The unequal effect of India's industrial liberalization on firms' decision to innovate: Do business conditions matter?

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The unequal effect of India's industrial liberalization on firms' decision to innovate: Do business conditions matter?

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Abstract

This paper examines the heterogeneous impact of industrial liberalization policy, the dismantling of the "License Raj" in India, on firms' innovation performance. Our results show that larger and more productive firms in liberalized industries were more likely to take up R&D while the smallest and least efficient firms were less likely to do so. We also show that this inequality of effects was strongest in economically less developed Indian states and where financial development and the knowledge base are weaker. This suggests business conditions shape heterogeneous impacts of liberalization policies to the advantage of initially larger and more efficient firms.

Keywords: Industrial liberalization, innovation, R&D, firm heterogeneities, policy impacts, policy complementarities, firms, India

JEL Codes: O25, O31, O14, D22, L2, L6

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1. Introduction

By defining the conditions businesses operate in, policies can critically affect the competitiveness of industries. In particular, the aggregate productivity gains obtained in many developing countries over the past decades as a result of widespread trade liberalization episodes testify to the importance of liberalization policies.[1] National liberalization efforts are a driver of change[2] by creating competitive environments, which in turn can be powerful catalysts of firms' investments in innovation (Griliches, 1979; Crépon et al., 1998; Hall, 2011 for a survey). In developing country contexts, liberalization policies could also play a critical role in reducing "dual economic structures", that is, the persistent co-existence of highly productive firms with a group of laggard firms, improving in this way aggregate industry performance (Hsieh and Klenow, 2009). Liberalization policies can bring about within-firm improvements[3] (i.e. adjustments at the intensive margin) and change resource reallocations across firms (i.e. adjustments at the extensive margin). Reallocations can bring about substantial aggregate gains if resources flow from the least to the most efficient performers. However, if initially less efficient or small businesses benefit less from liberalization this is not necessarily a reflection of such reallocations: These dynamics may reflect difficult business conditions representing higher non-competitive barriers for these firms' innovation activities than for their larger counterparts. Such barriers, which tend to be more pronounced in developing countries (Tybout, 2000), can effectively prohibit a "level playing field" for different firms and explain why returns from liberalization episodes were often less substantial than expected, namely by excluding a share of potential beneficiaries[4]. With regards to innovation, only those firms with access to financial resources as well as knowledge and skills will be able to innovate in reaction to competitive pressure excluding others – often smaller firms - that might lack the resources to engage in those investments (Hall, 2002; Hall and Lerner, 2010).

The objective of this paper is to analyse explicitly heterogeneous impacts of inward liberalization policies on firms' decisions to invest in research and development (R&D). We explore empirically, using a concrete policy example, the extent to which the business conditions firms face affect the heterogeneous nature of firms' innovation responses in reaction to liberalization. The policy example we focus on is the dismantling of the "License Raj", a system whereby the government controlled firm production activities in India. It provides a rare case of an inward liberalization episode that was unexpected and partial which is ideal for empirical analysis of causal impacts by providing a natural policy experiment (Meyer, 1995). Using the Prowess dataset, which has been used by

[1] See Amiti and Konings (2007); Fernandes (2007); Pavcnik (2002) and Topalova and Khandelwal (2011) for examples.
[2] The empirical evidence on the productivity-enhancing impacts of competition policy across OECD countries supports the idea that such impacts are potentially substantial (Aghion and Schankerman, 2004; Aghion et al., 2009).
[3] E.g. Harrison et al. (2013).
[4] Gupta et al. (2009), for instance, document of limited returns from India's extensive liberalization policies of the 1990s.

Topalova and Khandelwal (2011), Goldberg et al. (2010) and Bas and Berthou (2012) among many others, we apply a difference-in-difference approach to identifying the effects of the dismantling of "License Raj" on Indian manufacturing firms' decisions to invest in R&D.

Our findings confirm that industrial liberalization has a positive impact on firms' decision to invest in R&D. Results show that firms in industries where production licenses were removed increased their probability of undertaking investments in R&D by 9.2 per cent compared to firms in industries that were not delicensed. This indicates aggregate positive impacts of liberalization also via this specific channel: investments in innovation. However, aggregate effects hide substantial heterogeneities: the probability of investing in R&D increased by 14 per cent (14 per cent) for the initially largest (most productive) firms while smaller (least productive) firms reduced their likelihood to engage in such investments by 8 per cent (14 per cent). The econometric analysis includes, in addition to firm controls, firm and industry-year fixed effects. Therefore, it exploits the variation over time and across industries to identify changes in firms' decision to invest in R&D *controlling* for industry-specific trends. These results are also robust to a variety of tests including the use of alternative econometric models, various proxies for firm heterogeneities and the use of R&D intensity as dependent variable. Regarding the causes of heterogeneous impacts, we find that the largest group of firms only benefit exceptionally in environments that are economically less developed and where financial development and the knowledge and skills base are weaker. We, therefore, conclude that liberalization's effects on innovation were partly driven by the absence of a "level playing field" across key conditions for innovation.

