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DO FINANCIAL SECTOR POLICIES PROMOTE INNOVATIVE ACTIVITY IN DEVELOPING COUNTRIES? EVIDENCE FROM INDIA

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Abstract

This paper attempts to shed some light on the role of financial sector policies in generating new knowledge, drawing on the experience of one of the fastest growing and largest developing countries. Using relatively long time series data, the results in this paper indicate that interest rate restraints help generate knowledge in India's economy. Other financial repressionist policies, in the form of high reserve and liquidity requirements as well as significant directed credit controls, appear to have a dampening effect on ideas production. The results lend some support to the argument that some form of financial sector reforms may help stimulate economic growth via increasing innovative activity.

Key words: financial sector policies; innovative activity; endogenous growth; India.

JEL classification: E44; E58; O16; O53

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1. Introduction

The importance of finance in the process of technological innovation can be traced to the early work of Schumpeter (1911), who argues that adequate credit is required to facilitate the widespread adoption of new technologies. Hence, the availability of financial instruments, services and institutions is closely related to the course of technological change.[1] Recent developments in the theoretical growth literature have continued to emphasize the importance of finance in explaining innovative growth. In the models developed by de la Fuente and Marín (1996), Blackburn and Hung (1998) and Aghion *et al.* (2005), the relationship between finance and growth is analyzed in the context of innovation-based growth models. These models predict that financial market imperfections prevent innovators from adequately accessing external finance. The removal of credit constraints, which can be achieved through financial market development or financial sector reforms, makes credit more readily available to entrepreneurs and enables them to undertake inventive activity.

However, despite the important role of finance in facilitating the diffusion of new technologies and in the undertaking of innovative activity, as illustrated by the theoretical contributions of the above studies, the issue of what kind of financial policies contribute to innovation has not yet received much attention. The objective of this paper is to fill this gap in the literature by providing an empirical assessment of the influence of various financial sector policies on innovative activity with a case study of a large developing country. While the finance and development literature focuses on financial liberalization (see, e.g., Demetriades and Luintel, 1997; Demetriades *et al.*, 1998; Ang and McKibbin, 2007), a more satisfactory approach to assessing the effect of financial sector reforms would explicitly account for each component of the reform program. This would provide a more complete analysis of the costs and benefits associated with financial repression and liberalization. Thus, the overall effectiveness of the entire reform program would depend on each policy type. Analysis performed at the disaggregated level also helps identify an appropriate mix of financial liberalization and repressionist policies that is effective at stimulating innovative activity.

Using annual time series data for over half a century, the present study attempts to address the question of how government intervention in the financial system (including interest rate controls, directed credit programs and reserve and liquidity requirements) affects the evolution of knowledge production in India. We focus our analysis on India for several reasons. First, empirical research on endogenous growth models has focused exclusively on the U.S. and other OECD countries due to the

[1] For more discussions on Schumpeter's work on innovation and technical change, see Nelson and Winter (1982a, b), Dosi (1990) and Nelson (1996, 2005), among others.

lack of adequate and reliable R&D data for developing countries (see, e.g., Zachariadis, 2003; Ha and Howitt, 2007). So far there has been no case study evidence documented for developing countries.

Second, India provides an ideal ground for further analysis given that it has recently emerged as one of the fastest growing developing nations, and has also undergone significant financial sector reforms. Finally, the availability of long time series data on R&D going as far back as 1950 provides an added incentive for this research given that R&D data for developing countries are particularly scant. In this connection, it is worth noting that a majority of OECD countries have data starting only from 1965. The availability of a set of sufficiently long time series data allows for a meaningful time series investigation. This is important given that economic growth is a long-run phenomenon, which necessitates analyzing the evolution of the relevant variables over time in order to relate the findings to policy designs.

The remainder of this paper is organized as follows. The next section describes the experience of technological development and financial liberalization in India. Section 3 sets out the innovation-driven endogenous growth framework. It is augmented to take into consideration the influence of financial sector policies in producing knowledge. Data and construction of variables are discussed in Section 4. Section 5 describes the econometric techniques employed in this study. The estimated results are presented and analysed in Section 6. Some robustness checks are provided in Section 7, and the last section concludes.

2. Inventive Activity and Financial Reforms in India

After achieving independence in 1947, India's technology policy was focused on acquiring better technology from abroad, paving the way for rapid industrial growth over the following few decades. Motivated by the profitability of independent technological work, there was a shift in preference from foreign to indigenous technology in the 1960s and 1970s. As a result, inflows of technology were arranged through licensing that was subject to strict controls. MNCs were allowed to participate only in sectors in which local technology was unavailable (Lall, 1982). Emphasis has been placed on the effective absorption and adaptation of imported technology through the encouragement of more investment in engineering and in-house R&D activities. This is reflected by the granting of generous fiscal incentives and the establishment of R&D centers, which increased substantially from 106 in 1973 to 930 in 1986 (Sahu, 1998). Science and technology personnel increased markedly from about 0.2 million in 1950 to more than 3.8 million in 1990. R&D expenditure as a percentage of GDP increased considerably from just 0.05% in 1950 to 0.8% in 1990. While these figures may seem small compared to some of the OECD countries, they are nonetheless very impressive for a developing nation. Some liberalization efforts in industrial licensing and capital goods imports were initiated in the late 1980s to facilitate inflows of foreign technology. Between 1950 and 1990, over 140,000 foreign collaboration proposals were approved by the government. India's growing technological capability has subsequently enabled it to become a key player in the generation of industrial technology exports among the NICs.

Alongside the technological development, there has also been significant growth in the financial sector. The provision of finance for investments in local R&D has significantly enhanced the levels of absorptive and adaptive capacities in the technological sector, allowing the effective assimilation of foreign technology. The number of scheduled commercial banks rose sharply, thus providing significant financial resources to fuel industrial growth. Rapid expansion in bank branches has also facilitated the mobilization of savings, contributing to a tremendous increase in intermediary activity. In terms of financial policy, the Reserve Bank of India gradually imposed more controls over the financial system by introducing interest rate controls in the 1960s. The statutory liquidity ratio was raised from 25% in 1966 to 38% in 1989, and the cash reserve rate increased considerably from 3% to 15% during the same period. These requirements enabled the Reserve Bank to purchase government securities at low cost. The extent of directed credit programs has also increased markedly since the nationalization of the 14 largest private banks in 1969. A number of priority lending rates were set at levels well below those that would prevail in the free market. This process culminated in the late 1980s when directed lending was more than 40% of the total.

The major phase of financial liberalization was undertaken in 1991 as part of the broader economic reform in response to the balance of payments crisis of 1990-91. The objective was to redirect the entire orientation of India's financial development strategy from its position as a financially repressed system to that of a more open system so as to provide a greater role for markets in price determination and resource allocation. Consequently, interest rates were gradually liberalized and reserve and liquidity ratios were significantly reduced. The industrial licensing requirements that restricted entry and expansion of both domestic and foreign firms were relaxed in the same year. The equity market was formally liberalized in 1992, allowing foreign investors to access the domestic equity market directly. The formerly restrictive capital account regime has also become more open. The regulatory framework was also significantly strengthened. In addition, entry restrictions were deregulated in 1993, resulting in the establishment of more private and foreign banks. Regulations on portfolio and direct investment have since been eased. The exchange rate was unified in 1993 and most restrictions on current account transactions were eliminated in 1994.[2]

Following the financial liberalization measures, the volume of funds raised domestically has grown substantially. Increased access to credit has facilitated the undertaking of R&D activity and encouraged more investment in education, providing a large pool of scientific and technical personnel to the technological sector. Since liberalization, R&D personnel and expenditure have grown rapidly in India, increasing more than twofold in terms of personnel employed and over fivefold for expenditure, over the period 1991-2005. The transfer of technology has been greatly facilitated in recent years following India's accession to the WTO, where minimum standards of patent protection are mandated by the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) that came into force in 1995.

