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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 time series data for India over the period 1963–2005, the results indicate that interest rate restraints help generate ideas. 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. These results lend some support to the argument that some form of financial sector reforms may help stimulate economic growth via increasing technological innovation.

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. Recent developments in the theoretical growth literature have continued to emphasize the importance of finance in explaining innovative growth. In the models developed by Blackburn and Hung (1998), Aghion et al. (2005) and Aghion and Howitt (2009), the relationship between finance and growth is analyzed in the context of innovation-based growth models. These models predict that financial restrictions lead to higher monitoring costs or lower costs of hiding successful inventions. Financial reforms remove these restrictions and therefore tend to stimulate innovative production.

However, despite the important role of finance in facilitating the diffusion of new technologies and in the generation of new ideas, as illustrated by the theoretical contributions of the studies cited above, the issue of what kind of financial policies contribute to ideas production 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 the generation of new ideas with a case study of a large developing country. While the literature tends to focus on the overall financial liberalization (see, e.g., Levine, 2001; Hermes and Lensink, 2008; Ang, 2010d, 2011a, 2011b; Demetriades et al., 2013), a more satisfactory approach to assessing the effect of financial 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.

This study is more closely related to Ang (2010b) who examines the long-run impact of financial reforms, financial deepening and intellectual property protection on the accumulation of knowledge (or the stock of ideas) in India. His findings suggest that better patent protection is associated with higher knowledge accumulation. Moreover, while financial deepening facilitates the accumulation of ideas, the implementation of a series of financial liberalization policies is found to have a non-linear effect, implying that financial liberalization will exert a beneficial impact on technological deepening only if the financial system is adequately liberalized. The above study, however, does not consider how each component of the reform or repressionist program affects knowledge. Given that the overall effectiveness of the entire reform program would depend on each policy type, analysis performed at the disaggregated level is more satisfactory as it helps identify an appropriate mix of financial liberalization and repressionist policies that is effective at stimulating ideas production.

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Using annual time series data for more than four decades, 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 mainly on the U.S. and other OECD countries due to the lack of adequate and reliable R&D data for developing countries (see, e.g., Ha and Howitt, 2007; Ulku, 2007; Venturini, 2012a,b). With some exceptions such as Ang (2010c) and Madsen et al. (2010b), so far there has been little 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 the 1950s 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 results are presented and analysed in Section 6. Some robustness checks are provided in Section 7, and the last section concludes.

2. Innovative production 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. 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 ratio 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 towards a more open system in order 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 reduced 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.

These liberalization measures have significantly reduced restrictions in the financial system. Increased access to credit has encouraged more investment in education, providing a large pool of scientific and technical personnel to the technological sector. Since liberalization, R&D personnel have grown by more than two-fold 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:

$$g_A = \frac{\dot{A}_t}{A_t} = \rho \frac{\dot{SK}_t}{SK_t} \quad (2)$$

where SK_t is the stock of R&D knowledge. For low rates of depreciation of the R&D stock of knowledge, we can write Eq. (2) as:

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

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 (see, e.g., Howitt, 1999; Ha and Howitt, 2007; Madsen et al., 2010a; Ang and Madsen, 2011; Madsen and Ang, 2014). In the literature it is common to relate product variety to the labor force. For example, the fully-endogenous model of Aghion and Howitt (1998) predicts that product variety is proportional to the labor force in the long run due to the fact that 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.

3.2. Financial sector policies and knowledge production

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 ideas production for a number of reasons. Using a product variety model, Blackburn and Hung (1998) propose that firms have incentives to hide successful R&D projects 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 reducing delegation costs. The lower costs of monitoring spur technological development and ideas production (see also Aghion and Howitt, 2009). More recently, in the innovation-based growth model developed by Aghion et al. (2005), it is also argued that firms can conceal the results of successful innovations and thereby avoid repaying their creditors. A low degree of creditor protection, which is often associated with financial repression, makes fraud an inexpensive option, thus retarding the production of new ideas. In contrast, financial liberalization tends to increase the hiding costs by providing better laws and institutions, thus encouraging innovative entrepreneurs to produce and patent more new ideas.

However, some counter arguments suggest that financial reforms may not necessarily lead to higher ideas production. 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 ideas production.

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 ideas to be produced. Moreover, using a dynamic stochastic oligopoly model, Stadler (1992) shows that the optimal innovative output 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 production in the technological sector.

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 output, 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 output 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. Given the above, it appears that the impact of each of these financial sector policies on ideas production is theoretically ambiguous. It is therefore ultimately an empirical issue.

The discussion above also highlights that there are several ways through which financial reforms can impact on the production of new ideas. In particular, according to the models of Blackburn and Hung (1998), Aghion et al. (2005) and Aghion and Howitt (2009), financial liberalization spurs knowledge creation directly due to either reduced monitoring costs or increased hiding costs. On the other hand, van Wijnbergen (1982), Taylor (1983) and Stiglitz (1994) argue that interest rate controls can have a significant effect on domestic savings, implying that financial reforms can also affect ideas production indirectly via the channel of savings. In this paper, we will focus on testing the direct effect of financial reforms on ideas production. However, the indirect effect on knowledge creation through the channel of domestic savings will also be examined to shed further light on the results.

To test the direct effect of financial reforms on ideas production 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:

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

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.[1] While both β and γ are expected to carry a positive value, the expected signs for δ's cannot be determined *a priori* since the impact of each policy type on ideas production is theoretically ambiguous.

Eq. (4) will be estimated using annual data from 1963 to 2005. Although all data used in this study are available from 1950, we choose to commence the estimation period from 1963 due to the fact that the financial policy environment in India before 1963 was subject to little change. In particular, the cash reserve ratio and the statutory liquidity ratio had remained largely intact at 3.5% and 20%, respectively, over the period 1950–1962. Interest rate controls were first imposed by the Reserve Bank of India in 1963. The extent of directed credit controls was also negligible, at an average rate of only 2.4% over the same period. In one of the robustness checks carried out in Section 7.5, we demonstrate that the main results prevail even if the full sample period was used.

4. Data and construction of variables

This section describes the data sources, the construction of variables and some measurement issues. The descriptive statistics of the key variables used in the paper are presented in Table A1 in the Appendix A.

