain agile and to reallocate labor quickly as technology or market conditions change. Our results point to a flexible labor market as one of the institutional characteristics underpinning R&D UIC and the corresponding functioning national system of innovation. For policymakers in developing countries who aspire to develop knowledge-based economies, measures are needed to increase the supply of qualified workers, within a context of flexible and well-functioning labor markets. In developed countries, policymakers should be aware that even when qualified workers are abundant, rules that hamper their efficient movement around the economy may stunt the development of university-industry collaboration, undermining the national system of innovation. Results suggest that policymakers in both developed and developing countries seeking to promote university – industry collaboration will need to allow more flexibility in hiring and firing.

The two sets of models provide a useful insight into the role played by labor market rigidity within a national system of innovation where labor laws apply to all types of workers, and to employers of scientists and engineers as well as employers of less-skilled workers. The different operationalizations for R&D labor pool in a country improve robustness, particularly for the direct effect of firing rigidity and the indirect effect of hiring rigidity. In addition, while human development index will correlate highly with economic development level and governance quality, the four control variables were selected to minimize the potential for multi-collinearity. When entered alone these four controls account for 34% of the variance in the first sample, and 49% of the variance in the second. The samples encompass countries responsible for the vast majority of the world's R&D and with 195 out of the world's top 200 universities.

**Concluding remarks**

Our analysis across a large number of countries of the world in which R&D occurs has shown that the supply of R&D workers positively impacts the level of R&D UIC. Regulative institutions relating to labor market rigidity also have direct effects on R&D UIC. Furthermore, as the abundance of skilled workers that enable effective and efficient R&D collaboration increases, rigid labor laws can decrease the level of firms' partnerships with universities for joint R&D. These findings advance our understanding of the role played by labor market institutions within a national system of innovation.

Nonetheless, despite these important insights and implications, our study comes with limitations. Firstly, our empirical analysis was limited to only two recent years of data (albeit with a time lag between independent and dependent variables). Secondly, we did not tease out specific components of labor legislation due to limited comparability across countries or lack of data, and we were not able to unpack different types of R&D collaborations between universities and industrial firms. For instance, as mentioned above, R&D UIC might not always involve new labor in formal arrangements or reduction in labor. Some projects, especially small-scale ones and those narrow in scope can be informal (Hagedoorn, Link and Vonortas, 2000), carried out by dispatching or 'loaning' of existing employees as a form of weak integration. Unfortunately, we were not able to disentangle this using the World Bank data. Nor could we distinguish between the effects of labor laws on large, routinely innovating firms and smaller "garage-style" entrepreneurs, who might experience regulations in opposite ways. It is possible that certain types of labor market rigidity, such as permanent contracts offered to new employees, would enhance knowledge generation and accumulation, the willingness to take risks and the degree of university-industry collaboration; but we were not able to isolate those effects in our empirical tests. Similarly, there may be countries in the world where labor market legislation applies in a way that depends on the educational attainment (e.g., PhD) or scientific training of the worker. We were not able to unpack this in the current study and future research might need to investigate this angle. The World Bank has recently expanded its "Employing Workers" indicator, and future studies may be able to focus on single features of a labor market, such as redundancy pay, rather than using an "umbrella" indicator for overall rigidity. Thirdly, while our sample size is an improvement on country-level studies conducted on labor legislation and national innovation systems to date, we were not able to capture data for all countries in the world. We hope future research can tackle some of these issues.

The exploration of labor market rigidity and its implications offers a fertile avenue of research for scholars and policymakers interested in contemporary national innovation systems and technological competence of countries. The key role of human capital in exploring new fields of science and technology highlights the importance of the regulatory framework for labor relations in organizational strategy and eventual success in such environments. We hope that future research will build on this study to further deepen our understanding of how labor and other regulations affect national innovation systems and influence the dynamics of collaborations between universities and industry on R&D.

## References


Acworth, E.B. (2008) University-industry engagement: The formation of the Knowledge Integration Community (KIC) model at the Cambridge-MIT Institute. *Research Policy,* **37**, 1241-1254.

Allard, G. and Lindert. P. (2006) Euro-productivity and Euro-jobs since the 1960s: Which institutions really mattered? National Bureau of Economic Research (NBER) Working Paper 12460.