3. Analytical Framework

3.1 The R&D-based endogenous growth models

In this section, we present the analytical framework underlying our modeling strategy. Assuming a standard neoclassical production function with constant returns, we can write the aggregate output at time t, Y_t, as:

$$Y_t = A_t f(K_t, L_t) \tag{1}$$

where A_t is the stock of knowledge or ideas, K_t is the capital stock and L_t is the number of workers. The R&D-based endogenous growth literature (see, e.g., Romer, 1990) suggests that the rate of ideas production (g_A) depends on the growth rate of the R&D stock of knowledge:

$$g_A = \frac{\dot{A}_t}{A_t} = \rho \frac{\dot{SK}_t}{SK_t} \tag{2}$$

where SK_t is the stock of R&D knowledge. Griffith *et al.* (2003, 2004), among others, suggest that for low rates of depreciation of the R&D stock of knowledge, we can write Eq. (2) as:

$$\dot{A}_t = \upsilon A_t \left(\frac{X}{Q} \right)_t \tag{3}$$

[2] As a result of the significant devaluation of the rupee following the balance of payments crisis, a liberalized exchange rate system was introduced in 1992. This led to the introduction of a dual exchange rate system, which consisted of an official rate for selected public and private transactions and a market-determined rate for other transactions. The exchange rate regime was later unified in March 1993.

where X_t is R&D input and Q_t is product variety or the number of product lines. The ratio $(X/Q)_t$ is commonly referred to as research intensity. R&D input is divided by product variety since the effectiveness of R&D is diluted due to the proliferation of products when an economy expands (Ha and Howitt, 2007).

3.2 Financial Sector Policies and Knowledge Production

In their seminal work, McKinnon (1973) and Shaw (1973) noted that financial repression was largely accountable for the poor economic performance of developing countries in the 1960s, where low saving and credit rationing were widely observed. Investment suffered both in terms of quantity and quality as funds were allocated at the discretion of policy makers. They challenged the financial repression ideology and provided a new paradigm in the design of financial sector policies. Their theories proposed that distortions in the financial system, such as loans issued at artificially low interest rates, directed credit programs and high reserve requirements would reduce saving, retard capital accumulation and prevent efficient resource allocation. The elimination of these distortions would significantly deepen financial systems and therefore foster economic growth.

Recent developments in the theories of endogenous growth that consider financial factors are in agreement with the McKinnon-Shaw financial liberalization thesis. Financial sector reforms facilitate inventive activity for a number of reasons. In the work of de la Fuente and Marín (1996), the relationship between finance and growth is analyzed in a model of product innovation in which efficiency of financial systems arises endogenously. Risk aversion and private information in R&D activity lead to a moral hazard problem, and this makes innovative activity unattractive for risk-averse entrepreneurs. This problem, however, can be mitigated through improved monitoring by financial systems, which allow intermediaries to offer better insurance terms. Hence, the formulation of appropriate financial policy aimed at improving the monitoring system would yield a higher level of innovative activity.

Using a product variety model, Blackburn and Hung (1998) postulate that firms have incentives to hide successful R&D activity to avoid repaying their loans. Such a problem of moral hazard gives rise to the enforcement of incentive-compatible loan contracts through costly monitoring systems. In their model, financial liberalization allows financial intermediaries to diversify among a large number of projects, thus significantly reduces delegation costs. The lower costs of monitoring spur innovative activity and technological development. More recently, in the innovation-based growth model developed by Aghion *et al.* (2005), it is assumed that firms can conceal the results of successful innovations and thereby avoid repaying their creditors. A low degree of creditor protection makes fraud an inexpensive option, and this limits firms' access to external finance, which discourages the production of ideas. Financial liberalization tends to increase the hiding costs by providing better laws and institutions. This makes credit more readily available to entrepreneurs and allows them to undertake innovative activity.

However, some counter arguments suggest that financial reforms may not necessarily lead to higher inventive activity. For instance, the neostructuralist contributions of van Wijnbergen (1982) and Taylor (1983) suggest that the impact of lower taxation on financial systems may reduce the flow of credit to the private sector. Since the formal financial systems are subject to reserve requirements, which involve a leakage in the intermediation process, the neostructuralists argue that curb (unorganized) markets perform more efficiently in intermediating savers and investors. A rise in bank deposit rates following financial liberalization induces households to substitute curb market loans for bank deposits, resulting in a fall in the supply of loanable funds. Thus, in the presence of efficient curb markets, removing interest rate restraints tends to discourage lending to the private sector, thereby resulting in a lower level of innovative activity.

Stiglitz (1994) also argues that interest rate restraints may lead to higher financial saving when good governance is present in financial systems. When depositors perceive restrictions as policies aimed at enhancing the stability of the financial system, they may well be more willing to keep their savings in the form of bank deposits, thereby providing more resources for innovative investment in the absence of perfect capital mobility. Hellmann *et al.* (1996) show that in a competitive equilibrium, banks have no incentive to attract new customers and deepen market penetration since their profit margin on deposits is zero due to intense competition. However, if the government imposed a deposit rate ceiling, banks can make positive returns and therefore have an incentive to attract more depositors, as long as the market is not fully penetrated. This reasoning suggests that deposit rate controls can induce banks to spend more resources on attracting deposits, thus enabling more innovative activity to be carried out.

Using a dynamic stochastic oligopoly model, Stadler (1992) shows that the optimal innovative activity is inversely related to interest rates. This result is intuitive given that a reduction in interest rate restraints generally results in higher costs of capital, thereby retarding innovative initiatives in the technological sector. More recently, using an occupational choice model with moral hazard, Emran and Stiglitz (2009) show that deposit rate controls can foster the discovery of entrepreneurial talent by banks and provide incentives for entrepreneurial learning in the industrial sector of a developing country. Their results suggest that interest rate restraints, in the form of deposit rate controls, can result in the successful development of industrial entrepreneurship.

In the case of reserve requirements, Courakis (1984) shows that under the condition where the demand for loanable funds is not perfectly inelastic, higher reserve requirements may increase the profit-maximization deposit rate and hence the volume of loanable funds. Using a general equilibrium model, Bencivenga and Smith (1992) show that the optimal degree of financial repression depends on the size of government deficits. In the presence of large government deficits, it will be desirable to impose higher reserve requirements. Their model also implies that financial liberalization will not increase innovative activity, since savings in the formal sector translate into lower investment compared to savings in the informal sector, due to the absence of reserve requirements.

The implementation of directed credit programs generally involves the administered allocation of loans to priority sectors, in India's case mainly agriculture and small-scale industry (rather than the knowledge sector). Without such interventions, banks generally will not fund those activities with low returns. Although the McKinnon-Shaw thesis advocates the removal of directed credit programs since they displace investment projects with potentially higher returns, Stiglitz and Weiss (1981) show that financial liberalization is unlikely to result in allocative efficiency. This is because under asymmetric information, banks will practice credit rationing and be reluctant to raise interest rates in response to higher demand for loans, due to adverse selection problems. According to Schwarz (1992), directed credit programs may lead to increased investments in the targeted sectors. If more funds are allocated to the high-tech sector, an economy-wide increase in innovative activity will be expected. However, the allocation of funds involving the government in developing countries may be subject to the risk of biased assessments and corruption, and often results in sub-optimal outcomes (Emran and Stiglitz, 2009). Given the above, it appears that the impact of each of these financial sector policies on innovative activity is theoretically ambiguous. It is therefore ultimately an empirical issue.

Based on the above discussion, we augment the standard knowledge production function to consider the role of finance so that the empirical relationship between knowledge production and financial sector policies can be characterized as follows (see also Ang and Madsen, 2008):

$$\ln \dot{A}_t = \alpha + \beta \ln A_t + \chi \ln(X/Q)_t + \delta_1 IRR_t + \delta_2 DCP_t + \delta_3 RLR_t + \varepsilon_t \tag{4}$$

where $\dot{A}_t$ is the amount of new knowledge or ideas produced, A_t measures the stock of knowledge or ideas, $(X/Q)_t$ is research intensity and ε_t is Gaussian errors. The empirical specification of the knowledge production function in Eq. (4) considers how each type of financial repressionist policy, namely interest rate restraints (IRR_t), directed credit programs (DCP_t) and reserve and liquidity requirements (RLR_t), impacts on the production of knowledge in India's economy. While both β and χ are expected to carry a positive value, the expected signs for δs cannot be determined *a priori* since the impact of each policy type on ideas production is theoretically ambiguous.