The fact that disadvantageous business conditions lead to stronger heterogeneous impacts is critical from a policy perspective and points to the importance of complementary policies for innovation. These, as illustrated by our results, include policies in support of access to finance, knowledge and/or skills as well as, more generally, adequate business framework conditions. In other words, liberalization policies are not a "magic bullet" that will address the challenge of "dual economies" and may in fact in the absence of complementary policies restrain an efficient expansion of the group of innovators beyond businesses of initially large size and strong performance. It is worth noting that if suitable framework conditions are in place, the dynamics of liberalization will likely still be heterogeneous but reflect only efficiency-enhancing differences rather than diverging dynamics driven by disadvantageous business conditions.

Our paper draws on several discussions in the literature. First, it relates to a growing literature on the heterogeneous effects of liberalization policies on firms' performance. Most of these studies focus on outward liberalization policies and their heterogeneous impacts on productivity (e.g. Iacovone, 2012; Fernandes, 2007; Schor, 2004). Bustos (2011) focuses on the heterogeneous impacts on firms' innovation performance.[5] While few papers have assessed inward liberalization reforms

[5] Bas and Berthou (2012) look at a related question, the impact of trade liberalization on technology upgrading.

(since these are often implemented on a more gradual basis or applied simultaneously across all industries rendering empirical analysis of their impact difficult), various studies focused on competition policies and their impacts on productivity (e.g. Buccirossi et al., 2013; Blundell et al., 1999; Aghion et al., 2004, 2009). A few papers analysed the dismantling of the “Licensing Raj” following, however, a different perspective and empirical methodology from ours: Chari (2011) conducts an industry-level analysis and finds the 1985 delicensing led to aggregate productivity improvements of about 22 per cent. Harrison et al. (2013) find in a study that focuses on several reforms that aggregate productivity improvements due to delicensing were concentrated among larger firms. Their evidence is complemented by results from a study by Alfaro and Chari (2013). They identify a decline in the misallocation of resources but also note that in the aftermath of the “License Raj” India’s firm structure was characterized by a large number of small and a small number of large firms with few mid-sized firms. This distribution points to the presence of potential constraints faced by smaller businesses preventing them from growing beyond a certain threshold. None of these papers focus on the impacts of delicensing on innovation, a critical channel of productivity improvements.

Our paper also relates to another literature that has studied the impacts of policies, and liberalization reforms in particular, given the institutional and economic environments firms face. Aghion et al. (2008) focus in their analysis of the “License Raj” on labour market regulations and find that industries located in states with pro-employer labor market institutions grew more quickly than those in pro-worker environments. Gupta et al. (2009) also investigate the question of labour laws but also infrastructure bottlenecks and credit constraints as potential causes behind shortcomings of the reform. Both studies focus on industry-level impacts and do not cover heterogeneous impacts across firms. Their analysis is based on a theoretical model developed in Aghion et al. (2005) which posits that firms innovation performance are likely heterogeneous: there are two factors driving heterogeneous impacts, firms’ closeness to the technological frontier and the institutional environment they face, where they focus specifically on labor market regulations. Aghion et al. (2013) investigate empirically the impacts of a specific institutional context (the strength of patent rights) on how policies (product market competition) affect industries’ innovation performance.[6] Differently from ours, none of the papers focus explicitly on how complementary business environments might drive heterogeneous rather than average impacts.

The contributions of our paper are threefold. First, to the best of our knowledge, ours is the first paper to focus on the question how the institutional and economic environments firms face affect

[6] Related papers focusing on other outcome variable than innovation include Buccirossi et al. (2013) who explore the interactions between institutions and policies and find complementarities among them, including contract-enforcement conditions and quality of the judicial system which have impacts on the effects competition policy will have on TFP growth. Aghion and Schankerman (2004) provide a theoretical framework. Other papers that focus on complementary effects in development contexts are Freund and Bolaky (2008) who study trade impacts on growth depending on six domestic policies including business and labor regulations, which they find to be important. Finally, Topalova and Khandelwal (2011) find complementarities between trade liberalization and additional industry reforms in their analysis of India’s liberalization reforms.

heterogeneous rather than aggregate impacts of liberalization i.e. we explore the question how firms of different initial productivity and size levels are affected differently by liberalization due to the business conditions they are faced with. By exploiting differences across Indian states and industries, we focus on three dimensions that are critical drivers of firms' R&D investments: a) the institutional context proxied by the level of economic development, b) access to finance and c) access to knowledge and skills. In so doing, we expand the range of institutional factors beyond those most directly relevant for competition discussed in the previous literature to critical complementary factors for innovation. The evidence is not only important from the policy perspective, by helping document the complementary policy needs for making liberalization's pay-offs largest, but also for understanding better the determinants of heterogeneities and the extent to which increasing competition alone can help reduce inefficiencies. Second, ours is the first paper to investigate the impacts of the "Licensing Raj" on firms' decisions to invest in R&D, that is, we investigate the impacts of licensing on a specific channel behind productivity improvements. In this way the paper provides a direct test of the model presented in Aghion et al. (2005). This is the more so interesting to investigate for the case of Indian over the 1990s as the number of R&D investing firms expanded substantially over the period (see discussion below). Third, we apply a rigorous estimation strategy including 3-digit industry-year and firm fixed effects to identify effects, a procedure that allows isolating impacts of the "Licensing Raj" from other contemporaneous reforms as well as industry trends.

