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Drivers of Academic Research and Patenting in India: *Econometric Estimation of the Research Production Function*

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Contents

List of Table

List of Figure

List of Appendix

Foreword

This paper by Professor Amit Shovon Ray and Mr. Sabyasachi Saha explores the possible drivers of academic research and patenting in India in the wake of a new bill (*The Protection and Utilisation of Public Funded Intellectual Property Bill 2008*) that has been introduced in the Indian Parliament to stimulate public-funded research for greater industrial application. Patenting is still not very common among academic researchers in India, although some of the top-tier institutions have put in place institutional structures to encourage patenting of their research outputs.

The authors use econometric techniques to track the research behaviour of academic scientists at two of the premier academic institutions in India and come up with interesting insights. Such an analysis is possibly new in India and it would definitely enhance the knowledge content of policy making, not only for the forthcoming legislation on public funded research but also for any other institutional reform that could potentially affect academic research in science and technology in India.

(Rajiv Kumar)
Director and Chief Executive

April 3, 2010

Abstract

In this paper we attempt to provide a comprehensive understanding of the drivers of academic research and patenting in India. Academic research is conceptualised as a research production process where research inputs (like research time and number of research scholars) are transformed into research outputs in the form of publications and patents. We expect research inputs by a faculty member to be an outcome of his/her own decision-making process, which in turn determine his/her research outputs. Exogenous parameters, like faculty background, faculty attitude, research sponsorship and institutional factors, are expected to influence both set of endogenous variables (research inputs and outputs). We specify this production function as a recursive simultaneous equation model and estimate the structural parameters using standard econometric methods. Our results clearly identify several drivers of academic research and patenting in India, in terms of faculty background, faculty attitude and other parameters, from which we arrive at concrete policy lessons for patenting of academic research in India. In particular, we argue that putting in place institutional structures will not serve the purpose without addressing the fundamental issues of research environment, culture and attitude in the first place. In a sense, therefore, introducing an IPR legislation alone may not act as an instant magic formula to energise Indian academic research for commercial application.

Keywords: Academic Research, Patents, Bayh-Dole Act, India

JEL Classification: O31, O34, O38, I23, C51

Drivers of Academic Research and Patenting in India:
***Econometric Estimation of the Research Production Function*[1]**

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I. Introduction

From the history of inventions, we know that the *Edisons* of this world were not all university scientists. However, during the last century, basic scientific research got a fillip within the university system, mostly under state patronage, and had a direct and profound influence on the global frontiers of technology. The importance of university generated research ideas in promoting innovations for economic growth and competitiveness of industrialised economies is now well acknowledged in the literature (Jaffe 1989, Mansfield 1991). However, the research mandate of universities and public-funded organisations extends well beyond mere commercial or industrial application of their research outputs; advancing the frontiers of knowledge and generating human resources have been their twin principal objectives. Nevertheless, over the last three decades, new legal and institutional structures have been put in place within the university system to foster better university-industry linkages to ensure that ideas and inventions generated by academic research reach the marketplace.

It is with this objective in mind that the Bayh-Dole Act was introduced in the US in 1980, allowing universities to retain the intellectual property rights (IPR) of research outputs from public-funded research and to license them *exclusively* at their discretion. The US example was adopted by many other nations, developed and emerging, over the past decade and a half. India has also followed the footsteps and a new bill (*The Protection and Utilisation of Public Funded Intellectual Property Bill 2008*), inspired by the US Bayh-Dole Act of 1980, has been introduced in the Indian Parliament to stimulate public-funded research for greater industrial application.

[1] We gratefully acknowledge inputs and comments from A. L. Nagar, K. L. Krishna, Ashok Guha, Poonam Gupta and all seminar participants at ICRIER.

There is a large literature in economics on the implications of patenting public-funded research, essentially based on the US experience after the Bayh-Dole Act. However, the conclusions are far from unambiguous. While there was a surge in the number of university patents in the US after 1980, there are doubts not only about the quality of these patents but also about the extent to which the rising numbers of patents were matched by equivalent increases in licensing (Thursby and Thursby 2002, Henderson et al 1998, Mowery et al 2002).[2] Despite this, the faith in IPR as a magic formula to energise public-funded research and its commercial application has remained firmly rooted in the minds of policy makers across the world. In an earlier paper (Ray and Saha, 2010), based on a comprehensive conceptual-empirical synthesis of the US evidence, we have argued that institutionalising IPR for academic research in India might be tantamount to putting the cart before the horse if the realities of the differences in the context, environment, culture and levels of scientific achievement across nations are ignored.

It is against this backdrop that we attempt to provide a comprehensive understanding of the drivers of academic research and patenting in India. In fact, academic research may ideally be viewed as a research production process where research inputs (like research time and number of research scholars) are transformed into research outputs in the form of publications and patents. University faculty and researchers are the primary actors in this research production process and ultimately it is their behaviour, perception and performance that determine the co-ordinates of academic research. In this paper, we conceptualise a comprehensive research production function in the context of India and estimate this function using tools of applied econometrics. From the results of our econometric analysis, we arrive at policy conclusions regarding patenting of academic research in India.

The paper has five sections. Section II develops the analytical framework and conceptualises a research production function for Indian academic research. Section III presents the econometric model and describes the data and methodology of our

[2] Moreover, there have been apprehensions that the Bayh-Dole Act might have altered the research focus of universities from basic to applied fields, although some of these have been allayed by Mowery et al (2001) and Nelson (2001).

analysis. The results are discussed in section IV. Finally, section V summarises the paper by highlighting some of the key conclusions.