4. Data and Construction of Variables

4.1 Patent data

We use patent data as the proxy for innovation activity. The domestic stock of knowledge (A_t) is constructed based on the number of domestic patents applied for ($\dot{A}_t$). It is computed using the perpetual inventory method with a depreciation rate of 10%. Data over the period 1919-1950 are used to obtain a measure of the initial knowledge stock in 1950. The initial knowledge stock is set equal to the number of patents in 1919 divided by the depreciation rate plus the average growth in patents over the period 1919-1950, which is the steady-state capital stock in standard neoclassical growth models. The patent data are obtained from the World Intellectual Property Organization (WIPO).[3] The patent statistics reported in WIPO are based on information provided by the patent offices. The data are publicly available over a very large time span. Continuous patent data for India are available annually although there are some missing years for which we interpolate the data. While the WIPO data may be subject to heterogeneity in the patent systems, rendering patent counts not comparable across countries, this does not pose any issue for case studies such as the present one.

The use of patent data as a measure of innovation, however, is not free from criticism. For instance, as highlighted by Eaton *et al.* (2004), the data provide no information regarding whether the patents filed in different offices reflect the same invention. Moreover, the number of patent applications may change following a radical reform in the patent laws, but this is not necessarily translated into a change in innovative activity. Other problems which have been highlighted in the literature include: only a fraction of invention is patented (Cohen *et al.*, 2000), patents are applied for due to strategic reasons (Granstrand, 1999), and an increase in patent application is associated with the advent of computerized search (Hall *et al.*, 2002). Thus, it appears that patent counts are, at best, a noisy indicator for innovative activity. Nevertheless, in the absence of a perfect indicator, patent statistics remain one of the most commonly used measures of inventive activity, As Griliches (1990) notes, despite all the

[3] The number of patent counts is based on the patent filing date. It refers to an application filed at the Indian Patent Office by a domestic resident. The patent statistics can be downloaded from http://www.wipo.int/ipstats/en/statistics/patents/.

difficulties associated with the use of patent data, they remain an important source for the analysis of the process of innovation.

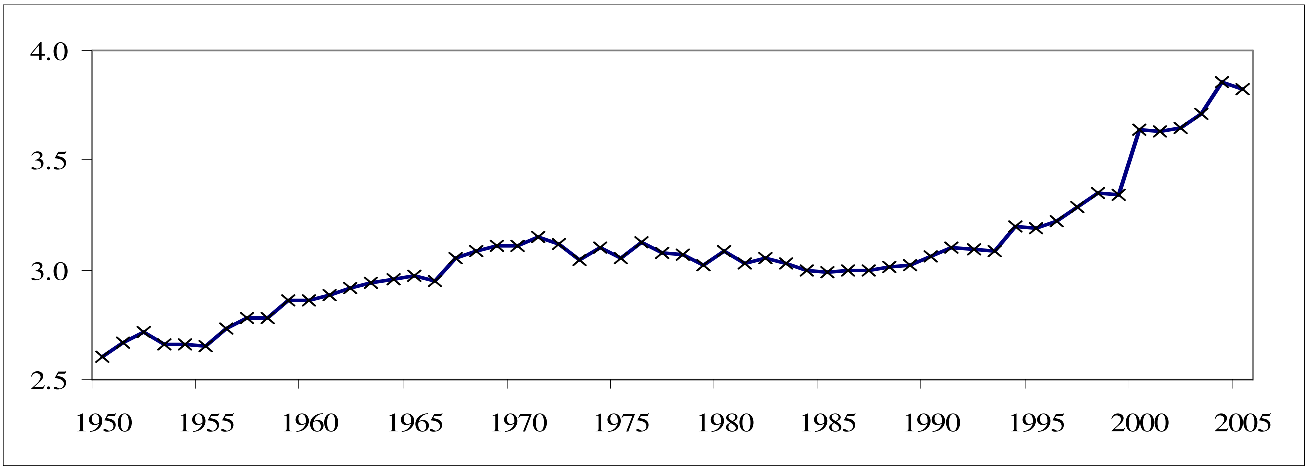
4.2 Measures of R&D activity

R&D labor (N_t) is used as the measure for R&D input (X_t). It refers to the number of scientists and technicians engaged in R&D activity. The data are collected from various publications of "R&D Statistics" by the Department of Science and Technology and Planning Commission, Government of India. Some missing data between years are interpolated. Product variety (Q_t) is measured by number of workers (L_t). The fully-endogenous model of Aghion and Howitt (1998) predicts that product variety is proportional to the labor force in the long run. A larger labor force allows more people to enter an industry with a new product. This results in more horizontal innovations, diluting the beneficial effect of R&D input. Some adjustments for the measure of product variety is necessary, given that there is a tendency for decreasing returns to R&D due to the increasing complexity of innovations (Ha and Howitt, 2007). Thus, we also consider the following three additional measures of research intensity: $N_t / h_t L_t$, $N_t / a_t L_t$ and $N_t / a_t h_t L_t$, where a_t is total factor productivity and h_t is an index of human capital. These additional measures therefore account for productivity or human capital adjustments or both.

Total factor productivity (a_t) is computed as $Y_t / K_t^{\pi} L_t^{1-\pi}$. We use gross domestic product at constant prices as the measure of real output (Y_t). Real capital stock (K_t) is computed using the perpetual inventory method. A depreciation rate of 10% and the growth rate of gross capital formation at constant prices during the sample period 1950-2005 are used to obtain the initial stock for the year 1950. Following the established practice in the literature, capital's share of income (π) is assumed to be 0.3. These data are obtained directly from the National Accounts Statistics published by the Government of India. Data for number of workers (L_t) are compiled from the Penn World Table. Human capital (h_t) is computed using the Mincerian approach, i.e., $h_t = e^{\theta s_t}$. The data for average years of schooling for the population over 25 years old (s_t) are taken from the Barro-Lee data set. θ is set to 0.048, following the estimate of Psacharopoulos (1994) for India.

Figure 1 shows the number of patents filed by domestic residents in India over the period 1950-2005. While patenting activity increased rapidly in the 1950s and 1960s, there was little variation in the amount of inventive activity recorded over the next two decades. However, it is evident that the number of patents filed has increased significantly since the early 1990s, coinciding with the launch of a series of financial liberalization programs.

Figure 1: Number of patents filed by domestic residents (on log scale)

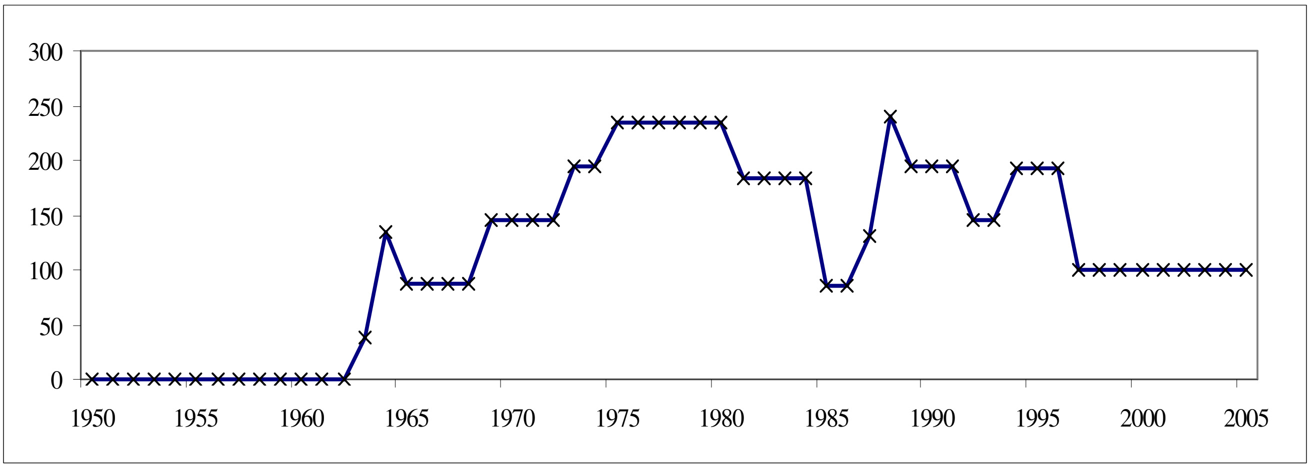


4.3 Measures of financial sector policies

As illustrated in Eq. (4), we consider three types of financial sector policies: 1) interest rate restraints; 2) directed credit programs; and 3) reserve and liquidity requirements. These financial policy measures are directly obtained or compiled from the Annual Report and the Report on Currency and Finance of the Reserve Bank of India. To provide a measure of the interest rate restraints (IRR_t), we follow the approach of Demetriades and Luintel (1997) by collecting six interest rate repressionist policies imposed on the Indian financial system. These include a fixed deposit rate, a deposit rate ceiling, a deposit rate floor, a fixed lending rate, a lending rate ceiling and a lending rate floor. An overall summary measure of interest rate restraints is obtained using the method of principal component analysis by considering the first three principal components for which their eigenvalues are greater than one (see Johnson and Wichern, 2002). They can jointly account for 85% of the total variation.