Ankrah, S. and AL-Tabbaa, O. (2015) Universities-industry collaboration: A literature review. *Scandinavian Journal of Management*, **31**, 387-408.

Archibugi, D. and CoCo, A. (2005) Measuring technological capabilities at the country level: A survey and a menu for choice. *Research Policy,* **34**, 175-194.

Archibugi, D. and Iammarino, S. (2002) The globalization of technological innovation: definition and evidence. *Review of International Political Economy,* **9**, 98-122.

Audretsch, D.B. and Thurik, A.R. (2001) What's new about the new economy? Sources of growth in the managed and entrepreneurial economies. *Industrial and Corporate Change*, **10**, 267-315.

Auer, P., Berg, J. and Coulibaly, I. (2005) Is a stable workforce good for productivity? *International Labour Review*, **144**, 3, 319-343.

Autor, D., Kerr, W. and Kugler, A. (2007) Does employment protection reduce productivity? Evidence from US states. *The Economic Journal*, **117**, 189-217.

Bertola, G., Blau, B. and Kahn, L. (2007) Labor market institutions and demographic employment patterns. *Journal of Population Economics,* **20**, 833-867.

Blanchard, O. (2005) European unemployment: The evolution of facts and ideas (downloaded on January 2013 from http://www.nber.org/papers/w11750).

Blanchard, O. and Wolfers, J. (2000) The role of shocks and institutions in the rise of European Unemployment: The aggregate evidence. *Economic Journal*, **110**, 1-33.

Boeri, T. and Garibaldi, P. (2007) Two tier reforms of employment protection: A honeymoon effect? *Economic Journal*, **117**, 357-385.

Botero, J., Djankov, S., La Porta, R., Lopez-de-Silanes, F. and Shleifer, A. (2004) The regulation of labor. *Quarterly Journal of Economics,* **199**, 1339-1382.

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

Bruneel, J., D'Este, P. and Slater, A. (2010) Investigating the factors that diminish the barriers to university-industry collaboration. *Research Policy,* **39**, 858-868.

Campos, N. and Nugent, J. (2012) The dynamics of the regulation of labor in developing and developed countries since 1960. IZA Discussion paper no. 6881.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R., Rosenberg, N. and Sampat, B. (2002) How do university inventions get into practice? *Management Science,* **48**, 61-72.

Eichhorst, W., Feil, M. and Braun, C. (2008) What have we learned? Assessing labor market institutions and indicators. IAB Discussion Paper.

Etzkowitz, H. (2010) *The triple helix: university-industry-government innovation in action*. Routledge.

Freeman, C. (1991) Networks of innovators: A synthesis of research issues. *Research Policy*, **20**, 499-514.

Freeman, C. (1995) The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics*, **19**, 5-24.

Freeman, R. (2009) Labor regulations, unions, and social protection in developing countries: Market distortions or efficient institutions? NBER Working Paper 14789.

Galán-Muros, V. and Plewa, C. (2016) What drives and inhibits university-business cooperation in Europe? A comprehensive assessment. *R&D Management*, **46**, 369-382.

(The) Global Competitiveness Report 2010-2011, 2010. World Economic Forum.

Hagedoorn, J., Link, A.N. and Vonortas, N.S. (2000) Research partnerships. *Research Policy*, **29**, 567-586.

Harman, G. (2001) University-industry research partnerships in Australia: Extent, benefits and risks. *Higher Education Research and Development*, **20**, 245-264.

Jacobsson, S. (2002) University – industry relations. *Science and Public Policy*, **29**, 345–365.

Lawton Smith, H. (2006) Universities, Innovation and the Economy. Abingdon, Routledge.

Lockett, A., Siegel, D., Wright, M. and Ensley, M.D. (2005) The creation of spin-off firms at public research institutions: Managerial and policy implications. *Research Policy*, **34**, 981-993.

Lockett, A. and Wright, M. (2005) Resources, capabilities, risk capital and the creation of university spin-out companies. *Research Policy*, **34**, 1043-1057.