II. Analytical Framework

Although, there is a large body of literature on the consequences and implications of patenting public-funded research, much of it focuses on overall trends in university patenting and long-term changes in the organisational structure and research focus and culture in universities. Very few studies investigate faculty research behaviour and perceptions that shape academic research and patenting. Owen-Smith and Powell (2001), for instance, conclude that faculty's perceived incentive structure for patenting their research varies significantly across broad research areas. Based on qualitative responses, they show that faculty decision to patent depends largely on the perceived (personal and professional) benefits of patenting as well as time and resource costs of interacting with technology transfer offices (TTOs).[3] Azoulay et al (2007), from a large sample of 3862 scientists, analysed patenting versus publishing behaviour, concluding that mid-career academics are much more likely to patent than their younger or older colleagues. It has also been shown that patents and publications are likely to encode similar pieces of knowledge. Indeed, several studies conclude that patents and publications are positively correlated at the individual faculty level (Meyer 2006, Breschi et al 2005, Fabrizio and DiMinin 2008). Another set of studies examine links between faculty's research behaviour and their industry interface or entrepreneurial drive. Gulbrandsen and Smeby (2005), from a large sample of university professors in Norway, show that faculty receiving industry-funding conduct more application-oriented research and they are more likely to collaborate. Landry et al (2006) analyse the factors explaining faculty's entrepreneurial drive and confirms that laboratory size, novelty of research, research experience, positive inclination towards IP protection and active participation in industry consulting augment the probability of a faculty creating spin-offs.

Most of these studies focus on specific aspects of faculty behaviour in a partial framework. None of them conceptualise a comprehensive research production

[3] Jensen and Thursby (2001) also suggest that faculty patenting involves some transaction cost.

function, incorporating a range of exogenous and endogenously determined research inputs and consequent research outputs. This paper attempts to bridge this gap and presents a conceptual framework to estimate a research production function for academic (science) research in India.

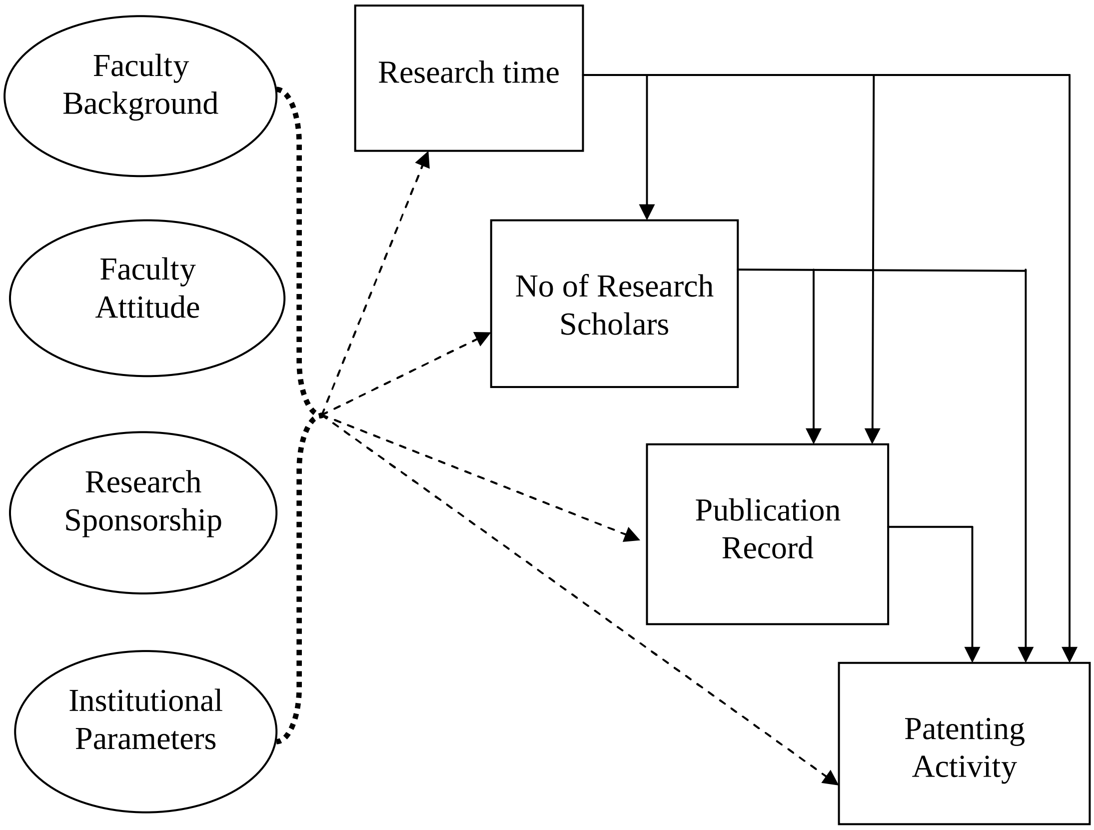
The edifice of science in India, as understood from the perspectives of research, innovation and human resource generation, stands on a complex but appropriately integrated network of public-funded institutions at various levels, comprising of universities and institutes of higher learning, research laboratories and various other autonomous organisations. Although these institutions are differently identified based on pre-assigned mandates for their research focus and skill generation, they might not operationally be very different from one another. Arguably, in most cases, their activities overlap in the primary disciplines of scientific research and modes of human resource generation – divergences in institute specific expertise, facilities and infrastructure notwithstanding.

Indeed, science research in India reflects enormous heterogeneity in terms of quality. Moreover, patenting is still not very common among academic researchers in India, with the exception of some of the top-tier institutions. In fact, some of them have put in place an institutional framework to encourage patenting of their research outputs. We, therefore, restrict the focus of our analysis to these premier academic institutions only. More specifically, we draw our data from two such leading institutes in India – the Indian Institute of Technology, Delhi and the Jawaharlal Nehru University, New Delhi. Our conclusions, by no means should be regarded as a generalisation for the entire quality spectrum of Indian academia.