The resulting index is presented in Figure 2. As is evident, the financial system in India appears quite liberal in the 1950s since no interest rate controls were imposed during that period. The first restriction was introduced in 1963 in the form of a maximum lending rate. After this, the index follows an upward trend reaching a peak during the period 1975-1980. In the early 1980s, it moves downwards, following the introduction of some deregulation measures, before bouncing back again in 1987. 1988 saw another peak, coinciding with the implementation of various interest rate controls. A major reform in interest rate policy occurred in the early 1990s when the Reserve Bank allowed banks to determine their own interest rates. In recent years, the extent of interest rate restraints was further moderated, towards the level of late 1960s, and has remained fairly stable since then.

Figure 2: Index of interest rate restraints (*IRR_t*)



Unlike Malaysia for which the priority sector target lending rates are directly available (see Ang and McKibbin, 2007), India has no direct *de jure* measure of directed credit programs (DCP_t). Therefore, we follow the approach of Demetriades and Luintel (1997) by using a *de facto* measure, which involves measuring the share of actual directed credit in total credit. Specifically, it is measured by 0, 1, 2 and 3 when the programs cover zero, up to 20%, 21% to 40%, and more than 40%, respectively, of total bank loans.[4] Figure 3 shows that the Reserve Bank progressively imposed more directed credit controls over the financial system from the early 1960s, providing subsidized credit to certain priority sectors, mainly agriculture and small-scale manufacturing. The extent of these programs reached its peak in the late 1980s. Although efforts were made to reduce directed credit controls following the liberalization, it is evident that significant restrictions still remain in place.

The measure for reserve and liquidity requirements (RLR_t) is given by the sum of the cash liquidity ratio and the statutory reserve ratio. The former requires banks to hold part of their deposits in the form of cash balances at the Reserve Bank, whereas the latter imposes a requirement for banks to keep a share of their assets in government securities at below-market interest rates. Figure 4 shows how reserve and liquidity requirements have evolved over time. Historically, the cash reserve ratio was kept low, at 3%-3.5% during the 1950s and 1960s. The ratio was gradually raised to 15% in 1990 to increase cash balances. Similarly, the statutory liquidity requirement was raised from 20% in 1950 to

[4] We have also considered the share of actual directed credit in total credit in the estimation in order to allow for more variation in the series. However, the results do not vary in any significant way.

38.5% in 1990, enabling the government to obtain cheap finance. Both requirements have fallen significantly following the liberalization initiated in 1991. Currently, the cash reserve ratio and statutory liquidity requirement stand at 5% and 25% of bank deposits, respectively.

Figure 3: Directed credit programs (DCP_t)

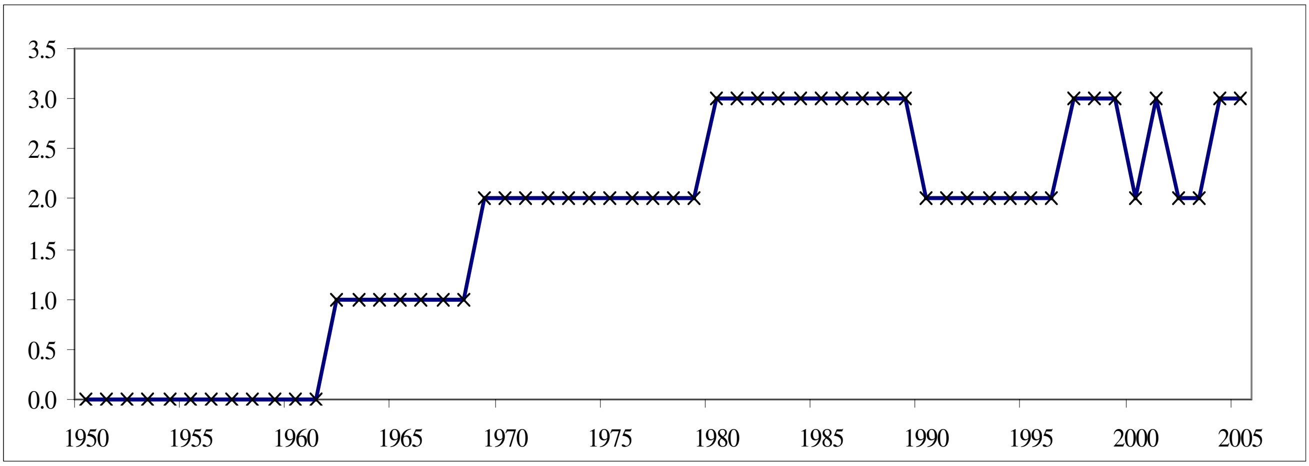
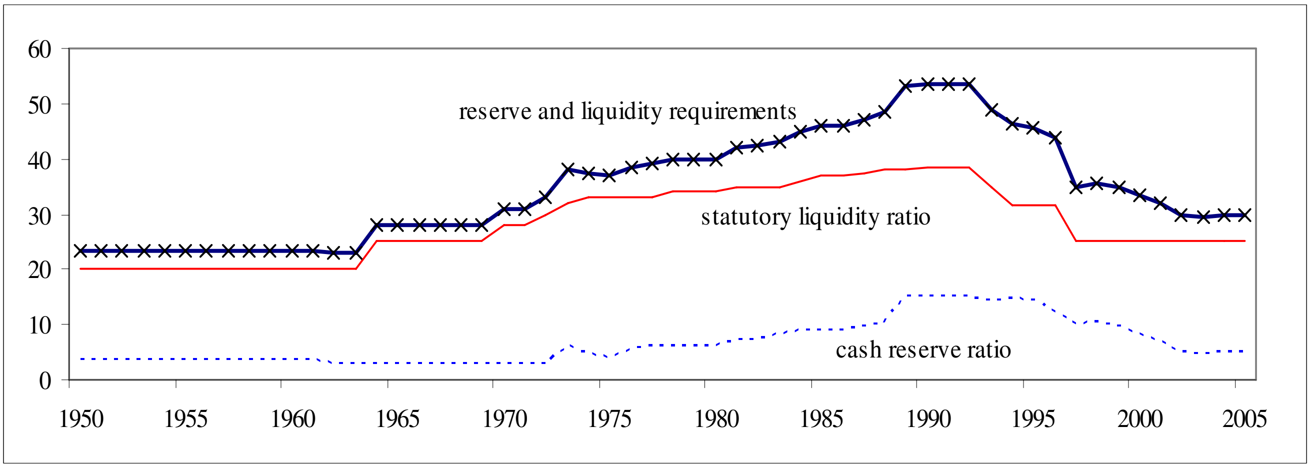


Figure 4: Reserve and liquidity requirements (RLR_t)



We employ three unit root tests to assess the order of integration of the underlying variables - the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowiski-Phillips-Schmidt-Shin (KPSS) tests. The ADF and PP test the null of a unit root against the alternative of stationarity whereas the KPSS tests the null of stationarity against the alternative of a unit root. The results, which are not reported here to conserve space but are available upon request, show that all variables appear to be either stationary, i.e. $I(0)$, or integrated at order one, i.e., $I(1)$. Given that none of the variables appears to be integrated at an order higher than one, this allows legitimate use of the cointegration procedures proposed in the next section.

5. Estimation Techniques

The dynamic adjustment of the ideas generation process can be characterized by a conditional ECM, which can be used to test for the existence of a long-run relationship using the ARDL bounds test developed by Pesaran *et al.* (2001) and the ECM test of Banerjee *et al.* (1998). The former involves a standard *F*-test whereas the latter is a simple *t*-test. Accordingly, the underlying error-correction model can be formulated as:

$$\Delta \ln \dot{A}_t = \alpha_0 + \beta_0 \ln \dot{A}_{t-1} + \sum_{j=1}^{k} \beta_j DET_{j,t-1} + \sum_{i=1}^{p} \gamma_{0i} \Delta \ln \dot{A}_{t-i} + \sum_{i=0}^{p} \sum_{j=1}^{k} \gamma_{ji} \Delta DET_{j,t-i} + \varepsilon_t \quad (5)$$

where $\dot{A}_t$ is the number of patents applied for by domestic residents and DET_t is a vector of the determinants of innovative activity, which includes $\ln A_t$, $\ln(X/Q)_t$, IRR_t, DCP_t and RLR_t.