Lucidi, F. and Kleinknecht, A. (2009) Little innovation, many jobs: An econometric analysis of the Italian labour productivity crisis. *Cambridge Journal of Economics*, **34**, 525-546.

Lundvall, B.Å., Johnson, B., Andersen, E.S. and Dalum, B., (2002) National systems of production, innovation and competence building. *Research Policy*, **31**, 213-231.

March, J. G. (1991) Exploration and exploitation in organizational learning. *Organization Science*, **2**, 71-87.

Metcalfe, S. (1997) Technology systems and technology policy in an evolutionary framework. In: Archibugi, D., Michie, J. (Eds.), Technology, Globalisation and Economic Performance. Cambridge University Press, Cambridge, 268–296.

Michie, J. and Sheehan, M. (2003) Labour market deregulation, ´flexibility´and innovation. *Cambridge Journal of Economics*, **27**, 123-143.

Motohashi, K. (2005) University-industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System. *Research Policy*, **34**, 3583-3594.

Nelson, R.R. and Winter, S.G. (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge, Mass.

Neter, J., Wasserman, W. and Kutner, M. (1985) Applied linear statistical models (2nd edition). Irwin, Homewood, Illinois.

North, D. (1990) Institutions, Institutional Change and Economic Performance. Cambridge University Press, New York.

Ortega, B. and Marchante, A. (2010) Temporary contracts and labour productivity in Spain: a sectoral analysis. *Journal of Productivity Analysis*, **34**, 199-212.

Perkmann, M. and Walsh, K. (2007) University-industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews*, **9**, 259-280.

Pieroni, L. and Pompei, F. (2007) Evaluating innovation and labour market relationships: the case of Italy. *Cambridge Journal of Economics*, **32**, 325-347.

Simonen, J. and McCann, P. (2008) Innovation, R&D cooperation and labor recruitment: evidence from Finland. *Small Business Economics*, **31**, 181-194.

Taplin, R. (2007) Innovation and Business Partnering in Japan, Europe and the United States. Abingdon, Routledge.

Tidd, J. (2001) Innovation management in context: environment, organization and performance. *International Journal of Management Reviews*, **3**, 169-183.

Trumbull, G. (2004) Silicon and the state: French innovation policy in the Internet age. Brookings Institution Press, Washington, D.C.

Van Looy, B., Debackere, K. and Andries, P. (2003) Policies to stimulate regional innovation capabilities via university-industry collaboration: An analysis and an assessment. *R&D Management*, **33**, 209-229.

Whitley, R. (2002) Developing innovative competences: the role of institutional frameworks. *Industrial and Corporate Change*, **11**, 497-528.

Wilson, T. (2012) A review of business-university collaboration. UK Government Department for Business, Innovation and Skills.

World Bank (2016) http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTEDUCATION/0,,contentMDK:20161496~menuPK:282412~pagePK:148956~piPK:216618~theSitePK:282386,00.html accessed 5th October 2016

Yoda, T. (2016) The effect of collaborative relationship between medical doctors and engineers on the productivity of developing medical devices. *R&D Management*, **46**, 193-206.

Zhou, H., Dekker, R. and Kleinknecht, A. (2011) Flexible labor and innovation performance: evidence from longitudinal firm-level data. *Industrial and Corporate Change*, **20**, 941-968.

**Table 1**
Variable definitions and sources

| Label | Variable Type | Definitions | Measurements | Sources |
|---|---|---|---|---|
| University - Industry Collaboration in R&D (R&D UIC) | Dependent | Extent of business – university collaboration on R&D in a country | Scale of 1 (does not collaborate) to 7 (collaborates extensively) (2011) | *Global Competitiveness Report (2010-2011)* World Economic Forum |
| Population (log) | Control | Number of inhabitants within the geographical boundaries of a country | Natural log of population | *World Development Indicators 2009-2010* (World Bank) |
| GDP Growth | Control | Economic growth in a country | GDP growth as percentage | *World Development Indicators 2009-2010* (World Bank) |
| Human Development Index | Control | Composite index of life expectancy, education and per capita income | Range from 0 (least developed) to 1 (most developed) | *United Nations Human Development Report (2009)* |
| Tertiary Education Spend % | Control | Education spending in tertiary sector as fraction of overall education spending | Percentage | World Bank Data Bank |
| R&D Labor Pool | Independent | Volume of people employed in R&D in a country (per million) | Sum of researchers in R&D per million + technicians in R&D per million | *World Development Report 2010* (World Bank) |
| Difficulty in Hiring | Independent / Moderator | Legal requirements for fixed-term contracts and minimum wage regulations | Units from 0-100; higher values indicating more rigid regulation | Doing Business Project (World Bank), 2010 |
| Difficulty in Firing | Independent / Moderator | Legal requirements on dismissals for economic reasons | Units from 0-100; higher values indicating more rigid regulation | Doing Business Project (World Bank), 2010 |