The Research Production Function

Research goes hand in hand with teaching, especially in the premier academic institutions in India. In fact, faculty members are expected to perform the multiple tasks of teaching, research and research supervision, stretched to personal initiatives of industry interface and (in many cases) administrative responsibilities. It might, therefore, be rather difficult for them to define their priorities to meet diverse institutional obligations.[4] However, within a broad mandate to carry out teaching and research simultaneously, faculty in premier institutions do enjoy a certain amount of freedom in setting their own work agenda and ultimately participate in shaping the institute's organisational character.[5] Accordingly, we may reasonably expect research inputs by a faculty member to be an outcome of his/her own decision-making process, which in turn determine the research outputs produced. It is in this perspective that we conceptualise a research production function for our analysis in the form of a schematic framework (Figure 1). Both research inputs as well as the resultant research outputs are endogenously determined in this framework in a recursive structure.

Figure 1: The Research Production Function – A schematic framework



The primary research input in our framework is the time devoted to research (**research time**). This is not merely a decision to meet the institutional obligations of

[4] Formal microeconomic models of multiple principals and multiple agents, following Holmstrom and Milgrom (1991) for instance, may be helpful in understanding the complex matrix of incentives determining faculty decision making.

[5] Colbeck (1997)

faculty but is actually a discretionary choice based on individual preferences.[6] On most occasions, research time becomes the residual of time devoted to teaching and administrative tasks and, therefore, crucially depends on faculty's own willingness to carve out time from other commitments. In a multi-tasking environment with competing demands on faculty time, this is indeed a critical element in the faculty's decision-making process that affects the entire fabric of academic research. Closely linked to the decision to devote time to research is the other decision to supervise research scholars. The **number of research scholars** a faculty accepts to supervise, therefore, constitutes the second research input in the research production function. It clearly depends *a priori* on how much time a faculty member has optimally decided to devote to research.

To capture research output, we restrict ourselves to the two standard measures of faculty research performance, namely, **publication record** and **patenting activity**.[7] We posit that publication record influences faculty patenting activity, but not the other way round. Given that Indian academia is still largely publication driven, it may be reasonable to assume that faculty in India will try to publish all academic research output. However, only a subset of this research is patentable. To the extent that publication acts as a proxy for the entire volume of research being conducted by a faculty member, it will directly affect the rate of patentable inventions and we may expect publication record to influence patenting activity positively. However, it could also be argued that if there is an inherent conflict between publishing and patenting,[8] a larger pool of publications might imply fewer patents.

Accordingly, we have four endogenous variables in our framework – research time, research scholars, publication record and patenting activity – all appearing in a recursive manner. To capture the drivers of academic research in India, we identify

[6] Thursby et al (2007) explain this as inter-temporal choice between research and leisure over a faculty's life-cycle.

[7] R&D output, whether in industry or in the academia, has been conventionally captured by patents and publications, the former reflecting applied research and the latter basic research as a general rule of thumb. Consequently, R&D by industry is expected to generate relatively more patents, while academic research would perhaps lead to more publications than patents. However, such clear lines of distinction between the two are getting increasingly blurred.

[8] This possible substitution effect has been discussed in Klitkou and Gulbrandsen (2006). Blumenthal et al (1997) find that 19.8 per cent of a sample of U.S. academic life scientists had withheld research results for more than six months due to intellectual property rights discussions, patent applications etc.

four broad categories of parameters that are expected to determine faculty research behaviour. These include not only conventional factors like faculty background but also other factors that are particularly relevant in the Indian context, like faculty attitude (towards research, research supervision and publication), research sponsorship and institutional parameters. *Prima facie*, these parameters shaping faculty research behaviour are expected to be exogenously determined.[9] In figure 1, depicting academic research as a production process, exogenous variables are marked in oval shapes and the endogenous (outcome) variables in rectangles.

Faculty Background

Faculty background refers to their experience and training. It has often been contended that junior faculty, both in terms of designation as well as years of experience, would have greater research drive. This may be attributed to several factors, including considerations of career advancement, aspirations for recognition among peers and a plethora of fresh research ideas to explore. Indeed, after attaining the professorial rank, a senior faculty may display a greater preference for leisure and hence a lower research drive due to complacency.[10] The divergence in research drive would imply that junior faculty would not only devote more time to research but also be more productive in terms of research publications and more active in patenting, for given research inputs, compared to their senior counterparts. However, it is unclear whether the same is valid for the other research input, namely the number of research scholars supervised. While junior faculty may have greater enthusiasm to supervise more scholars, students may be keen to work under a full professor with academic stature.[11]

Apart from faculty's experience strictly measured by rank and/or years of service, there is another dimension pertaining to the work experience of individual members in

[9] Arguably, some of these parameters (particularly faculty attitude and research sponsorship) may not be truly exogenous in the strictest sense, since faculty behaviour and performance could conceivably shape and alter these factors over time through a slow but prolonged influence. However, in a cross sectional model, it is difficult to capture such inter-temporal evolution and hence we may justifiably use them as exogenously determined.

[10] Thursby et al (2007)

[11] Crosta and Packman (2005) sought to address faculty productivity in terms of number of scholars supervised. The results show that, on average, a faculty member's prestige and her length of time at the institution significantly determines faculty productivity on this count.

industry during the course of their career. We believe that such industry experience may influence patenting activity of faculty in a positive way, as they would better appreciate how rudimentary inventive ideas generated from academic research can be developed for commercial applications through IPR protection.