4.1. Patent data

As suggested by Kortum (1993), the amount of patenting activity can be used as a proxy for the extent of innovation activity. Hence, we use the number of domestic patents applied for ($\dot{A}_t$) as the measure of the amount of new ideas or knowledge. The domestic stock of ideas or knowledge (A_t) is constructed using the perpetual inventory method with a depreciation rate of 10%. Data over the period 1919–1963 are used to obtain a measure of the initial knowledge stock in 1963. 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 1919–1963, which is the steady-state capital stock in standard neoclassical growth models. The patent data are obtained from the World Intellectual Property Organization (WIPO). 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 different patent systems, rendering patent counts not comparable across countries, this does not pose any significant 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 does not necessarily translate into a change in innovative production. Other problems which have been highlighted in the literature include: only a fraction of invention is patented, patent applications are made due to strategic reasons, an increase in patent applications is associated with the advent of computerized search, and the steady increase in patent counts reflects additional modifications built on existing innovations rather than new independent inventions. Thus, it appears that patent counts are, at best, a noisy indicator for innovative production. Nevertheless, in the absence of a perfect indicator, patent statistics remain one of the most commonly used measures of inventive output, As Griliches (1990) notes, despite all the 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) due to the prediction of the fully-endogenous model of Aghion and Howitt (1998) that product variety is proportional to the labor force in the long run. 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_tL_t, N_t/a_tL_t and $N_t/a_th_tL_t$, 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 1963–2005 are used to obtain the initial stock for the year 1963. 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

[1] The empirical estimates are consistent when interest rate restraints (IRR_t), directed credit programs (DCP_t) and reserve and liquidity requirements (RLR_t) are expressed in logs.

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.

Fig. 1 shows the number of patents filed by domestic residents in India over the period 1963–2005. While patenting activity increased rapidly in the 1960s, there was little variation in the amount of inventive output 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.

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 collect 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. They can jointly account for 85% of the total variation.

The resulting index is presented in Fig. 2. The financial system in India prior to 1963 was quite liberal, 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 imposition 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 the late 1960s, and has remained fairly stable since then.

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 use a *de facto* measure, which involves measuring the share of actual directed credit in total non-food credit extended by large commercial banks. Fig. 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 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 reserve ratio and the statutory liquidity 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. Fig. 4

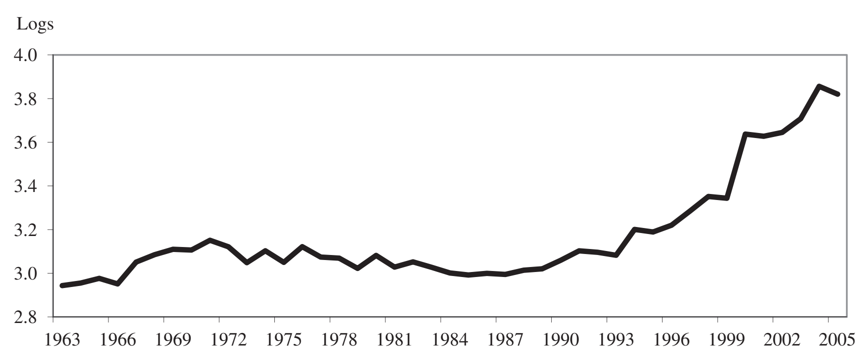

Fig. 1. Number of patents filed by domestic residents ($ln\dot{A}_t$). *Notes:* The diagram reflects the number of patents applications filed by domestic residents in India over the period 1963–2005 (in logarithmic scales). The data source is World Intellectual Property Organization (WIPO).

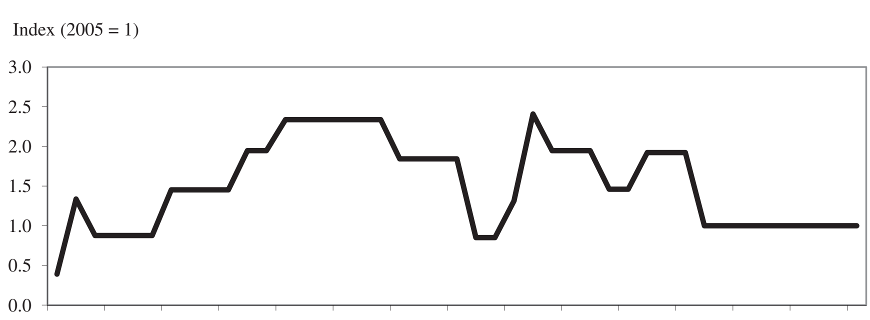

Fig. 2. Index of interest rate restraints (IRR_t). *Notes:* The summary index of interest rate restraints is constructed using the first three principal components (with eigenvalues > 1) of the following six interest rate policy dummies: a fixed deposit rate, a deposit rate ceiling, a deposit rate floor, a fixed lending rate, a lending rate ceiling and a lending rate floor. The data are rescaled using 2005 as the base year (2005 = 1). The sources are the Annual Report and the Report on Currency and Finance of the Reserve Bank of India.

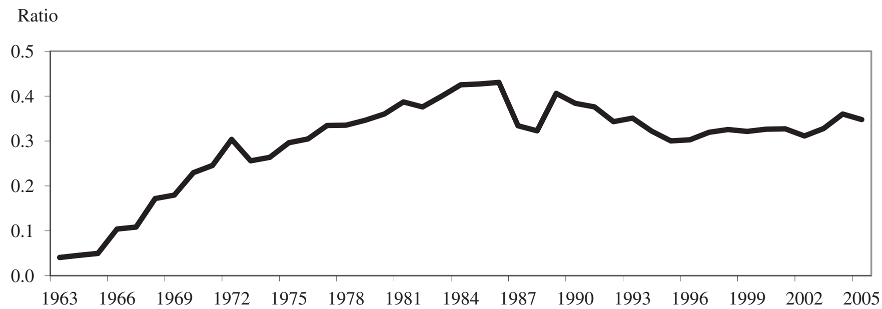

Fig. 3. Directed credit programs (DCP_t). *Notes:* The extent of directed credit programs is measured by the ratio of actual directed credit (priority loans to agriculture, small-scale industries, and other sectors) to total non-food credit of scheduled commercial banks. The sources are the Annual Report and the Report on Currency and Finance of the Reserve Bank of India.

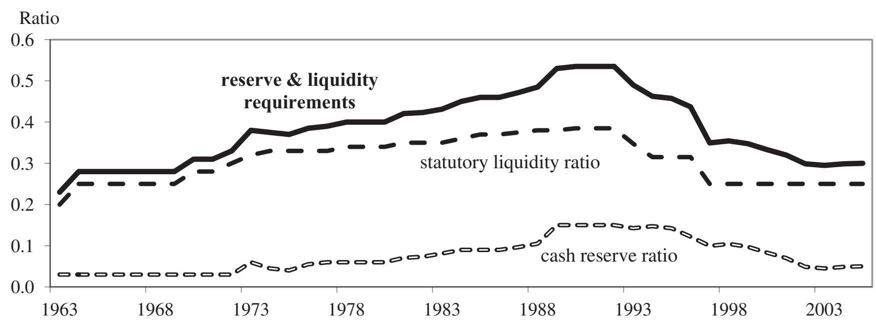

Fig. 4. Reserve and liquidity requirements (RLR_t). *Notes:* The measure of reserve and liquidity requirements is given by the sum of the cash reserve ratio (requirements for banks to hold part of their deposits in the form of cash balances at the Reserve Bank) and the statutory liquidity ratio (the requirement for banks to keep a share of their assets in government securities at below-market interest rates). The sources are the Annual Report and the Report on Currency and Finance of the Reserve Bank of India.

shows how reserve and liquidity requirements have evolved over time. Historically, the cash reserve ratio was kept low, at 3% during the 1960s. The ratio was gradually raised to 15% in 1990 to increase cash balances. Similarly, the statutory liquidity requirement was raised from 20% in the early 1960s to 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.