The above can be estimated by OLS. Pesaran and Shin (1998) show that the OLS estimators of the short-run parameters are consistent and the ARDL based estimators of the long-run coefficients are super-consistent in small sample sizes. Hence, valid inferences on the long-run parameters can be made using standard normal asymptotic theory. The main advantage of this approach is that it can be applied to the model regardless of whether the underlying variables are $I(0)$ or $I(1)$.

Specifically, two separate statistics are employed to test for the existence of a long-run relationship in Eq. (5): 1) an *F*-test for the joint significance of coefficients of lagged levels terms of the conditional ECM ($H_0 : \beta_0 = \beta_1 = ... = \beta_k = 0$), and 2) a *t*-test for the significance of the coefficient associated with $\ln \dot{A}_{t-1}$ ($H_0 : \beta_0 = 0$). The test for cointegration is provided by two asymptotic critical value bounds when the independent variables are either $I(0)$ or $I(1)$. The lower bound assumes all the independent variables are $I(0)$, and the upper bound assumes they are $I(1)$. If the test statistics exceed their respective upper critical values, the null is rejected and we can conclude that a long-run relationship exists. The above ARDL model also provides a convenient step to derive the long-run estimates and short-run dynamics for the ideas production function, as discussed by Pesaran and Shin (1998).

6. Empirical Results

The cointegration tests on the knowledge production equation are performed by regressing the conditional error-correction model in Eq. (5). To ascertain the existence of a level relationship between the variables, this requires satisfying both the *F*- and the *t*-tests. Table 1 gives the *F*-statistics for the ARDL bounds tests, *t*-statistics for the ECM test, model selection criteria AIC and SBC, and several diagnostic test statistics for the model up to two lags. The table contains four columns, where each column corresponds to the estimation results using different measures of research intensity $(X/Q)_t$.

Table 1: Cointegration tests

	Model A $(X/Q)_t=(N/L)_t$		Model B $(X/Q)_t=(N/hL)_t$		Model C $(X/Q)_t=(N/aL)_t$		Model D $(X/Q)_t=(N/ahL)_t$	
	$p=1$	$p=2$	$p=1$	$p=2$	$p=1$	$p=2$	$p=1$	$p=2$
ARDL bounds test (Pesaran *et al.* 2001)	5.906***	4.601**	6.146***	5.147***	5.809***	5.264***	5.591***	5.297***
ECM test (Banerjee *et al.*, 1998)	-5.450***	-4.766**	-5.540***	-5.067***	-5.203***	-5.025***	-5.099***	-5.061***
AIC	-4.167	-4.287	-4.184	-4.336	-4.143	-4.301	-4.123	-4.299
SBC	-3.504	-3.394	-3.521	-3.445	-3.480	-3.408	-3.460	-3.407
χ^2_{NORMAL}	0.926 (0.624)	1.950 (0.377)	0.879 (0.644)	2.065 (0.356)	0.477 (0.787)	1.448 (0.484)	0.561 (0.755)	0.953 (0.621)
$\chi^2_{SERIAL}(1)$	4.497** (0.041)	0.926 (0.336)	7.146*** (0.008)	0.590 (0.442)	8.846*** (0.003)	0.082 (0.774)	8.857*** (0.003)	0.148 (0.699)
$\chi^2_{SERIAL}(2)$	6.148** (0.046)	1.308 (0.519)	7.153** (0.028)	0.927 (0.629)	9.033** (0.011)	0.139 (0.933)	9.016** (0.011)	0.202 (0.904)
χ^2_{ARCH}	0.003 (0.955)	1.109 (0.292)	0.016 (0.898)	0.907 (0.341)	1.981 (0.159)	1.028 (0.311)	3.678* (0.055)	0.707 (0.401)
χ^2_{WHITE}	24.125 (0.116)	15.699 (0.868)	23.506 (0.133)	15.826 (0.863)	23.137 (0.145)	16.878 (0.815)	23.191 (0.143)	17.358 (0.791)

Notes: p is the lag length. The test statistics of the bounds tests are compared against the critical values reported in Pesaran *et al.* (2001). The estimation allows for an unrestricted intercept and no trend. The 10%, 5% and 1% critical value bounds for the F-test are (2.26, 3.35), (2.62, 3.79) and (3.41, 4.68), and for the t-test are (-2.57, -3.86), (-2.86, -4.19) and (-3.43, -4.79), respectively. χ^2_{NORMAL} refers to the Jarque-Bera statistic of the test for normal residuals, $\chi^2_{SERIAL}(1)$ and $\chi^2_{SERIAL}(2)$ are Breusch-Godfrey LM test statistics for no first and second-order serial relationship, respectively, χ^2_{ARCH} is the Engle's test statistic for no autoregressive conditional heteroskedasticity, and χ^2_{WHITE} denotes the White's test statistic to test for homoskedastic errors. Numbers in parentheses indicate p-values. *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

The results indicate that the null hypothesis of no level knowledge production equation is firmly rejected at the 1% significance level in most cases, irrespective of the lag length and measures of research intensity chosen. This provides strong support for the existence of a long-run relationship between knowledge production and its determinants. No evidence of cointegration is found when other variables are used as the dependent variables, suggesting that these variables can be interpreted as long-run forcing variables explaining $\ln \dot{A}_t$. We do not find any evidence of non-normality, serial correlation, autoregressive conditional heteroskedasticity, and functional misspecification at the conventional significance levels, when the lag length is chosen to be two across all models. However, the choice of a more parsimonious dynamic structure of one lag leads to some problems of serial correlations. We will therefore choose a richer dynamic structure of two lags for the remaining analyses, as also suggested by the AIC.

Table 2 presents the results for the knowledge production model estimated using the ARDL procedure. It is evident that the stock of knowledge enters the long-run knowledge production equation significantly at the 1% level with the expected sign. Specifically, the coefficients of the stock of knowledge variables are found to be in the range of 0.823-0.861. The measures of research intensity are found to have an economically and statistically significant effect on knowledge production. Its effect is found to be greatest when the labor force is adjusted for productive efficiency.

Interestingly, financial sector policies appear to have mixed effects on knowledge creation. In particular, an increase in interest rate restraints is found to have a significant positive impact on innovative activity. The estimated elasticity of patenting activity with respect to a steady-state increase in the index of interest rate restraints ranges from 0.019 to 0.041. With regard to directed credit programs, our results suggest that an increase in the extent of directed credit controls discourages innovations, although the effect of directed credit programs is found to be statistically significant only in Models C and D. The estimates are found to be -0.018 and -0.019, respectively. Finally, the results also suggest that higher reserve and liquidity requirements tend to discourage knowledge production, with negative long-run elasticities in the range of 0.461-0.605. This effect is found to be significant at the 1% level across all models.

Turning to the short-run dynamics, the regression results for the conditional ECM of $\Delta \ln \dot{A}_t$ reported in panel II of Table 2 show several important features. In particular, most coefficients are statistically significant at the conventional levels. In first-differenced form, all coefficients have signs consistent with the long-run estimates. Interestingly, except for the coefficients of $\Delta \ln A_t$ and the coefficient of ΔRLR_t in Model D, all coefficients have magnitudes (in absolute terms) smaller than their long-run counterparts, suggesting that knowledge creation in the long run depends more critically on research intensity and financial sector policies. Furthermore, the coefficients of ECT_{t-1} (error-correction term), which measure the speed of adjustment back to the long-run equilibrium value, are statistically significant at the 1% level and are correctly signed, i.e., negative. This implies that an error-correction mechanism exists so that the deviation from long-run equilibrium has a significant impact on the growth rate of ideas production. The results further support the finding of a cointegrated relationship between the variables reported earlier in Table 1.