Another important parameter of faculty background that is particularly relevant in the Indian context pertains to the kind of institutions the faculty has been trained in. Here, we make a distinction between those trained in India versus those trained abroad (mostly in the western world). The academic milieu in India has been rather different from that in the West, with the relative emphasis of Indian academia perhaps being more on teaching than research. Accordingly, we expect faculty members trained abroad to have a different exposure to a research culture and environment that may generate a greater research drive in them compared to their counterparts trained in India. This would not only positively influence research inputs such as research time and the number of scholars supervised, faculty are also likely to be more productive in terms of both publications and patenting because they were groomed in a research culture of *publish or perish* (or a more recent coinage of *publish, patent and prosper*).[12]

Faculty Attitude

Faculty attitude towards research supervision is an important exogenous factor influencing research time. University science departments in India (especially in the premier institutions) are not only mandated to undertake undergraduate and masters level teaching, but are also focused on postgraduate research supervision. However, faculty may differ in their attitude towards research supervision. While a few may consider it merely an institutional obligation and an additional workload, and hence, would be rather hesitant to accept research scholars for supervision, others may perceive that research students enrich their own research by not only staffing their

[12] Eisemon (1974) examined whether training had any long-term influence on attitudes and scholarly behaviour of Indian engineering faculty who were trained in the US. Probably in those days, it was more true that returnees were expected to display greater professional commitment and were considered to be more productive scholars. However, the study did not find any evidence that returnees were more productive researchers or more professionally involved.

research laboratories but also providing "new" research ideas.[13] Therefore, a positive attitude towards research supervision is expected to act as a key driver of academic research in India, positively influencing research inputs and outputs.

Another dimension of attitude that we incorporate in our framework is the motivation behind research publications – whether they publish with career advancement in mind or just for peer recognition.[14] Research is creative work. We know little about motivation for any creative work, and less so about how one gets motivated to do research. Of course, when research is taken up as a profession, considerations of career advancement cannot be denied. However, it is debatable whether intrinsic motivation for research (one's innate urge towards solving research puzzles) in anyway gets crowded out by extrinsic motivations like career advancement or financial gains. This poses an interesting question addressing the research motivations of faculty as a driver of academic research. Indeed, it is important to understand whether encouraging publications as a yardstick for career advancement actually motivates faculty towards research.

Research Sponsorship

Scientific research requires infrastructure, equipment and supplies. While the university may be in a position to provide basic research infrastructure, project specific requirements may involve huge expenditure that must be sponsored by a funding agency, including government departments, research foundations or private bodies. Indeed, research in Indian universities is no longer funded by the university alone – external funding has become a common practice. Needless to say, not all faculty have the same extent of research funding and there is considerable variation in their portfolio of sponsored versus non-sponsored research. There is a popular

[13] Indeed, research scholars might be equally important for a faculty who is less dependent on laboratory research and focuses more on theoretical research.

[14] According to a report prepared by the University of California (2007), "Faculty appear to consider the act of publishing itself to be sufficient for accomplishing their goals. Once an article or monograph has been published (presumably by a publisher with a solid reputation), scholars are less concerned about the process of dissemination, and whether its impact is measured directly rather than via surrogate of the publication venue. In large measure, this lack of concern is due to the tenure and promotion system, which rewards publication over broader dissemination." In an earlier study, Gomez-Mejia and Balkin (1992) find that the primary determinants of faculty pay are the number of top-tier journal publications and changes in institutional affiliation.

perception that research sponsorship *per se* acts as a driver of university research. In other words, faculty engaged in sponsored research in applied fields will devote more research time and supervise more students. However, it is unclear if they will also publish more. In fact, given their commitment to fulfil the deliverables to the sponsors, they might as well end up publishing less. But they may perhaps come up with more patentable research output.[15]

Institutional Parameters

The institutional framework can play an important role in shaping academic research. The overall mandate of the institution along with the organisational structures that are put in place may act as key drivers of research.[16] Although our data set covers two premier academic institutions in India (JNU and IIT Delhi) which have a lot in common, we expect each institution to have its own character and type influencing the drivers of academic research. JNU has a broader disciplinary focus where sciences co-exist with equally strong areas of humanities and social sciences. IIT Delhi, on the other hand, is essentially focused on science and engineering. In popular perception, IIT, as compared to JNU, is more oriented towards research in the frontiers of technology, which has more direct industrial application. Accordingly, IIT Delhi has a streamlined organisational structure for facilitating technology transfer and commercialisation with a clear mandate to encourage faculty patenting in the form of an autonomous foundation called FITT (Foundation for Innovation and Technology Transfer) that has been in existence for over a decade and a half now. JNU, on the other hand, has recently introduced an IPM (intellectual property management) cell. We believe that these subtle differences in the institutional framework and structures of the two institutes may shape faculty research behaviour and performance differently.

[15] Gulbrandsen and Smeby (2005) find that professors with industrial funding are more engaged in applied research, have more scientific publications and engage in entrepreneurial activities more frequently.

[16] According to Owen-Smith and Powell (2001), who attempted to investigate widely disparate rates of invention disclosure across institutes, there is an influence of the institutional environment in this regard, especially whether it promotes simultaneous pursuit of academic and commercial endeavours or not.

III. Econometric Specification

Data

Data for our analysis has been collected from two top-tier higher educational institutes in India – Jawaharlal Nehru University (JNU), New Delhi, which is a central university and the Indian Institute of Technology, Delhi (IITD), which is one among the seven IITs. This serves our purpose of covering in our dataset two apparently different kinds of institutes of higher learning in India to look for institute-specific differences in faculty behaviour, if any. Individual faculty level information was collected through administering a semi-structured questionnaire through personal interviews with university faculty. The data covers information from a randomly selected sample of 49 faculty members, 24 from IITD and 25 from JNU, spread across the departments of electrical engineering, civil engineering, chemical engineering, mechanical engineering and textile technology in IITD and the school of physical sciences, centre for molecular medicine, school of life sciences, school of biotechnology and school of information technology in JNU. The information collected through interviews was crosschecked wherever possible with faculty information provided in the institutes' websites to minimise human errors associated with the field survey.