5. Estimation techniques

The dynamic adjustment of the ideas generation process can be characterized by a conditional error-correction model (ECM), which can be used to test for the existence of a long-run relationship using the ARDL (Autoregressive Distributed Lag) bounds test developed by Pesaran et al. (2001) and the ECM (error-correction model) 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:

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

where $\dot{A}_t$ is the number of patents applied for by domestic residents and DET_t is a vector of the determinants of ideas production, which includes lnA_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:$\beta_0 = \beta_1 = \cdots = \beta_k = 0$), 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 conditional ECM can be re-parameterized to yield an Autoregressive Distributed Lag model, which provides a convenient step to derive the long-run estimates and short-run dynamics for the ideas production function (see Pesaran and Shin (1998) for discussion).

6. Empirical results

6.1. Integration and cointegration analyses

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 above.

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, $(X/Q)_t$.

The results indicate that the null hypothesis of no level knowledge production equation is rejected at the 5% 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 $ln\dot{A}_t$. Except for two cases for which some evidence of non-normality is detected, we do not find any evidence of serial correlation, autoregressive conditional heteroskedasticity, or 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 Akaike information criterion.

6.2. Long-run estimates and short-run dynamics

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 0.788–0.981. The measures of research intensity are found to have an economically and statistically significant effect on knowledge production. The 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 production. The coefficients do not differ widely across models, ranging only from 0.028 to 0.038. With regard to directed credit programs, our results suggest that an increase in the extent of directed credit controls tends to discourage innovative production, 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 −0.609 and −0.645, respectively. Finally, the results also suggest that higher reserve and liquidity requirements tend to discourage knowledge production, with negative long-run estimates in the range of 0.477–0.524. This effect is found to be significant at least at the 5% 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, although the statistical correlations between the long-run variables are somewhat stronger. In first-differenced form, all coefficients have signs consistent with the long-run estimates. The short-run coefficients of research intensity are consistently insignificant, and therefore this variable is dropped from the estimations. Interestingly, except for the coefficients of $\Delta ln\dot{A}_t$, 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

Table 1
Cointegration tests (1963–2005).

	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 $(X/Q)_t=(N/ahL)_t$	
	$p=1$	$p=2$	$p=1$	$p=2$	$p=1$	$p=2$	$p=1$	$p=2$
ARDL bounds test Pesaran et al. (2001)	4.468**	4.226**	4.584**	4.416**	5.126***	5.601***	5.417***	6.298***
ECM test Banerjee et al. (1998)	−4.805***	−3.557	−4.845***	−3.641	−4.893***	−4.265**	−4.995***	−4.529**
Akaike information criterion (AIC)	−4.004	−4.284	−4.015	−4.306	−4.031	−4.328	−4.062	−4.406
Schwarz Bayesian criterion (SBC)	−3.252	−3.270	−3.263	−3.293	−3.279	−3.315	−3.310	−3.392
NORMAL	1.175	9.462***	1.171	10.161***	0.889	1.476	1.112	2.393
	(0.555)	(0.008)	(0.556)	(0.006)	(0.640)	(0.477)	(0.573)	(0.302)
SERIAL(1)	7.595**	0.231	7.922**	0.249	10.865***	0.389	12.724***	0.709
	(0.012)	(0.637)	(0.011)	(0.624)	(0.003)	(0.541)	(0.002)	(0.412)
SERIAL(2)	3.721**	0.605	3.872**	0.612	5.235**	1.076	6.128***	1.300
	(0.041)	(0.559)	(0.037)	(0.556)	(0.014)	(0.367)	(0.008)	(0.303)
ARCH	0.003	0.323	0.002	0.309	0.121	0.029	0.113	0.055
	(0.959)	(0.573)	(0.961)	(0.581)	(0.729)	(0.865)	(0.737)	(0.814)
WHITE	0.657	0.248	0.639	0.243	0.555	0.233	0.486	0.234
	(0.811)	(0.998)	(0.825)	(0.998)	(0.891)	(0.999)	(0.934)	(0.999)

Notes: (X/Q) is research intensity where X refers to R&D input and Q refers to product variety. R&D input is measured using R&D labor (N) whereas product variety is measured by the number of workers (L). Product variety is adjusted for total factor productivity (a) and human capital (h) to account for the fact that innovations become increasingly more complex over time. p is the lag length. The test statistics of the cointegration 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. *NORMAL* refers to the Jarque–Bera statistic of the test for normal residuals, *SERIAL*(1) and *SERIAL*(2) are Breusch-Godfrey LM test statistics for no first and second-order serial relationship, respectively, *ARCH* is the Engle's test statistic for no autoregressive conditional heteroskedasticity, and *WHITE* denotes the White's test statistic to test for homoskedastic errors. Numbers in parentheses indicate p-values.

** Indicates 5% levels of significance.
*** Indicates 1% levels of significance.

Table 2
ARDL estimates of the augmented knowledge production function (1963–2005).

	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 ($Dep.Var. = ln\dot{A}_t$)								
Intercept	0.491	0.476	0.497	0.463	−0.495	0.276	−0.499	0.255
lnA_t	0.788^{***}	0.000	0.797^{***}	0.000	0.962^{***}	0.000	0.981^{***}	0.000
$ln(X/Q)_t$	0.133^{***}	0.000	0.145^{***}	0.000	0.223^{***}	0.000	0.251^{***}	0.000
IRR_t	0.038^{***}	0.007	0.037^{***}	0.007	0.030^{***}	0.003	0.028^{***}	0.005
DCP_t	−0.081	0.593	−0.093	0.531	-0.609^{***}	0.000	-0.645^{***}	0.000
RLR_t	-0.477^{**}	0.022	-0.487^{**}	0.018	-0.524^{***}	0.001	-0.503^{***}	0.001
II. The short-run dynamics ($Dep.Var. = \Delta ln\dot{A}_t$)								
Intercept	0.008	0.177	0.008	0.178	0.007	0.302	0.007	0.306
ECT_{t-1}	-0.839^{***}	0.000	-0.845^{***}	0.000	-0.942^{***}	0.000	-0.948^{***}	0.000
ΔlnA_t	5.631^{***}	0.000	5.628^{***}	0.000	5.303^{***}	0.000	5.314^{***}	0.000
ΔIRR_t	0.023^{*}	0.086	0.022^{*}	0.091	0.009	0.544	0.006	0.658
ΔDCP_t	−0.082	0.588	−0.090	0.549	-0.292^{*}	0.089	-0.308^{*}	0.075
ΔRLR_t	-0.399^{*}	0.070	-0.393^{*}	0.072	−0.153	0.526	−0.108	0.657
III. Diagnostic checks								
	Test-stat.	*p*-value	Test-stat.	*p*-value	Test-stat.	*p*-value	Test-stat.	*p*-value
NORMAL	0.961	0.617	1.053	0.591	2.291	0.317	2.105	0.349
SERIAL(1)	0.431	0.515	0.479	0.493	0.303	0.585	0.186	0.668
SERIAL(2)	0.546	0.583	0.517	0.601	0.147	0.863	0.128	0.880
ARCH	0.001	0.983	0.002	0.963	1.232	0.273	1.749	0.193
WHITE	1.511	0.211	1.509	0.211	0.575	0.718	0.561	0.728