Table 2: ARDL estimate of the augmented knowledge production function (1950-2005)

	Model A $(X/Q)_t = (N/L)_t$		Model B $(X/Q)_t = (N/hL)_t$		Model C $(X/Q)_t = (N/aL)_t$		Model D $(X/Q)_t = (N/ahL)_t$	
	Coeff.	*p*-value	Coeff.	*p*-value	Coeff.	*p*-value	Coeff.	*p*-value
I. The long-run relationship ($Dep. = \ln \dot{A}_t$)								
Intercept	0.179	0.674	0.199	0.634	0.169	0.696	-0.018	0.965
$\ln A_t$	0.823***	0.000	0.828***	0.000	0.842***	0.000	0.861***	0.000
$\ln(X/Q)_t$	0.122***	0.000	0.131***	0.000	0.162***	0.000	0.157***	0.000
IRR_t	0.041***	0.000	0.037***	0.000	0.024***	0.009	0.019**	0.041
DCP_t	-0.013	0.180	-0.014	0.143	-0.018*	0.075	-0.019*	0.075
RLR_t	-0.605***	0.000	-0.603***	0.000	-0.534***	0.000	-0.461***	0.002
II. The short-run dynamics ($Dep. = \Delta \ln \dot{A}_t$)								
Intercept	0.004	0.466	0.009*	0.089	0.010*	0.052	0.002	0.650
ECT_{t-1}	-0.886***	0.000	-0.890***	0.000	-0.880***	0.000	-0.877***	0.000
$\Delta \ln A_t$	5.700***	0.000	5.698***	0.000	5.787***	0.000	5.828***	0.000
ΔIRR_t	0.026**	0.017	0.024**	0.028	0.014	0.190	0.012	0.268
ΔDCP_t	-0.007	0.450	-0.007	0.394	-0.011	0.211	-0.012	0.183
ΔRLR_t	-0.513***	0.009	-0.513***	0.009	-0.501**	0.012	-0.515**	0.010
III. Diagnostic checks	Test-stat.	*p*-value	Test-stat.	*p*-value	Test-stat.	*p*-value	Test-stat.	*p*-value
χ^2_{NORMAL}	1.040	0.594	0.612	0.592	0.377	0.828	0.502	0.778
$\chi^2_{SERIAL}(1)$	0.111	0.739	0.265	0.207	0.525	0.468	0.466	0.495
$\chi^2_{SERIAL}(2)$	0.572	0.751	0.541	0.763	0.654	0.721	0.532	0.767
χ^2_{ARCH}	0.206	0.649	0.313	0.576	1.743	0.187	2.476	0.116
χ^2_{WHITE}	8.699	0.122	8.607	0.126	9.143	0.104	8.688	0.122

Notes: A maximum lag length of two was used, following the results of the cointegration tests. The optimal lag structure for the resulting ARDL model was chosen using AIC. *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

Overall, our results highlight the importance of reducing the extent of directed credit controls as well as reserve and liquidity requirements in order to facilitate innovative activity. However, financial restraint in the form of interest rate controls appears to be an effective device enabling entrepreneurs to obtain external finance and initiate knowledge creation. The results therefore highlight the importance of considering each component of financial reforms separately in the analysis of the impact of financial liberalization or repression on innovative activity.

How could the above results be interpreted within the specific context of India? Firstly, our results indicate that interest controls have a positive effect on stimulating innovative activity in India. This finding is not surprising given that the deregulation of lending rates may increase the cost of borrowing and the removal of deposit interest floors may discourage savings. The former increases the cost of capital for innovative entrepreneurs whereas the latter reduces the amount of credit available to them. The extent of interest rate restraints in India rose sharply following the direct intervention of the Reserve Bank of India in the setting of interest rates in 1963. Despite these regulations, the ratio of M3 to GDP increased significantly from 24% to 51% during the period 1963-1988. This process of saving mobilization was much quicker than many other developing countries during the same period, and reflected a high propensity to save and confidence in the banking system. Given India's closed capital account regime, high saving mobilization has provided ample domestic resources to facilitate inventive activity. Moreover, the imposition of interest rate ceilings from the 1960s to 1980s also ensured that innovative entrepreneurs who lacked funding were able to obtain credit at a reasonably low cost.

The finding that interest rate restraints in India have a positive effect on innovation is intriguing and invites more discussion. Although the theoretical work of Emran and Stiglitz (2009) clearly suggests that financial restraint, in the form of deposit rate controls, directly encourages innovative activity in the industrial sector of a developing country, others argue that interest rate restraints may also encourage it indirectly via the channel of savings (see van Wijnbergen, 1982; Taylor, 1983; Stiglitz, 1994). In principle, savings and inventive activity are positively related since greater mobilization of savings increases the total amount of funds available for innovative activity. These insights invite further analysis and therefore an empirical test of whether the indirect effect of interest rate restraints on innovation via saving is operative in India is warranted.

Table 3: The effect of interest rate restraints on savings rates

	(1)	(2)	(3)	(4)	(5)
Intercept	0.278	0.764	-2.473	-4.853	-2.861***
Per capita real GDP growth	0.016	0.021*	0.019*		
Per capita real income				0.449*	0.688***
Age dependency	0.195	0.015			
Young age dependency			0.567		
Old age dependency			0.690		
Real interest rate	0.007				
Agriculture output (% GDP)	-0.862***	-0.788***	-0.948**	-0.278	
Interest rate restraints (IRR_t)	0.167***	0.167***	0.147***	0.449*	0.196***
ARDL bounds test	3.528*	4.551**	5.094***	6.033***	4.413*
ECM test	-3.962*	-4.133**	-5.131***	-4.651***	-3.448

Notes: the dependent variable is the ratio of gross domestic saving to GDP. Young dependents refer to population with ages 0-14 and old age dependents are the population with ages 65 and above. Age dependency refers to the number of young and old dependents to working-age population with ages 15-64. The real interest rate is the bank deposit rate minus the rate of inflation. *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

The effect of interest rate restraints on savings is examined using both the life cycle model and the permanent income hypothesis. The results reported in columns (1)-(3) of Table 3 show that interest rate restraints exert a positive and significant effect on the savings rate. The estimates, however, provide little support for the use of a life cycle framework. Estimates based on the permanent income hypothesis reported in columns (4) and (5) give similar findings that savings rates respond positively to interest rate controls. However, it should be highlighted that household savings may be discouraged if bank deposit rates are suppressed to a very low level. As emphasized by Chiappori *et al.* (1995) and Emran and Stiglitz (2009), savings will respond positively only when an optimal level of deposit ceiling is chosen. On the whole, our results suggest that interest rate restraints have both direct and indirect effects on innovative activity in India.

Secondly, our results suggest that directed credit programs tend to retard innovative activity. These findings are highly plausible for India. Due to the nationalization of banks in 1969, the allocation of credit has been mainly performed by government banks, which are often less efficient and subject to the risks of biased assessments. There is in fact evidence suggesting that finance in India has been subject to political interference. For instance, using data for the period 1992-1999, Cole (2009) finds that directed lending by government-owned banks increases significantly in election years and the surge is most prominent in the highly contested districts. Given that the provision of capital to industrial firms for innovative activity may be rather discretionary as it depends largely on general political objectives, it is unsurprising that these programs have been found to have negative or no impacts on expanding the amount of innovative capacity.

Moreover, although the allocation of credit under the direction of the central bank has benefited some farmers and small traders by allowing them to have adequate access to finance, this may have also discouraged household savings and hence reduced funds available for innovative activity. An important component of financial liberalization is the easing of priority sector loans. Although the actual share of directed loans in total lending remains high in recent years, bank compliance with these targets reduced sharply after financial liberalization, following a change in the priority sector definition to include many other activities. As a result, most banks have avoided lending to innovative entrepreneurs who are deemed less creditworthy, thereby depriving the innovators of institutional lending for investing in inventive activity. Given that government intervention in credit allocation has not created new sources of innovative entrepreneurship, our results point to the importance of eliminating these distortionary policies so that funds can be allocated efficiently to fuel innovative investment.

Finally, our results also suggest that higher reserve and liquidity requirements have a detrimental effect on innovative activity in India. High reserve requirements before liberalization have provided the Reserve Bank of India with funds to buy government securities at low cost, leaving insufficient funds to finance innovative investment. However, a significant reduction in the ratios of reserve and liquidity requirements after the liberalization has greatly expanded the amount of loanable funds, which has contributed to an economic boom during the 1990s. Therefore, it appears that lowering these requirements can provide significantly more loanable funds, enabling more inventive activity to be carried out. Our results therefore argue in favor of a policy of deregulation in the financial system by way of reducing reserve and liquidity requirements in order to boost innovative activity.