**Table 2**
Descriptive statistics

| Variable | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| R&D UIC | 2.8 | 5.8 | 4.12 | 0.82 |
| Population (log) | 12.67 | 21.01 | 16.60 | 1.55 |
| GDP growth | -4 | 15 | 3.97 | 3.43 |
| Human Development Index | 0.32 | 0.93 | 0.75 | 0.16 |
| Tertiary Education Spend % | 5.16 | 36.44 | 21.46 | 6.24 |
| R&D Labor Pool (log) | 2.46 | 9.21 | 6.99 | 23.57 |
| Difficulty hiring | 0 | 89 | 32.25 | 25.97 |
| Difficulty firing | 0 | 100 | 27.78 | 23.57 |

n=73

**Table 3**
Correlation matrix

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| R&D UIC 1 | | | | | | | |
| Population (log) 2 | 0.07 | | | | | | |
| GDP growth 3 | -0.08 | 0.33** | | | | | |
| Human Dev. Index 4 | 0.58*** | -0.10 | -0.38*** | | | | |
| Tertiary Edu. Spend % 5 | 0.23+ | -0.11 | -0.04 | 0.19 | | | |
| R&D Labor Pool (log) 6 | 0.66*** | -0.06 | -0.41*** | 0.82*** | 0.19 | | |
| Difficulty Hiring 7 | -0.37*** | -0.03 | -0.08 | -0.19 | -0.27** | -0.19 | |
| Difficulty Firing 8 | -0.32** | 0.14 | 0.05 | -0.12 | -0.12 | 0.31** | 0.31** |

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

n=73

**Table 4**
Regression results

| | | R&D UIC | | | |
|---|---|---|---|---|---|
| | Hypothesis | 1 | 2 | 3 | 4 |
| Population (log) | | 0.05<br>(0.06) | 0.04<br>(0.05) | 0.05<br>(0.05) | 0.05<br>(0.05) |
| GDP Growth | | 0.03<br>(0.03) | 0.04<br>(0.03) | 0.03<br>(0.02) | 0.03<br>(0.02) |
| Human Development Index | | 3.13***<br>(0.54) | 0.93<br>(0.87) | 0.70<br>(0.83) | 0.63<br>(0.83) |
| Tertiary Education Spend % | | 0.02<br>(0.01) | 0.01<br>(0.01) | 0.01<br>(0.01) | 0.01<br>(0.01) |
| R&D Labor Pool (log) | H1 (+) | | 0.44**<br>(0.14) | 0.42**<br>(0.13) | 0.42**<br>(0.13) |
| Difficulty Hiring | H2a (-) | | | -0.14+<br>(0.08) | -0.16+<br>(0.08) |
| Difficulty Firing | H3a (-) | | | -0.14+<br>(0.08) | -0.14+<br>(0.08) |
| R&D Labor Pool X Difficulty Hiring | H2b (-) | | | | -0.14+<br>(0.08) |
| R&D Labor Pool X Difficulty Firing | H3b (-) | | | | -0.01<br>(0.08) |
| Max. VIF | | 1.31 | 3.56 | 3.58 | 3.58 |
| F | | 10.23*** | 11.22*** | 10.12*** | 8.51*** |
| F Change | | | 9.83** | 4.44* | 1.88 |
| Adj. R2 | | 0.34 | 0.42 | 0.47 | 0.49 |

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1 Standard errors in parentheses.
All models, n=73