Notes: ARDL stands for Autoregressive Distributed Lag. (X/Q) is research intensity where X refers to R&D input and Q refers to product variety. R&D input is measured using R&D labor (N), whereas product variety is measured by the number of workers (L). Product variety is adjusted for total factor productivity (a) and human capital (h) to account for the fact that innovations become increasingly more complex over time. 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 the Akaike information criterion. *NORMAL* refers to the Jarque–Bera statistic of the test for normal residuals, *SERIAL*(1) and *SERIAL*(2) are Breusch-Godfrey LM test statistics for no first and second-order serial relationship, respectively, *ARCH* is the Engle's test statistic for no autoregressive conditional heteroskedasticity, and *WHITE* denotes the White's test statistic to test for homoskedastic errors. Numbers in parentheses indicate *p*-values.
* Indicates 10% levels of significance.
** Indicates 5% levels of significance.
*** Indicates 1% levels of significance.

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.

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 knowledge production. 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 production.

6.3. Interest rate restraints and savings

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

The effect of interest rate restraints on savings is examined using both the life cycle model and the permanent income hypothesis. The specifications include the share of agricultural output in total production to account for structural changes that have taken place in the economy of India. 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, given that the coefficients of income growth and age dependency are barely significant. 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. On the whole, our results suggest that interest rate restraints have both direct and indirect positive effects on ideas production in India.[2]

6.4. Further discussion of results

How could the above results be interpreted within the specific context of India? Firstly, our results indicate that interest rate controls have a positive effect on stimulating ideas production 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 in many other developing countries during the same

[2] The results are consistent if interest rate restraints were measured using the first principal component of the deposit rate policy dummies, namely a fixed deposit rate, a deposit rate ceiling, and a deposit rate floor.

Table 3
The effect of interest rate restraints on savings rates (1963–2005).

	(1)	(2)	(3)	(4)	(5)
I. The long-run relationship (*Dep.Var.* = log(gross domestic savings/GDP))					
Intercept	3.344	2.929	−3.079	−0.018	−7.621***
	(0.493)	(0.547)	(0.642)	(0.997)	(0.000)
Real GDP growth per capita	0.016	0.020*	0.018*		
	(0.175)	(0.073)	(0.066)		
Age dependency	−0.715	−0.604			
	(0.637)	(0.690)			
Young age dependency			−0.035		
			(0.980)		
Old age dependency			1.362		
			(0.259)		
Real interest rate	0.002				
	(0.606)				
Per capita real income				0.073	0.663***
				(0.813)	(0.000)
Agriculture output (% GDP)	−0.641	−0.664	−0.387	−0.744	
	(0.193)	(0.178)	(0.438)	(0.126)	
Interest rate restraints (IRR_t)	0.198***	0.199***	0.165***	0.200***	0.177***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
II. Cointegration tests					
ARDL bounds test	3.936**	4.253**	3.923**	4.224*	3.009
ECM test	−3.705	−3.476	−3.195	−3.295	−2.487

Notes: the dependent variable is the ratio of gross domestic saving to GDP (logs). 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 depen $(X/Q)_t = (N/ahL)_t$ dents to the working-age population with ages 15–64. The real interest rate is the bank deposit rate minus the rate of inflation. The maximum lag length allowed for is two. Figures in parenthesis are *p*-values. The test statistics of the cointegration tests are compared against the critical values reported in Pesaran et al. (2001). The estimation allows for an unrestricted intercept and no trend. The critical value bounds for the *F*-test and *t*-test vary according to the number of variables included in the estimations. For more details refer to Table CI(iii) (for the *F*-statistic) and Table CII(iii) (for the *t*-statistic) of Pesaran et al. (2001).
* Indicates 10% levels of significance.
** Indicates 5% levels of significance.
*** Indicates 1% levels of significance.

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 production. Moreover, the imposition of interest rate ceilings from the 1960s to 1980s ensured that innovative entrepreneurs who lacked funding were able to obtain credit at a reasonably low cost. The introduction of these interest rate controls also helped stabilizing the financial system, providing more confidence for innovative firms to invent.

Another implication is that directed credit programs tend to retard ideas production. These findings are highly plausible for India.[3] 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 highly contested districts. Given that the provision of capital to industrial firms for ideas production 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 impact on the amount of innovative output.

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 knowledge creation. An important component of financial liberalization is the easing of priority sector loans. Although the actual share of directed loans in total lending has remained 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 patenting 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 production.

Finally, our results also suggest that higher reserve and liquidity requirements have a detrimental effect on knowledge production 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 projects. However, a significant reduction in the ratios of reserve and liquidity requirements after the liberalization has greatly expanded the amount of loanable funds, which contributed to an economic boom during the 1990s. Therefore, it appears that lowering these requirements can provide significantly more loanable funds, enabling the production of more ideas. Consequently, our results support a policy of deregulation in the financial system by way of reducing reserve and liquidity requirements in order to boost innovative production.

Nevertheless, 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 innovative production in developing countries. However, as noted by Honohan and Stiglitz (2001), 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

[3] A previous study by Odedokun (1996), for instance, has also found that directed credit programs have resulted in inefficient allocation of resources in developing countries.

way that benefited the small number of Europeans that settled in and ran the economy. This highlights the importance of strengthening the institutional framework so that financial policies can be effectively implemented to deepen technological development (see, e.g., Law et al., 2013).

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

While the ARDL approach is used to derive the main results, to provide a sensitivity check we also consider three other single-equation estimators, namely the fully modified ordinary least squares (FM-OLS) procedure, the fully modified unrestricted error-correction model (FM-UECM) estimator and the dynamic ordinary least squares (DOLS) procedure. Since our focus is on the long-run results, the short-run 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

Table 4
Alternative single-equation time series estimators (1963–2005).