Variables

Research time ***(restime)***: We construct a variable depicting the percentage share of working time a faculty devotes to research and research supervision from amongst other academic activities.

Number of Research Scholars ***(phdno)***: This is calculated as a simple count of the number of PhD scholars under the supervision of a particular faculty at the time of interview.

Publication Record ***(pub)***: This is a standard yardstick of faculty research performance. There are two dimensions of publication record – quantity and quality. Given that it is always difficult to arrive at an objective measure of quality across disciplines, we restricted ourselves to the quantity dimension of faculty's publication record. To avoid biases due length of service, we considered the current annual rate of publication averaged over the last three years. Given that it is easier to report the rate of publication clubbed under categories, we constructed a binary which takes the value 1 (one) if annual publication rate is high (≥ 4) and 0 (zero) otherwise.

Patenting Activity ***(pat)***: Patenting as a conscious effort is a relatively recent phenomenon in Indian academia and only a very few faculty members have actually obtained patents to date, although a number of them have started taking initiatives in this direction. Therefore, we felt the actual grant of patents might not be an accurate reflection of patenting activity among faculty at this juncture. Rather, we consider patent *application* along with patents *granted* to capture patenting activity. After all, our primary objective is to quantify faculty's inclination towards patenting in the first place.[17] We therefore construct a binary variable ***pat*** to represent patenting activity of a faculty, which takes the value 0 (zero) if the faculty has neither applied for nor been granted a patent, and 1 (one) otherwise.

Faculty background

Faculty background essentially includes seniority and training. Seniority is captured in terms of both designation and years of experience. With respect to designation, there is a common perception that in India 'academic merit' has not always been the key driver for faculty promotions. However, in institutions like JNU and IIT, academic merit has, by and large, been seriously recognised for faculty promotions. We create a binary variable ***prof*** which takes the value 1 (one) if a particular faculty is a full professor and 0 (zero) otherwise (i.e. if he/she is an assistant or an associate professor). To capture the length of professional experience of a faculty, we construct two variables – the number of years in academics (***yrsexpacad***) and the number of years in industry (***yrsexpind***). While the former enters all four structural equations, the latter is included only in the function for patenting activity. Finally, faculty training is

[17] We must also note that there is a fundamental difference between applying for a publication and for a patent. The former goes through a tough academic screening process with a very high probability of failure. The latter, however, is much less rigorous in its technical screening – the scientist feels that it is easy to get a patent as long as the three legal criteria (novelty, inventive step and commercial appeal) are established. The same scientific result may not pass the review process of an academic journal.

captured by a binary variable ***foreignphd*** taking the value 1 (one) if a faculty has a doctoral degree from abroad and 0 (zero) otherwise.

Faculty attitude

To capture faculty attitude towards research supervision, we define a variable ***ressupvsn*** which takes the value 1 (one) if a particular faculty considers research supervision to be 'important' and 0 (zero) otherwise. With regard to faculty's motivation to publish, we consider two distinct motivations, namely peer recognition and career advancement, which are neither mutually exclusive nor exhaustive. It is possible that faculty may indicate both, any one or none of these motivations for publishing their research. Accordingly, we construct two binary variables to capture faculty motivation to publish – ***recogp*** that takes the value 1 (one) if they publish for academic recognition and ***careerp*** that takes the value 1 (one) if they publish for career advancement.

Research sponsorship

The general impression that came out of our faculty interviews is that research cannot be precisely compartmentalised into mandated sponsored research and unencumbered research undertaken with little external financial support. The latter is often based on insights drawn from the former. Nevertheless, we did ask faculty members to specify a rough distribution of their research portfolio into sponsored versus non-sponsored. We construct a variable, ***resspons,*** reflecting the percentage share of total research that is sponsored by external agencies.

Institutional parameters

We construct a dummy variable to capture the institutional affiliation of the faculty, ***JNU,*** which takes the value 1 (one) if the faculty member belongs to JNU and 0 (zero) if faculty belongs to IIT Delhi.

Nature of the Sample: Selected Descriptive Statistics

Our sample of 49 observations is fairly balanced as evident from the following frequencies:

- JNU faculty = 25, IITD faculty = 24
- Professors = 24, Assistant/Associate Professors = 25

– Faculty with PhD from abroad = 15, PhD from India = 34
– Faculty with high publication rate = 26, low publication rate = 23
– Faculty active in patenting = 20, non-active = 29
– Faculty Attitude:
  • Publish for recognition = 29
  • Publish for career advancement = 12
  • Consider research supervision to be important = 40

The mean and standard deviation for *restime* (Research time) turn out to be 44.27 per cent and 15.79, while the mean of *phdno* (No of research scholars) is 4.47 with a standard deviation of 3.04. The mean share of sponsored research in faculty portfolio appears to be 63.9 per cent with a standard deviation of 38.08. While 18 per cent of respondents report no sponsored research, about 32 per cent indicate 100 per cent sponsored research. Years of academic experience ranges from 1 to 35 years, with a mean of 14.2 years and standard deviation of 8.8. In our sample, only 25 per cent have industry experience and that too, mostly, for a very short period (75 per cent of them with 4 years or less).

The Econometric Models

We specify the following econometric models for estimation.