Nevertheless, as Aghion *et al.* (2004) have shown, unrestricted financial liberalization may induce instability. While financial repression may not be desirable, the evidence presented in this paper does provide some support for the argument that some form of financial restraint may promote innovation in developing countries. However, as noted by Honohan and Stiglitz (2001) and Rajan and Zingales (2003b), both financial liberalization and financial restraint are more likely to work well in environments with strong regulatory capacity. Although the legal system in India was originally based on the British model that emphasizes protection of property rights, India ended up with a much less effective institutional framework since the legal system was modified in a way that benefited the small number of Europeans that settled in and ran the economy (Mishkin, 2006). This highlights the importance of strengthening the institutional framework so that financial policies can be effectively carried out to deepen technological development.

7. Robustness

7.1. Diagnostic checks

The results reported in panel III of Table 2 show that the regression specifications fit remarkably well. All models pass the diagnostic tests against non-normal residuals, serial correlation, heteroskedasticity and autoregressive conditional heteroskedasticity. The structural stability of the knowledge production equation is examined using the cumulative sum (CUSUM) tests on the recursive residuals. The tests are able to detect systematic changes in the regression coefficients. The results (not reported) indicate that the test statistics lie within the 5% confidence interval bands, suggesting that there is no structural instability in the residuals of the knowledge production equation.

7.2. Alternative estimators

Table 4: Alternative estimators for the augmented long-run knowledge production function

	Model A $(X/Q)_t = (N/L)_t$		Model B $(X/Q)_t = (N/hL)_t$		Model C $(X/Q)_t = (N/aL)_t$		Model D $(X/Q)_t = (N/ahL)_t$	
I. FM-OLS	Coeff.	*p*-value	Coeff.	*p*-value	Coeff.	*p*-value	Coeff.	*p*-value
Intercept	0.847	0.477	0.769	0.518	0.074	0.953	-0.649	0.602
$\ln A_t$	0.991***	0.000	1.013***	0.000	1.108***	0.000	1.174***	0.000
$\ln(X/Q)_t$	0.339***	0.000	0.354***	0.000	0.408***	0.000	0.382***	0.000
IRR_t	0.005	0.848	0.004	0.875	0.049*	0.064	0.063**	0.020
DCP_t	-0.106***	0.000	-0.108***	0.000	-0.123***	0.000	-0.124***	0.000
RLR_t	-2.470***	0.000	-2.424***	0.000	-2.270***	0.000	-2.102***	0.000
II. FM-UECM								
Intercept	1.664	0.120	2.049	0.210	1.211	0.476	0.137	0.934
$\ln A_t$	0.943***	0.000	1.039***	0.000	1.171***	0.000	1.286***	0.000
$\ln(X/Q)_t$	0.401***	0.000	0.582***	0.000	0.691***	0.000	0.676***	0.000
IRR_t	0.031	0.200	0.003	0.939	0.066*	0.062	0.121***	0.001
DCP_t	-0.111***	0.000	-0.163***	0.000	-0.187***	0.000	-0.194***	0.000
RLR_t	-1.936***	0.000	-3.942***	0.000	-3.801***	0.000	-2.789***	0.000
III. DOLS								
Intercept	0.853**	0.041	0.717*	0.059	0.487	0.212	0.179	0.615
$\ln A_t$	0.772***	0.000	0.787***	0.000	0.811***	0.000	0.832***	0.000
$\ln(X/Q)_t$	0.165***	0.000	0.164***	0.000	0.181***	0.000	0.162***	0.000
IRR_t	0.059***	0.000	0.052***	0.000	0.034***	0.000	0.030***	0.001
DCP_t	-0.036***	0.001	-0.036***	0.000	-0.039***	0.000	-0.036***	0.001
RLR_t	-0.553***	0.005	-0.483***	0.007	-0.325**	0.032	-0.209	0.135

Notes: *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

While the ARDL approach is used to derive the main results of this paper, to provide a sensitivity check of the results we also consider three other single-equation estimators, namely the FM-OLS procedure of Phillips and Hansen (1990), the FM-UECM estimator of Inder (1993) and the DOLS procedure of Stock and Watson (1993).[5] Since our focus is on the long-run results, the short-run

[5] The FM-OLS estimator directly estimates the long-run relationship by correcting the simple OLS estimator for serial correction and endogeneity in a semi-parametric way. The FM-UECM approach uses the same correction procedure to estimate the long-run parameters by incorporating adequate dynamics into the specification to avoid omitted lagged variable bias. The DOLS procedure involves regressing one of the *I*(1) variables on the remaining *I*(1) variables, the *I*(0) variables, leads and lags of the first difference of the *I*(1) variables, and a constant. It is similar to the UECM approach except that lead

dynamics of each estimator are not reported here for brevity. In general, these approaches give quite similar results compared to those estimated using the ARDL approach. As we can see from Table 4, all variables enter the long-run equation significantly at the conventional levels in most cases. Although the magnitude of the coefficients shows some small variations, the qualitative aspects of the results are, by and large, consistent with those obtained using the ARDL estimator. The main theme is that, with few exceptions, the R&D intensity measures and financial sector policies continue to be highly significant. Hence, we conclude that our main results are insensitive to the choice of estimators.

7.3 Control variables

This section addresses the issue regarding whether the previous results are robust to the inclusion of control variables, especially those that may have a crucial effect on inventive activity. The following control variables are considered. First, there is an established literature arguing that innovative activity is positively associated with international R&D spillovers (see Coe and Helpman, 1995). Our measure of knowledge spillovers via the channel of imports (SPI_t) follows the approach of Lichtenberg and van Pottelsberghe de la Potterie (1998). It considers bilateral trade between India and 20 OECD countries. Second, the number of patent applications may be affected by a significant change in patent laws. A strengthening patent protection framework may prevent the free flows of ideas and retard technological development. But on the other hand, it may enhance the innovators' ability to recoup expensive R&D costs, thereby encouraging further innovation. The intellectual property rights index (IPR_t) constructed by Park and Lippoldt (2005) is used to capture the extent of patent protection. The missing years are interpolated.

Third, we use the tariff rate, which is measured by import duties over total imports, to capture the effect of trade barriers (TB_t). Fourth, technology transfer in India may have occurred through foreign investment. Although the ratio of FDI to GDP may be an appropriate measure to capture this effect, data for FDI are only available from 1970. Therefore, we consider the number of technical collaborations (COL_t) and the share of foreign firms in total firms (FF_t) as the alternative measures. The latter is also interacted with distance to the frontier (DTF_t) (measured by the US's TFP over India's TFP) to allow for the possibility that the ability of a developing country to absorb the frontier's technology depends on the extent of foreign firm presence (see also Madsen *et al.*, 2009).

Although innovation activity may also depend on the depth of the financial system, the inclusion of an indicator of financial development in the specification may pose some difficulties.

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terms are involved in the estimation. By doing so, it corrects for potential endogeneity problems and small sample bias, and provides estimates of the cointegrating vectors which are asymptotically efficient.

There is now an established literature arguing that financial development is crucially shaped by financial sector policies (see, e.g., Demetriades and Luintel 1996; Ang 2008). As such, the inclusion of both an indicator of financial development and measures of financial policy as regressors in the same specification may pose some conceptual and econometric problems. Moreover, in a study that examines the effect of finance on income inequality in India, Ang (2009a) highlights the fact that despite attention having been paid to mitigate any problems associated with multicollinearity, entering both financial development and financial policy variables in the income inequality equation yields unsatisfactory econometric results. Our specification therefore excludes the indicators of financial development.[6]

Table 5: Controlling for the effects of other macroeconomic variables

	CV_t = $\ln SPI_t$	CV_t = $\ln IPR_t$	CV_t = $\ln TB_t$	CV_t = $\ln COL_t$	CV_t = $\ln FF_t$	CV_t = FF_t x $\ln DTF_t$
Intercept	0.179	-0.366	-0.006	0.188	0.546	-0.057
$\ln A_t$	0.824***	0.886***	0.839***	0.822***	0.822***	0.852***
$\ln(N/L)_t$	0.123***	0.109***	0.121***	0.123***	0.162***	0.133***
IRR_t	0.039***	0.027**	0.038***	0.041***	0.025**	0.029***
DCP_t	-0.138	-0.021*	-0.018	-0.013	-0.013	-0.145
RLR_t	-0.608***	-0.646***	-0.642***	-0.606***	-0.523***	-0.531***
CV_t	-0.034	-0.082	0.015	-0.001	0.032**	1.821***
ARDL bounds test	4.777***	4.934***	3.904**	3.658**	6.078***	5.569***
ECM test	-4.534**	-5.035***	-4.827**	-4.547**	-6.076***	-5.683***