$Dep.Var. = ln\dot{A}_t$	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. Fully modified ordinary least squares (FM-OLS)								
Intercept	1.080	0.206	1.418**	0.036	0.496	0.143	0.234	0.314
lnA_t	0.956***	0.000	0.948***	0.000	1.077***	0.000	1.130***	0.000
$ln(X/Q)_t$	0.337***	0.000	0.376***	0.000	0.452***	0.000	0.486***	0.000
IRR_t	0.044**	0.025	0.044***	0.004	0.025***	0.001	0.018***	0.001
DCP_t	−0.305*	0.098	−0.255*	0.074	−0.492***	0.000	−0.591***	0.000
RLR_t	−2.779***	0.000	−2.856***	0.000	−2.694***	0.000	−2.582***	0.000
II. Fully modified unrestricted error-correction model (FM-UECM)								
Intercept	0.923***	0.004	1.023***	0.002	−0.104	0.764	−0.288	0.737
lnA_t	0.968***	0.000	0.979***	0.000	1.122***	0.000	1.178***	0.000
$ln(X/Q)_t$	0.324***	0.000	0.354***	0.000	0.419***	0.000	0.479***	0.000
IRR_t	0.021***	0.005	0.021***	0.005	0.001	0.973	0.001	0.955
DCP_t	−0.336***	0.000	−0.346***	0.000	−0.591***	0.000	−0.804***	0.000
RLR_t	−2.711***	0.000	−2.709***	0.000	−2.458***	0.000	−2.313***	0.000
III. Dynamic ordinary least squares (DOLS)								
Intercept	0.602	0.461	0.676	0.389	1.275*	0.094	1.348**	0.042
lnA_t	0.832***	0.000	0.841***	0.000	0.859***	0.000	0.895***	0.000
$ln(X/Q)_t$	0.199***	0.002	0.221***	0.001	0.377***	0.000	0.442***	0.000
IRR_t	0.073***	0.004	0.073***	0.003	0.059***	0.001	0.056***	0.000
DCP_t	−0.449**	0.018	−0.454**	0.014	−0.565***	0.002	−0.619***	0.003
RLR_t	−0.792**	0.044	−0.810**	0.033	−0.934***	0.009	−0.968**	0.042

Notes: (X/Q) is research intensity where X refers to R&D input and Q refers to product variety. R&D input is measured using R&D labor (N) whereas product variety is measured by the number of workers (L). Product variety is adjusted for total factor productivity (a) and human capital (h) to account for the fact that innovations become increasingly more complex over time.
* Indicates 10% levels of significance.
** Indicates 5% levels of significance.
*** Indicates 1% levels of significance.

Table 5
Alternative estimates based on the vector-error correction model (1963–2005).

$Dep.Var. = ln\dot{A}_t$	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.	*Std. err.*	Coeff.	*Std. err.*	Coeff.	*Std. err.*	Coeff.	*Std. err.*
lnA_t	0.883***	0.048	0.894***	0.044	0.875***	0.042	0.907***	0.035
$ln(X/Q)_t$	0.214***	0.027	0.224***	0.028	0.220***	0.046	0.286***	0.045
IRR_t	0.038***	0.012	0.039***	0.011	0.034***	0.010	0.035***	0.008
DCP_t	−0.706***	0.120	−0.695***	0.112	−0.760***	0.114	−0.777***	0.098
RLR_t	−0.291	0.183	−0.293*	0.172	0.162	0.175	−0.053	0.149

Notes: (X/Q) is research intensity where X refers to R&D input and Q refers to product variety. R&D input is measured using R&D labor (N) whereas product variety is measured by the number of workers (L). Product variety is adjusted for total factor productivity (a) and human capital (h) to account for the fact that innovations become increasingly more complex over time. An intercept but no deterministic trend is included in the estimations. The estimations involve two lags.
* Indicates 10% levels of significance.
*** Indicates 1% levels of significance.

those obtained using the ARDL estimator. The main theme is that, with very 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.

Given that the approaches considered so far are all single-equation time series techniques, we also consider a dynamic system approach that treats all underlying variables as endogenous, namely the vector-error correction model (VECM). The estimates presented in Table 5 clearly show our results are by and large similar even if endogeneity is allowed for. It should be noted, however, that while this approach allows for the possibility of reverse causality it does not deal with omitted variable bias, an issue we will address in the next sub-section.

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 production. The following control variables are considered: intellectual property protection, international knowledge spillovers, technical collaborations, and technological gap between India and the global frontier. First, the number of patent applications may be affected by a significant change in patent laws. A strengthening patent protection framework may prevent the free flow of ideas and retard technological development. But on the other hand, it may enhance the innovators' ability to recoup expensive R&D costs, thereby

Table 6
Controlling for the effects of patent protection and technology transfer (1963–2005).

	(1) Control for intellectual property rights protection	(2) Control for international knowledge spillovers	(3) Control for technical collaborations	(4) Control for distance to the technological frontier	(5) Control for all effects (columns (1) to (4))
I. The long-run relationship ($Dep.Var. = ln\dot{A}_t$)					
Intercept	−1.323	−0.211	0.008	0.117	−0.151
	(0.215)	(0.726)	(0.988)	(0.892)	(0.927)
lnA_t	0.983***	0.874***	0.859***	0.834***	0.931***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$ln(N/L)_t$	0.093***	0.125***	0.136***	0.119***	0.145*
	(0.006)	(0.000)	(0.000)	(0.000)	(0.050)
IRR_t	0.028*	0.031**	0.041***	0.036***	0.016
	(0.081)	(0.036)	(0.005)	(0.008)	(0.370)
DCP_t	−0.384*	−0.267	−0.275*	−0.161	−0.472**
	(0.055)	(0.111)	(0.062)	(0.249)	(0.014)
RLR_t	−0.477**	−0.519***	−0.511***	−0.549**	−0.490**
	(0.010)	(0.007)	(0.008)	(0.010)	(0.021)
$lnIPR_t$	−0.157*				−0.072
	(0.067)				(0.634)
$lnSPI_t$		−0.133			0.008
		(0.325)			(0.966)
$lnCOL_t$			−0.012		−0.032
			(0.374)		(0.259)
$lnDTF_t$				−0.031	−0.121
				(0.820)	(0.448)
II. The short-run dynamics ($Dep.Var. = \Delta ln\dot{A}_t$)					
Intercept	0.019***	0.010*	0.008	0.006	−0.281***
	(0.002)	(0.086)	(0.147)	(0.278)	(0.000)
ECT_{t-1}	−0.881***	−0.893***	−0.886***	−0.881***	−0.933***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔlnA_t	5.719***	5.550***	5.579***	5.617***	5.505***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔIRR_t	0.007	0.012	0.016	0.022*	−0.002
	(0.562)	(0.358)	(0.187)	(0.099)	(0.888)
ΔDCP_t	−0.337**	−0.252*	−0.284**	−0.157	−0.439***
	(0.027)	(0.095)	(0.047)	(0.292)	(0.004)
ΔRLR_t	−0.398*	−0.473**	−0.472**	−0.504**	−0.425**
	(0.056)	(0.026)	(0.022)	(0.020)	(0.034)
$\Delta lnIPR$	−0.194				0.107
	(0.128)				(0.412)
$\Delta lnSPI_t$		−0.216*			−0.154
		(0.072)			(0.208)
$\Delta lnCOL_t$			0.016		0.013
			(0.296)		(0.379)
$\Delta lnDTF_t$				0.072	0.043
				(0.566)	(0.721)
III. Cointegration tests					
ARDL bounds test	5.356***	4.983***	3.401*	3.307*	2.293
ECM test	−5.562***	−5.184***	−3.758	−4.531**	−3.478