1. $restime = \alpha_1 + \beta_{11} foreignphd + \beta_{12} prof + \beta_{13} yrsexpacad + \beta_{14} ressupvsn + \beta_{15} resspons + \beta_{16} JNU + u_1$

2. $$phdno = \alpha_2 + \gamma_{21} restime + \beta_{21} foreignphd + \beta_{22} prof + \beta_{23} yrsexpacad + \beta_{24} ressupvsn + \beta_{25} resspons + \beta_{26} JNU + u_2$$

3. $$pub^* = \alpha_3 + \gamma_{31} restime + \gamma_{32} phdno + \beta_{31} foreignphd + \beta_{32} prof + \beta_{33} yrsexpacad + \beta_{34} ressupvsn + \beta_{35} resspons + \beta_{36} recogp + \beta_{37} careerp + \beta_{38} JNU + u_3$$

   where pub* reflecting propensity to publish is unobserved in practice but proxied by a dummy pub which takes the value 1 if pub*> θ (a threshold level beyond which we consider the propensity to be high) and 0 otherwise.

4. $$pat^* = \alpha_4 + \gamma_{41} restime + \gamma_{42} phdno + \gamma_{43} pub + \beta_{41} foreignphd + \beta_{42} prof + \beta_{43} yrsexpacad + \beta_{44} yrsexpind + \beta_{45} ressupvsn + \beta_{46} resspons + \beta_{47} JNU + u_4$$

where pat* reflecting 'propensity to engage in patenting' is unobserved in practice but proxied by a dummy pat which takes the value 1 if pat*> □ (a threshold level beyond which we consider the propensity to be high) and 0 otherwise.

This is a simultaneous equation model with four structural equations for four endogenous variables (*restime, phdno, pub* and *pat*). It is evident that this set of equations constitutes a fully ***recursive model***, where Γ is triangular. We assume the disturbances (u's) to be mutually uncorrelated, i.e., the matrix Σ is diagonal and there are no restrictions on B.[18] In this case, the structural coefficients of the recursive model can be consistently estimated by applying classical least squares to each individual equation.[19] We constructed the partial correlation matrix for all explanatory variables and found that none of the partial correlation coefficients are high enough to indicate any serious presence of multicollinearity that could violate the standard assumption of least square estimation (see Appendix I). To test for the presence of hetroscedasticity, we use the Cook-Weisberg (1983) test. For equation 1, we apply robust estimation method (weighted least squares) to correct for possible presence of heteroscedasticity.[20] The dependent variable in the second equation (number of research scholars) is a non-negative count variable. We, therefore, use POISSON regression in this case. The last two equations representing publication rate and patenting activity, have both binary dependent variables and we apply the LOGIT model to estimate these.

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[18] We tested for the validity of this assumption of uncorrelated error terms across equations in our model by calculating the estimated values of $\hat{u}_1$ $\hat{u}_2$ $\hat{u}_3$ $\hat{u}_4$ to obtain the correlation matrix (see Appendix II). We find that none of the correlation coefficients are statistically significant, vindicating our assumption of mutually uncorrelated error terms across equations.

[19] Wold and Jureen (1953) forcefully argued that even if a simultaneous equation model is deemed necessary to describe interdependent economic systems, it will usually be of the recursive type for which the method of least squares is known to be valid under certain assumptions.

[20] The Cook Weisberg test failed to reject the null hypothesis of homoscedasticity in this equation when we use the STATA default option covering all RHS variables. However, when we re-performed the Cook-Weisberg test specifying RHS=JNU, the estimated $\chi^2(1)$ value turned out to be 4.43, rejecting the null hypothesis of homoscedasticity for model 1 at 5 per cent level of significance.

IV. Results and Analysis

Table 1: Structural Estimation of the Recursive Simultaneous Equation System

	Eqn 1 ***restime*** (Robust)	*Eqn 2* ***phdno*** (POISSON)	*Eqn 3* ***pub*** (LOGIT)	*Eqn 4* ***pat*** (LOGIT)
restime		-0.003	0.044	-0.061
		(-0.60)	(1.40)	(-1.64)
phdno			0.085	0.635***
			(0.50)	(2.68)
pub				0.146
				(0.15)
foreignphd	0.804	-0.094	-1.042	3.976***
	(0.17)	(-0.53)	(-0.95)	(2.71)
prof	-5.279	0.488**	-1.333	3.057**
	(-1.00)	(2.50)	(-1.11)	(1.89)
yrsexpacad	0.668**	0.019*	0.032	-0.196**
	(2.18)	(1.77)	(0.49)	(-1.90)
yrsexpind				0.461*
				(1.79)
ressupvsn	5.411	0.390*	-1.722	4.488***
	(1.01)	(1.90)	(-1.35)	(2.12)
recogp			0.249	
			(0.22)	
careerp			-5.196**	
			(-2.43)	
resspons	-0.109*	0.006***	0.009	-0.015
	(-1.85)	(0.007)	(0.63)	(-1.13)
JNU	11.920**	-0.069	-3.860***	2.038
	(2.62)	(-0.38)	(-2.81)	(1.37)
cons	35.088***	0.365	1.828	-5.566*
	(4.60)	(1.08)	(0.92)	(-1.94)
Diagnostics				
F / χ^2	2.68**	38.10***	27.53***	32.81***
No. of obsv.	49	49	49	49

*Note: t-values are given in parentheses; * significant at the 10% level; ** 5% level; *** 1% level*

<u>*Equation 1: Restime*</u>

We find that time devoted to research is explained primarily by two variables - years of academic experience and the institutional affiliation. Contrary to the popular notion that junior faculty will have greater research drive and hence devote more time to research, we find that years of academic experience positively affects the fraction of time devoted to research by a faculty member. However, since professorial designation does not appear to matter in this regard, it may not be entirely correct to interpret the positive impact of experience on research time solely in terms of the maturity-driven urge for research by senior faculty. Junior and newly recruited faculty often bear a greater burden of teaching load vis-à-vis their experienced counterparts, especially in Indian academia.