**Table 5**
Robustness test using availability of scientists and engineers as proxy for R&D labor pool

| | | R&D UIC | | | |
|---|---|---|---|---|---|
| | Hypothesis | 1 | 2 | 3 | 4 |
| Population (log) | | 0.09+<br>(0.04) | -0.01<br>(0.04) | 0.01<br>(0.04) | -0.00<br>(0.04) |
| GDP Growth | | 0.04<br>(0.02) | 0.04*<br>(0.02) | 0.04*<br>(0.02) | 0.03<br>(0.02) |
| Human Development Index | | 3.40***<br>(0.40) | 2.13***<br>(0.41) | 1.94***<br>(0.40) | 1.78***<br>(0.40) |
| Tertiary Education Spend % | | 0.02*<br>(0.01) | 0.01<br>(0.01) | 0.00<br>(0.01) | 0.01<br>(0.01) |
| Availability of Scientists and Engineers (R&D Labor Pool) | H1 (+) | | 0.45***<br>(0.08) | 0.45***<br>(0.07) | 0.45***<br>(0.07) |
| Difficulty Hiring | H2a (-) | | | -0.01<br>(0.06) | -0.02<br>(0.06) |
| Difficulty Firing | H3a (-) | | | -0.15*<br>(0.06) | -0.16**<br>(0.06) |
| R&D Labor Pool X Difficulty Hiring | H2b (-) | | | | -0.12+<br>(0.07) |
| R&D Labor Pool X Difficulty Firing | H3b (-) | | | | -0.05<br>(0.06) |
| Max. VIF | | 1.24 | 1.95 | 1.99 | 2.00 |
| F | | 26.88*** | 35.81*** | 28.28*** | 23.81*** |
| F Change | | | 35.66*** | 4.01* | 3.42* |
| Adj. R2 | | 0.49 | 0.62 | 0.64 | 0.66 |

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1 Standard errors in parentheses.
All models, n=109

**Figure 1**. Impact of Difficulty in Hiring on the Relationship between R&D Researchers and R&D UIC in 73 Countries

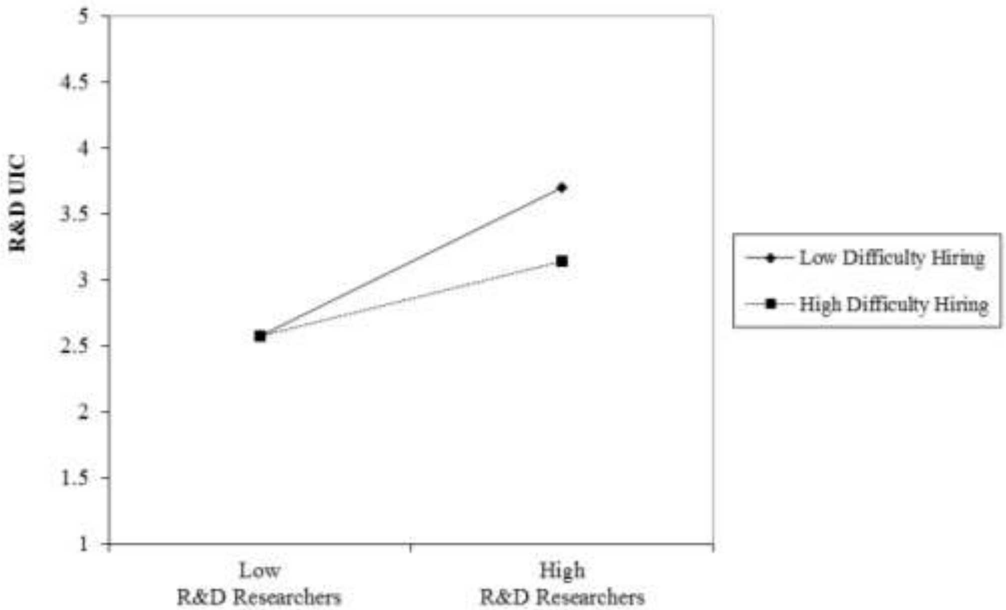


**Figure 2**. Impact of Difficulty in Hiring on the Relationship between Availability of Scientists and Engineers R&D UIC in 109 Countries