Notes: (N/L) is research intensity measured using the ratio of R&D workers to the total labor force. The control variables are intellectual property rights protection (IPR_t), spillovers of R&D international stocks (SPI_t), the number of technological collaborations with foreign firms (COL_t), and distance to the technological frontier or US's TFP relative to India's TFP (DTF_t). The maximum lag length allowed for is two. Figures in parenthesis are p-values. The test statistics of the cointegration tests are compared against the critical values reported in Pesaran et al. (2001). The estimation allows for an unrestricted intercept and no trend. In the case with six explanatory variables (the first four columns), the 10%, 5% and 1% critical value bounds for the F-test are (2.72, 3.77), (3.23, 4.35) and (4.29, 5.61), and for the t-test are (−2.57, −3.46), (−2.86, −3.78) and (−3.43, −4.37), respectively. For the case with nine explanatory variables (the last column), the 10%, 5% and 1% critical value bounds for the F-test are (1.88, 2.99), (2.14, 3.30) and (2.65, 3.97), and for the t-test are (−2.57, −4.56), (−2.86, −4.88) and (−3.42, −5.54), respectively.

* Indicates 10% levels of significance.

** Indicates 5% levels of significance.

*** Indicates 1% levels of significance.

Table 7
Controlling for the effects of other reforms (1963–2005).

	(1) Control for trade reforms	(2) Control for industrial reforms	(3) Control for other financial deregulations	(4) Control for product market reforms	(5) Control for all effects (columns (1) to (4))
I. The long-run relationship ($Dep.Var. = ln\dot{A}_t$)					
Intercept	−0.068	0.145	0.530	1.425	0.668
	(0.909)	(0.818)	(0.466)	(0.178)	(0.402)
lnA_t	0.844***	0.863***	0.859***	0.687***	0.878***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$ln(N/L)_t$	0.112***	0.174***	0.220***	0.143***	0.262***
	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)
IRR_t	0.034**	0.037***	0.050***	0.048***	0.035**
	(0.025)	(0.006)	(0.002)	(0.006)	(0.037)
DCP_t	−0.166	−0.287*	−0.326**	−0.001	−0.279**
	(0.225)	(0.096)	(0.032)	(0.996)	(0.035)
RLR_t	−0.483**	−0.457**	−0.901***	−0.456**	−0.702**
	(0.028)	(0.019)	(0.007)	(0.031)	(0.013)
$lnTR_t$	0.023				0.073*
	(0.615)				(0.099)
$lnIR_t$		0.096			−0.199***
		(0.198)			(0.003)
FD_t			−0.015		−0.013
			(0.167)		(0.157)
PM_t				0.206	0.087
				(0.178)	(0.817)
II. The short-run dynamics ($Dep.Var. = \Delta ln\dot{A}_t$)					
Intercept	0.005	0.007	0.009	0.009	0.009
	(0.382)	(0.228)	(0.180)	(0.143)	(0.135)
ECT_{t-1}	−0.881***	−0.905***	−0.915***	−0.830***	−0.995***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔlnA_t	5.601***	5.497***	5.561***	5.586***	5.433***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔIRR_t	0.021	0.017	0.024*	0.026**	0.017
	(0.104)	(0.172)	(0.060)	(0.040)	(0.140)
ΔDCP_t	−0.174	−0.165	−0.259*	−0.088	−0.312**
	(0.239)	(0.249)	(0.080)	(0.549)	(0.020)
ΔRLR_t	−0.480**	−0.339	−0.808***	−0.451*	−0.776***
	(0.027)	(0.101)	(0.006)	(0.036)	(0.003)
$\Delta lnTR_t$	−0.030				−0.018
	(0.548)				(0.692)
$\Delta lnIR_t$		0.053			0.013
		(0.534)			(0.874)
ΔFD_t			−0.021*		−0.019*
			(0.056)		(0.062)
ΔPM_t				0.226**	0.068
				(0.024)	(0.413)
III. Cointegration tests					
ARDL bounds test	3.917*	6.052***	3.941*	3.277	3.272*
ECM test	−4.478***	−6.115***	−4.658***	−4.174**	−4.243

Notes: (N/L) is research intensity measured using the ratio of R&D workers to the total labor force. The control variables include: (1) trade reforms, defined as one minus the tariff rate (TR_t); (2) industrial reforms, measured by the sum of six industrial policy dummies (IR_t); (3) other financial deregulations, including deregulations in entry barriers (pro-competition measures), banking supervision, privatization, openness to international capital flows, and security markets reforms (FD_t); and (4) product market reforms, including deregulation in the electricity and telecommunication sectors (PM_t). The maximum lag length allowed for is two. Figures in parenthesis are p-values. The test statistics of the cointegration tests are compared against the critical values reported in Pesaran et al. (2001). The estimation allows for an unrestricted intercept and no trend. In the case with six explanatory variables (the first four columns), the 10%, 5% and 1% critical value bounds for the F-test are (2.72, 3.77), (3.23, 4.35) and (4.29, 5.61), and for the t-test are (−2.57, −3.46), (−2.86, −3.78) and (−3.43, −4.37), respectively. For the case with nine explanatory variables (the last column), the 10%, 5% and 1% critical value bounds for the F-test are (1.88, 2.99), (2.14, 3.30) and (2.65, 3.97), and for the t-test are (−2.57, −4.56), (−2.86, −4.88) and (−3.42, −5.54), respectively.
* Indicates 10% levels of significance.
** Indicates 5% levels of significance.
*** Indicates 1% levels of significance.

encouraging further innovation. The intellectual property rights index (IRR_t) constructed by Park (2008) is used to capture the extent of patent protection. The missing years are interpolated.[4]

Second, there is an established literature arguing that innovative output is positively associated with international R&D spillovers (see, e.g., Coe and Helpman, 1995; Ang and Madsen, 2013). 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.

Third, 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) between domestic firms and their foreign partners as a possible channel through

[4] The updated dataset of Park (2008) provides data on the patent protection index over the period 1960–2010. As the data are only available in five-year intervals, missing data between years are interpolated to obtain an annualized series. The complete set of data can be accessed at: http://nw08.american.edu/~wgp/. Although the degree of patent protection does not tend to fluctuate from year to year unless there is a drastic policy change, interpolating the data severely undermines the value added of this robustness exercise since data presented at a lower frequency may not provide sufficient variation to track the changes in patenting output closely. The estimates are therefore unable to fully capture the association between patent right protection and patenting activity.

which foreign technology and know-how can be transmitted to India.