The JNU dummy has a positive and highly significant coefficient in this equation. Given that JNU has no undergraduate teaching in sciences and it was established primarily as a research university with a multidisciplinary focus, it is natural that JNU faculty would devote a larger share of their time to research relative to their counterparts in IIT Delhi with a large and strong, flagship undergraduate programme.

Finally, we also observe that research sponsorship determines research time, although it is statistically significant only at 10 per cent level. Interestingly, faculty with a greater share of sponsored research tend to devote a lower fraction of their time to research. Perhaps, project administration takes up a significant chunk of their time, leaving them with very little residual time for research over and above their pre-determined teaching obligations.

Equation 2: Number of Research Scholars

The number of research scholars supervised by a faculty member is again best explained by two factors – seniority and the share of sponsored research in his/her portfolio. We find that senior faculty, both in terms of designation and experience, are likely to supervise more PhD scholars, rejecting once again the popular belief that junior faculty might have greater research drive. Indeed, senior faculty may be more experienced in supervising scholars and are expected to be able to manage a large research team. Of course, we must note that the positive and significant coefficients of *prof* and *yrsexpacad* may also be a reflection of the fact that scholars are driven more towards senior faculty because of their stature and recognition.

Secondly, as expected, we do find faculty with a larger portfolio of sponsored research supervise more PhD scholars. Sponsored research, usually more applied than theoretical, demands larger infrastructure in terms of laboratories and equipment, and hence a larger research team to manage the work. Therefore, faculty with more sponsored research projects will have larger teams of research scholars.

Finally, although marginally significant at the 10 per cent level, faculty's positive attitude towards research supervision does influence their decision to supervise more scholars. In fact, we must note that while one may consider PhD students to be important for research, such attitude needs to backed by infrastructural support like large laboratories, which sponsored projects are likely to provide. Our results vindicate this position by confirming that the number of research scholars is positively influenced by the share of sponsored research in the faculty research portfolio, backed by a positive attitude towards research supervision.

Equation 3: Publication Record

Our results for this model show that direct research inputs like research time and the number of research scholars have little role in determining faculty's publication record. Rather, the institutional affiliation and faculty attitude towards publication appear to be somewhat important in this regard. The most interesting result in this model is the negative and significant (at 5 per cent level) coefficient of *careerp*, implying that faculty who publish with career advancement considerations in mind end up with a lower rate of publication. This vindicates our earlier conjecture that creative pursuits like research cannot be incentivised by parameters of extrinsic motivation.

The institutional dummy (*JNU*) has a negative and highly significant (at 1 per cent level) coefficient, suggesting that JNU faculty has a relatively lower publication rate, although we found that they devote a larger share of their professional time to research vis-à-vis IIT Delhi faculty. This might indicate that JNU faculty perhaps engage in more long drawn research that could conceivably slow down the publication rate.

Equation 4: Patenting Activity

This is the most powerful and statistically robust of all estimated equations. Among the direct research inputs, although research time has no significant impact on patenting activities, the coefficient of *phdno* appears positive and significant (at 5 per cent level). Indeed, a faculty working with a large team of research scholars is perhaps more likely to come up with patentable research ideas and outputs. This is corroborated by the fact that a positive faculty attitude towards research supervision, as captured by *ressupv*, also appears to have a positive and significant impact on faculty patenting activity.

Interestingly, publication record (*pub*) does not appear to have any significant impact on faculty patenting activity. We thus fail to find evidence of either a trade-off or any complementarities between publication and patenting at the individual faculty level.

Faculty background seems to play an important role in determining faculty patenting activity. We find that a full professor is more inclined towards patenting, although academic experience (*yrsexpacad*) has a negative impact. In other words, faculty who have become full professors at a relatively early date engages more in patenting activities. Perhaps they have the dynamism of the younger generation to appreciate the need for commercial application of university research as well as the professorial maturity to identify the patentable components of their research agenda.[21] We also find that faculty trained (with doctoral degree from) abroad and those with experience of working in the industry are more likely to be engaged in patenting, as hypothesised.

We note that research sponsorship and institutional parameters do not come up with statistically significant coefficients in this model. Contrary to our expectation, a larger portfolio of sponsored research does not necessarily facilitate greater patenting activities. Likewise, given that there is no significant difference between patenting in the two institutes under consideration (JNU and IIT Delhi, the latter with long established systems for faculty patenting), we may conclude that appropriate organisational structures to facilitate faculty patenting may not be enough to encourage patenting activity in any significant way.

[21] This is somewhat in harmony with the findings of Azoulay et al (2007) that mid-career academics are much more likely to patent than their younger or older colleagues

V. Conclusion

The objective of this paper was to identify the drivers of academic research and patenting in India based on a conceptual framework of a research production function that we derived in section 2. It is in this light that we now summarise our results.

In terms of faculty background, we fail to confirm the hypothesis that junior faculty (in designation and experience) have a greater research drive. On the contrary, our results show that the more experienced faculty devote greater research inputs in terms of research time and the number of research scholars. Further, full professors supervise more research scholars and are more inclined towards patenting activity. Indeed, faculty's urge for research seems to increase with experience and professional maturity. Only with regard to patenting, we find that years of experience has a negative and significant coefficient, indicating that younger faculty is more active in this regard – in particular, those who have been full professors at a relatively young age.

With regard to the other dimension of faculty background, namely their training, we fail to find any evidence to suggest that faculty trained abroad have greater research drive than their counterparts trained in India, although the former appear to be more active in patenting their research. Perhaps the general academic milieu in the premier institutions in India is not very different from that in the West. Indian academia does not appear to be primarily teaching centric as generally perceived, with considerable focus and emphasis on research, especially in the premier institutes. However, from the results of our model 4, we can conclude that the culture and practice in Indian academia with regard to patenting and commercialisation of academic research may be different from that in the Western world.