Notes: CV_t = control variable, which includes: SPI_t = spillovers of R&D international stocks; IPR_t = intellectual property rights protection; TB_t = trade barriers (import duties / total imports); COL_t = number of collaborations with foreign firms; FF_t = the share of foreign firms in the total number of firms; and DTF_t = distance to the frontier (US's TFP / India's TFP). *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

In the remaining analyses, the estimates are derived based on Model A using only the ARDL estimator. Moreover, for space reasons, only the long-run estimates and cointegration test statistics are reported. The estimates reported in Table 5 show that our core results remain robust to the inclusion of these control variables. Except for the share of foreign firms in total firms and its interaction with the distance to the frontier (columns 5 and 6) for which positive significant effects are found, all control

[6] Venture capital funds may potentially play a more important intermediary role in providing capital to small and young innovative firms, which are generally plagued with high levels of uncertainty, than alternative sources of funds raised through banks or stock markets. However, an examination of this issue is not possible in the present context given that venture capital data for India are first available in 1996, following the establishment of an organized venture capital industry in India in the same year.

variables (CV_t) turn out to have insignificant effects on innovative activity. Importantly, we continue to find fairly strong evidence of cointegration in all regressions. Consistent findings with those obtained earlier, in Table 2, suggest that our results are not sensitive to the inclusion of these control variables.

7.4 Individual and overall effects of financial repression

Financial policies may be jointly implemented and therefore the underlying financial policy variables may be highly correlated. This concern is addressed by: 1) entering each type of financial policy separately in the regressions, and 2) providing a composite measure of financial repression capturing all three repressionist policies. We first look at how each type of financial policy affects innovative activity. To conserve space, only the long-run results and the cointegration test statistics are reported in Table 6. In each regression, we continue to find strong support for cointegration. The results reported in columns (1) to (3) give evidence consistent with the earlier results, providing some support for the proposition that our results are robust to different specifications and perhaps are also unlikely to be subject to multicollinearity problems.

In column (4), we consider the overall effect that repressionist policies may have on innovative activity. The aggregate measure is obtained by the first principal component of IRR_t, DCP_t and RLR_t given that there exists only one dominant principal component with an eigenvalue of greater than one. However, the coefficient of this variable turns out to be statistically insignificant. This result along with our mixed findings regarding the effects of financial policies on innovative activity indeed highlights the importance of considering each component of these policies separately in order to avoid aggregation bias (see also Ang 2009b).

Table 6: The effects of individual repressionist policy and overall financial repression

	(1)	(2)	(3)	(4)
Intercept	-0.319	-0.935^{**}	-0.489	-0.399
$\ln A_t$	0.815^{***}	0.884^{***}	0.865^{***}	0.819^{***}
$\ln(N/L)_t$	0.063^{***}	0.052^{**}	0.082^{***}	0.057^{***}
IRR_t	0.029^{**}			
DCP_t		-0.009		
RLR_t			-0.314^{*}	
FR_t				-0.399
ARDL bounds test	8.262^{***}	6.912^{***}	5.467^{**}	6.772^{***}
ECM test	-5.364^{***}	-4.786^{***}	-4.379^{***}	-4.735^{***}

Notes: *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

7.5 Further robustness checks

It is probable that our results may be sensitive to the estimation periods chosen given that a majority of the reforms occurred in the second half of the sample. The first two columns in Table 7 report the estimates for the periods 1960-2005 and 1970-2005. The estimates are largely consistent with the previous findings. Column 3 provides results based on alternative measure of DCP_t where it is measured based on the actual share of directed credit in total credit. It is evident that our results remain insensitive to this consideration, given that our measure of directed credit programs and the actual share of directed credit in total credit shows a high correlation structure of 0.94. While the results are insensitive to the choice of the measure, the former is preferred since it is consistent with previous studies (see, e.g., Demetriades and Luintel, 1996; Ang, 2009).

Finally, following Madsen *et al.* (2009), we use trademarks as the alternative measure of product variety. Gao and Hitt (2004) argue that trademarks contain more useful information about product differentiation that is not included in other measures of product variety such as income and labor force. Moreover, they reflect non-trivial variation among products. It is evident that the estimates do not show any significant variations (see column 4) except that the coefficient of RLR_t now becomes smaller. This finding provides some support for the proposition that the estimates are not sensitive to the way product variety is measured.[7]

Table 7: Alternative sample periods, measures of directed credit program and product variety

	(1) Period = 1960-2005	(2) Period = 1970-2005	(3) DCP_t = directed credit (% total credit)	(4) $(N/L)_t$ = no. trademarks / labor force
Intercept	0.202	0.286	0.348	-2.245***
$\ln A_t$	0.828***	0.822***	0.798***	0.951***
$\ln(N/L)_t$	0.128***	0.127***	0.121***	0.108***
IRR_t	0.038***	0.031*	0.041***	0.019*
DCP_t	-0.017*	-0.024	-0.002	-0.019**
RLR_t	-0.665***	-0.674***	-0.571***	-0.265**
ARDL bounds test	5.104***	3.373*	5.672***	5.832***
ECM test	-4.505**	-2.989	-5.492***	-5.360***

Notes: *, ** and *** indicate 10%, 5% and 1% levels of significance, respectively.

[7] Financial sector policies may have a direct effect on research intensity and hence bias our results. To allow for this possibility, we have: (1) specified Eq. (4) without research intensity; and (2) regress research intensity on financial sector policies. In both cases, the results indicate that nearly all the coefficients of financial policies are statistically insignificant. Moreover, these alternative econometric specifications provide little evidence of cointegration and also fail a number of diagnostic checks. These findings suggest that the equations are either misspecified or subject to omitted variable bias. We therefore do not consider these alternative specifications.

8. Conclusions

Financial repression or restraint, which is prevalent in many developing countries, may impede the development or adoption of new production techniques, thereby retarding technological deepening. Greater availability of financial resources, which can be achieved through financial reforms, offers the opportunities for the utilization of existing technologies and development of new techniques. The stimulus to innovation is therefore a result of decreasing financial constraints faced by firms, and at the broader level, a reduction of restraints in the financial system. Financial liberalization lifts restrictions in financial systems and spurs technological innovation. Thus, the crucial role of finance in the analysis of technological development cannot be understated.

While recent endogenous growth theories have highlighted the important role of finance in facilitating inventive activity, so far there has been little effort attempting to explore the role of finance in knowledge production. If innovation is to be encouraged, which type of financial sector policy should be formulated to facilitate it? This study contributes to the literature by providing fresh evidence on how each type of financial sector policy, including interest rate controls, directed credit programs and reserve and liquidity requirements, influences the evolution of knowledge creation using India as the case study. An understanding of how inventive activity reacts to each type of financial policy provides policy makers with some guidance in undertaking the institutional reform of financial markets and intermediaries.

Employing the ARDL and ECM cointegration tests, the empirical evidence shows a significant long-run relationship between knowledge production and its determinants. After documenting these basic cointegration results, we derive the long-run estimates using several different estimators. The qualitative aspects of the results are insensitive to the choice of estimators and measures of research intensity. The estimated results based on annual data for over half a century suggest that knowledge creation critically depends on the stock of knowledge and R&D input, providing strong support for the use of an innovation-based growth framework in the analysis. The results also highlight the important role of formulating appropriate financial policies in order to ease the acquisition of technical know-how and in stimulating innovation. Our findings indicate that financial sector policies appear to have mixed effects on knowledge creation. Specifically, financial repressionist policies, in the form of the significant presence of directed credit controls and high reserve requirements, appear to have retarded knowledge creation through preventing the adoption of improved machinery with embodied technological change.

However, the results do not provide full support for the financial liberalization thesis, given that policy intervention in the form of interest rate restraints appears to be an effective device for enhancing knowledge creation. To encourage innovation, greater emphasis should be given to allocating finance to small high-tech firms, which often occupy an important role in the process of technological innovation. Imposing interest rate ceilings on lending to innovative entrepreneurs can foster technological development by making finance more affordable. There is also significant potential for developing the venture capital market as it becomes a more important source of finance for innovative entrepreneurs.

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