Fourth, technology can also flow freely across borders, independent of any channels. To allow for this possibility, we include a distance to the technological frontier (DTF_t) measure in the specification. It is measured by the US's TFP over India's TFP to allow for the possibility that the ability of a developing country to tap into the frontier's technology depends on their technological gap in that technology flows more easily if their gap is wider due to the lower adoption costs.

These additional control variables are included separately as well as jointly in the specifications. In all remaining analyses, the estimates are derived based on Model A using only the ARDL estimator since our previous results show that the results are not sensitive to the way research intensity is measured. Moreover, for space reasons, only the long-run estimates, short-run dynamics and cointegration test statistics are reported. The diagnostic statistics, which are not reported, do not suggest any major econometric issues.

It should be noted, however, that although innovative production 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. There is now an established literature arguing that financial development is crucially shaped by financial sector policies (see, e.g., Ang and McKibbin, 2007). 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 (2010a) 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.

The estimates reported in Table 6 show that our core results remain robust to the inclusion of these control variables. Except for the patent protection index (column (1)), for which a negative and mildly significant effect is found, all control variables turn out to have insignificant effects on ideas production. The short-run estimates also provide consistent findings in terms of how interest rate controls and directed credit as well as reserve and liquidity requirements are related to patenting activity. Similar to their long-run counterparts, the short-run effects of these control variables are found to be insignificant. Importantly, we continue to find fairly strong evidence of cointegration in all regressions. Taken as a whole, consistent findings with those obtained earlier, in Table 2, suggest that our results are not sensitive to the inclusion of these control variables and hence are unlikely to be driven by omitted variable bias.

The correlations found between patent applications and financial sector policies may be driven by the failure to account for other reforms undertaken in the economy, given that financial sector reforms may occur simultaneously with these reforms (Bekaert et al., 2006). This concern is particularly pertinent for India given that the financial sector reforms in the early 1990s were part of a larger package of economic reforms aimed at enhancing growth. To ensure that other policy reforms have not been responsible for the observed relationship between financial sector policies and innovative production, the following variables are added singly as well as jointly to the specification as an attempt to deal with endogeneity bias: trade reforms, industrial reforms, other financial deregulations (excluding interest controls, directed credit, and reserve requirements), and product market reforms.

First, to capture the effects of trade reforms (TR_t), we measure the degree of liberalization in the trade sector using one minus the tariff rate (the ratio of import duties to total imports) whereby an increase in the value of this index reflects greater relaxation of trade barriers.

Second, the extent of reform in the industrial sector (IR_t) is captured by six policy dummy variables, including the Industrial Policy Resolutions of 1948 and 1956, the Industrial Policy Statements of 1973, 1977 and 1980, and the 1991 Industrial Policy 1991. These policies were introduced over the last few decades with an aim of increasing the role of the private sector in market activities to fuel industrial growth. A value of one is assigned for the years following the introduction of an industrial policy. An overall summary measure reflecting the degree of industrial policy deregulation is obtained by summing up all six policy variables. The resulting index is then normalized so that its highest value is one.

Third, a variable that considers several additional financial deregulation measures (FD_t) is constructed by considering deregulations in entry barriers (pro-competition measures), banking supervision, privatization in the banking sector, openness to international capital flows, and security market reforms. These data are obtained from Abiad et al. (2010). For each dimension a value of 0, 1, 2 or 3 is assigned, where a larger value indicates a higher degree

Table 8
The effects of individual repressionist policy and overall financial repression (1963–2005).

	(1)	(2)	(3)	(4)
I. The long-run relationship (*Dep.Var.* = $ln\dot{A}_t$)				
Intercept	0.429	−1.157**	−0.138	−0.544
	(0.437)	(0.031)	(0.758)	(0.290)
lnA_t	0.750***	0.917***	0.834***	0.841***
	(0.000)	(0.000)	(0.000)	(0.000)
$ln(N/L)_t$	0.098***	0.053**	0.089***	0.054**
	(0.001)	(0.011)	(0.002)	(0.032)
IRR_t	0.034**			
	(0.045)			
DCP_t		−0.285*		
		(0.054)		
RLR_t			−0.387**	
			(0.042)	
FR_t				−0.367
				(0.716)
II. The short-run dynamics (*Dep.Var.* = $\Delta ln\dot{A}_t$)				
Intercept	0.012*	0.005	0.004	0.296***
	(0.084)	(0.460)	(0.565)	(0.001)
ECT_{t-1}	−0.755***	−0.850***	−0.845***	−0.325***
	(0.000)	(0.000)	(0.000)	(0.000)
ΔlnA_t	5.930***	5.782***	5.595***	2.852***
	(0.000)	(0.000)	(0.000)	(0.000)
ΔIRR_t	0.018			
	(0.171)			
ΔDCP_t		−0.149		
		(0.331)		
ΔRLR			−0.493**	
			(0.023)	
ΔFR_t				−0.112**
				(0.032)
III. Cointegration tests				
ARDL bounds test	6.652***	6.349***	5.578**	5.528**
ECM test	−4.653***	−4.732***	−4.379***	−4.735***

Notes: (N/L) is research intensity measured using the ratio of R&D workers to the total labor force. *FR* is a summary index of financial repression, which is obtained based on the first principal component of the standardized values of *IRR*, *DCP*, and *RLR*. The maximum lag length allowed for is two. Figures in parenthesis are *p*-values. The test statistics of the cointegration 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 (2.72, 3.77), (3.23, 4.35) and (4.29, 5.61), and for the *t*-test are (−2.57, −3.46), (−2.86, −3.78) and (−3.43, −4.37), respectively.
* Indicates 10% levels of significance.
** Indicates 5% levels of significance.
*** Indicates 1% levels of significance.

of financial deregulation. Following their approach, the sum of the values for all these policy variables is taken to be the overall measure of financial deregulation. It should be noted that interest controls, directed credit, and reserve requirements are not considered in the construction of this measure since they have been captured in our econometric specifications.

Fourth, another variable capturing the degree of product market reform (PM_t) is also used. This indicator measures the extent of deregulation in the telecommunication and electricity markets. It considers factors such as the extent of competition in the provision of these services, the presence of a non-governmental regulatory authority, the degree of liberalization in the markets of these services, and privatization. The data are taken from Giuliano et al. (2013).

It is evident in the results reported in Table 7 that the inclusion of these reform variables does not alter the main findings of the paper in any significant manner. The results are consistent whether these reform variables are considered individually or jointly in the regressions. In most cases, these reform variables are found to have no statistical impact on innovative production. Hence, the results suggest that observed associations found between patent counts and financial policies are unlikely to be affected by the failure to consider other reforms in the economy that may confound the relationships detected, although it is not possible to ensure that all confounders have been taken into account.