An important dimension of our conceptual framework was to incorporate parameters of faculty attitude as drivers of research. As far as faculty's attitude towards research supervision is concerned, we find, quite obviously, a positive attitude translates into a larger number of research scholars and greater patenting activity. The other attitudinal parameter that we considered was possible motivations behind research publications, defined in terms of faculty's aspirations for career advancement or academic recognition. Here, we find that career considerations appear to be actually counterproductive for publications, since faculty who publish with career advancement in mind end up with a lower publication rate. This is perfectly in line with theories of intrinsic motivation shaping human creativity. Aspirations for academic recognition, however, do not appear to play a significant role in explaining faculty publications.

Our study also explicitly addressed the question of how far sponsored research acts as a driver of academic research in India. We fail to find a satisfactory answer to this question. Faculty with a larger portfolio of sponsored research will supervise more scholars but end up devoting a lower share of time to research, perhaps due to the demands of project administration over and above pre-determined teaching obligations. Interestingly, a larger portfolio of sponsored research does not ensure that faculty will publish more or be more active in patenting.

Finally, a key objective of our econometric analysis was to explore some of the less understood relationships that could explain faculty inclination towards patenting in Indian universities to derive concrete policy lessons. If indeed, the policy objective is to encourage academic researchers in India to come forward and patent their research results, it is important that we take cognisance of the drivers of patenting activity among Indian academics. First, we find evidence in support of our hypothesis that faculty with a doctoral degree from abroad and those with work experience in industry are more inclined to patenting. Their different exposures have helped them bring in a culture of patenting to Indian universities. It may therefore be important to encourage short and medium-term exchange programmes for faculty to get exposure abroad and in industry. Second, we found that the dynamism of the younger generation of faculty combined with academic maturity at the professorial level proves to be the ideal combination for encouraging university patenting. This group should be encouraged to take the lead in creating a demonstration effect among the rest of their faculty colleagues. Third, given that faculty with a positive attitude towards research supervision and a larger team of research students engage more in patenting their research, research supervision must be given due credit when evaluating faculty performance. Finally, we did not find IIT faculty to be more inclined towards patenting than JNU faculty, the long-established organisational structures for facilitating IPR management in IIT notwithstanding. This clearly suggests that putting in place institutional structures will not serve the purpose without addressing the fundamental issues of research environment, culture and attitude in the first place. In a sense, therefore, a hurriedly implemented IPR law, as envisaged in the ‘Indian Bayh-Dole Bill 2008’, can hardly be expected to act as an instant magic formula to energise Indian academic research for commercial application.

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Appendix I: Matrix of Partial Correlation Coefficents of All Varaibles

	restime	phdno	pub	pat	foreig~d	prof	yrsex~ad	yrsex~nd	ressup~n	resspons	recogp	careerp	JNU
restime	1.0000												
phdno	0.0026	1.0000											
	0.9861												
pub	-0.0154	0.1059	1.0000										
	0.9162	0.4690											
pat	-0.2399	0.3532	0.1987	1.0000									
	0.0968	0.0128	0.1712										
foreignphd	-0.0849	-0.1918	0.1811	0.2593	1.0000								
	0.5617	0.1868	0.2131	0.0721									
prof	0.0043	0.4439	0.1035	0.1831	-0.1193	1.0000							
	0.9768	0.0014	0.4791	0.2080	0.4142								
yrsexpacad	0.1635	0.4213	0.0956	-0.0733	-0.2606	0.6604	1.0000						
	0.2617	0.0026	0.5136	0.6169	0.0705	0.0000							
yrsexpind	-0.2193	0.0376	0.0151	0.2458	-0.1474	0.0604	-0.1244	1.0000					
	0.1300	0.7975	0.9178	0.0887	0.3120	0.6801	0.3943						
ressupvsn	-0.0189	0.1790	-0.0237	0.1795	-0.1424	-0.1678	-0.1289	-0.2535	1.0000				
	0.8973	0.2185	0.8715	0.2173	0.3292	0.2490	0.3775	0.0788					
resspons	0.0737	0.2362	-0.1557	-0.0381	-0.1641	-0.1305	-0.1222	-0.0290	0.2459	1.0000			
	0.6146	0.1022	0.2855	0.7949	0.2598	0.3713	0.4028	0.8429	0.0886				
recogp	-0.0789	0.1019	-0.1987	-0.0707	-0.2593	-0.0170	-0.2109	0.0922	0.1422	0.5670	1.0000		
	0.5900	0.4861	0.1712	0.6293	0.0721	0.9080	0.1458	0.5288	0.3296	0.0000			
careerp	-0.0188	-0.1676	-0.5104	-0.0867	-0.2753	-0.2732	-0.1845	-0.1580	0.0250	0.1728	0.2798	1.0000	
	0.8981	0.2497	0.0002	0.5536	0.0556	0.0575	0.2045	0.2782	0.8645	0.2350	0.0515		
JNU	0.4111	0.0443	-0.4307	-0.1831	-0.3236	-0.1017	0.0566	0.0604	-0.0430	0.3959	0.2661	0.1782	1.0000
	0.0033	0.7626	0.0020	0.2080	0.0233	0.4870	0.6991	0.6801	0.7691	0.0049	0.0645	0.2204	

Appendix II: Matrix of Partial Correlation Coefficients of the Error Terms

	û1	û2	û3	û4
û1	1.0000			
û2	-0.0000 1.0000	1.0000		
û3	0.0213 0.8845	0.0122 0.9335	1.0000	
û4	0.0228 0.8765	-0.0474 0.7464	0.0895 0.5409	1.0000

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