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 production. In each regression, we continue to find strong support for cointegration. The results reported in columns (1) to (3) of Table 8 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 knowledge generation. The aggregate measure is obtained by the first principal component of the standardized values 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 patenting activity indeed highlights the importance of considering each component of these policies separately in order to avoid aggregation bias.

7.5. Further robustness checks

To enhance the credibility of our results, we perform several additional sensitivity checks in this section. First, a more comprehensive set of data covering the period starting from 1950 is available for this study. We decided to commence the sample period in 1963 since there was little change in the financial policy environment in India prior to that. However, it would be useful to check if our estimates are robust to this alternative estimation period. The

Table 9
Other robustness checks.

$Dep.Var. = ln\dot{A}_t$	(1) Sample period is 1950–2005	(2) DCP_t is a categorical variable (0, 1, 2 or 3)	(3) $(N/L)_t$ is unlogged	(4) $(N/L)_t$ is R&D workers / No. of trademarks	(5) $(N/L)_t$ is lagged by one period
I. The long-run relationship ($Dep.Var. = ln\dot{A}_t$)					
Intercept	−0.048	0.168	−0.122	−3.086***	0.403
	(0.926)	(0.715)	(0.835)	(0.000)	(0.557)
lnA_t	0.841***	0.831***	0.763***	1.056***	0.792***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$ln(N/L)_t$	0.113***	0.126***	14.289***	0.102***	0.125***
	(0.000)	(0.000)	(0.000)	(0.005)	(0.000)
IRR_t	0.039***	0.035***	0.042***	0.020*	0.034**
	(0.000)	(0.008)	(0.005)	(0.090)	(0.013)
DCP_t	−0.153	−0.019*	0.065	−0.507***	−0.094
	(0.178)	(0.095)	(0.695)	(0.000)	(0.535)
RLR_t	−0.501***	−0.656***	−0.438**	−0.217*	−0.405**
	(0.004)	(0.000)	(0.034)	(0.080)	(0.044)
II. The short-run dynamics ($Dep.Var. = \Delta ln\dot{A}_t$)					
Intercept	0.001	−0.025***	0.015**	0.001	0.004
	(0.988)	(0.000)	(0.021)	(0.977)	(0.541)
ECT_{t-1}	−0.887***	−0.874***	−0.841***	−0.917***	−0.833***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔlnA_t	5.731***	5.505***	5.634***	5.883***	5.659***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ΔIRR_t	0.021*	0.027**	0.026**	−0.001	0.020
	(0.065)	(0.043)	(0.050)	(0.969)	(0.122)
ΔDCP	−0.158	−0.003	−0.019	−0.460***	−0.083
	(0.223)	(0.795)	(0.899)	(0.005)	(0.582)
ΔRLR_t	−0.471**	−0.574**	−0.429*	−0.666***	−0.388*
	(0.017)	(0.014)	(0.054)	(0.004)	(0.078)
III. Cointegration tests					
ARDL bounds test	6.189***	4.108**	4.857***	4.921***	4.578**
ECM test	−5.702***	−4.180*	−4.340**	−4.800***	−4.025*

Notes: (N/L) is research intensity measured using the ratio of R&D workers to the total labor force. Figures in parenthesis are p-values. The test statistics of the cointegration 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.

* Indicates 10% levels of significance.

** Indicates 5% levels of significance.

*** Indicates 1% levels of significance.

first column in Table 9 reports the estimates for the period 1950–2005. They are largely consistent with the previous findings.

Second, while we have chosen to measure the extent of directed credit programs using the share of actual directed credit in total (non-food) credit, it is more common in the literature to capture this repressionist policy using a categorical variable. In column (2), we provide results based on this alternative approach where DCP_t 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 (see, e.g., Abiad et al., 2010; Ang, 2010a for this approach). It is evident that our results remain insensitive to this consideration. This is unsurprising since our measure of directed credit programs and this categorical variable shows a rather high correlation structure of 0.81.

Next, we consider an alternative expression of the research intensity measure without taking logs, to allow for the possibility that the functional relationship between the rate of patenting ($\dot{A}_t/A_t$) and research intensity can be a non-linear one. The results, however, are largely invariant to this consideration (see column (3)).

Fourth, 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 qualitative aspects of our estimates do not show any variations (see column (4)). This finding provides additional confidence that our estimates are not sensitive to the way product variety is measured.

Finally, our estimates may be subject to specification bias given that the R&D activity may be driven by the extent of credit constraint, which in turn depends on financial regulation (see de la Fuente and Marín, 1996). We address this issue by considering a lagged measure of R&D intensity ($(N/L)_{t-1}$) since the decision to conduct research activity is unlikely to be driven by future financial regulation, which is often hard to predict. The results reported in the last column show that our findings regarding how each type of financial policy affects patenting activity are in line with those reported earlier in Table 2, suggesting that potential specification bias associated with R&D may not be an issue.

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 the 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 increases the costs associated with hiding successful innovations by improving the monitoring system, thus spurring 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 ideas production, so far there has been little effort attempting to explore this issue empirically. 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 production 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 results are also robust to the consideration of other reforms in the economy, the inclusion of intellectual property rights protection and cross-border technological spillover variables.

The estimated results based on annual data for over four decades 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. There is also some evidence suggesting that, in addition to this direct effect, interest rate restraints may encourage innovative production indirectly via the channel of savings.

Table A1
Summary statistics (1963–2005).

Variables	Mean	Median	Min.	Max.	Std. Dev.
Number of patent applications filed by domestic residents ($\dot{A}_t$)	1813	1210	878	7180	1523
The stock of patent applications filed by domestic residents (A_t)	12236	10711	5820	33658	5879
Research intensity (N_t/L_t)	0.010	0.007	0.003	0.020	0.006
Research intensity adjusted for human capital (N_t/h_tL_t)	0.008	0.006	0.003	0.015	0.004
Research intensity adjusted for productivity (N_t/a_tL_t)	0.010	0.009	0.004	0.015	0.003
Research intensity adjusted for both human capital and productivity ($N_t/a_th_tL_t$)	0.008	0.008	0.004	0.012	0.002
Index of interest rate restraints (IRR_t)	1.518	1.453	0.390	2.409	0.556
Ratio of directed credit to total non-food credit (DCP_t)	0.298	0.326	0.041	0.431	0.101
Ratio of reserve and liquidity requirements (RLR_t)	0.382	0.380	0.230	0.535	0.084
Ratio of gross domestic savings to GDP	0.219	0.217	0.127	0.356	0.055

Notes: the total number of observations is 43. R&D input is measured using R&D labor (N) whereas product variety is measured by the number of workers (L). Product variety is adjusted for total factor productivity (a) and human capital (h) to account for the fact that innovations become increasingly complex over time.

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Appendix A.

(See Table A1)

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