The reminder of the paper is organized as follows. Section 2 discusses the theoretical framework behind heterogeneous impacts of liberalization on firms' innovation decisions focusing on impacts of initial firm characteristics and external business conditions. Section 3 discusses the natural experiment we use for testing impacts empirically: India's 1991 dismantling of the "License Raj". Section 4 describes the data and establishes a few empirical facts. Section 5 specifies the empirical framework while Section 6 presents the results. Section 7 concludes.

2. Theoretical framework

2.1. Efficiency and heterogeneous impacts of liberalization

Multiple factors can adversely impact the efficient allocation of resources across firms of different productivity potential (Restuccia and Rogerson, 2008). Regulations governing free entry and firm size are a critical source of inefficiencies. Liberalization policies are, therefore, particularly attractive also for increasing resource allocations in favour of those with largest capacities. Various theoretical models predict that only a subset of initially most efficient firms will innovate or upgrade technology in response to liberalization (Aghion et al., 2005; Iacovone, 2012; Bustos, 2011). The main assumptions underlying this framework are that R&D investments have a fixed cost component and that firms are heterogeneous in terms of their size and marginal costs. Lower-cost firms can set lower prices and have greater sales. In this context the most efficient firms are most likely to increase R&D investments in response to liberalization to exploit economies of scale they were previously prevented from taking advantage of. These firms will be incentivized to invest in innovation to defend their market position *vis-à-vis* potential entrants as liberalization reduces barriers to entry. However, firms of lower productivity and much more distant from the technology frontier will be less likely to do so because for them chances to effectively compete with entrants are much lower (Aghion et al., 2005). We would, therefore, expect liberalization to have heterogeneous impacts on firms' decisions to invest in R&D. This would be in line with reallocation dynamics from the least to the most efficient firms and would, from an aggregate economy's perspective, be efficiency-enhancing by facilitating the exploitation of economies of scale in R&D. However, as emphasized in Aghion et al. (2005) firms' responses to liberalization will also be affected by external factors: the business conditions they face. This dimension will be discussed next.

2.2. Business conditions and heterogeneous impacts of liberalization

Factors external to the firm can lead to differential responses to liberalization when it comes to innovation: Access to critical enabling factors for firm R&D investments might differ. The following three can be identified: i) favourable institutional and business framework conditions, ii) access to external financial resources for R&D investments, and iii) access to relevant knowledge and skills. Shortcomings across these dimensions in developing countries have effectively been identified as stumbling blocks for firms' innovation performance (Tybout, 2000); this includes in particular the performance of smaller and catching-up businesses.[7] Beck and Demirguc-Kunt (2006) conclude based on an overview that: "Small firms not only suffer more from market frictions such as transaction costs and information asymmetries than large firms- but these market frictions have a disproportionately larger effect on small firms in countries with less developed institutions." We will discuss each of the three critical dimensions for innovation in turn illustrating reasons behind expected heterogeneous impacts.

First, institutional and business framework conditions (which include government services to businesses e.g. for the registration of intellectual property rights or to obtain permits as well as the provision of critical business infrastructure) can have important impacts on innovators since they require government-supplied goods such as permits, import and tax licenses and, in the case of start-up initiatives, a series of permits for operation that established producers no longer require. That is why, a critical weakness for institutional business conditions, corruption, can discourage investments in innovation. For instance, firms may adopt inefficient "fly-by-night" technologies of production because these have a high degree of reversibility to be prepared to close down if necessary as new demands from corrupt officials arise (Svensson, 2003). What is more, in the absence of adequate

[7] See e.g. OECD Reviews of Innovation Policy for a range of assessments of developing countries.

economic, political and legal institutions, the payoffs to growth-enhancing innovation activities may be reward innovators less and more unproductive activities more (notably activities aimed at rent-seeking such as excessive lobbying or lawsuits) (Baumol, 1990).

These factors will likely impact firms differentially, affecting larger firms much less than the remainder. For instance, Paunov (2014) finds that negative impacts of corruption on firms' ownership of intellectual property rights, which critically depend on institutional quality, are much larger for smaller firms than for larger ones. Reasons for such differences include scale benefits in bribing i.e. payments to officials might allow wider access to government services and, thus, bring higher returns for given payments to larger firms. Moreover, large established firms might be more favored in corruption games as "collusion" with large firms can create "trusted" relationships with corrupt officials. Finally, large firms can internalize some of the costs arising from weak business framework conditions in instances where infrastructure services are missing or unreliable and produce their own power, transport and/or communication service (Tybout, 2000). This requires a certain scale of production which small firms normally lack.

Second, access to finance is another core factor for innovation investments. There is wide evidence showing that financial constraints hold back firms' innovation activities in both developed and developing countries (e.g. Hottenrott and Peters, 2012; Gorodnichenko and Schnitzer, 2013). A wide theoretical literature has effectively identified inefficiencies in financial markets when it comes to financing innovation (Cabral and Mata, 2003; Albuquerque and Hopenhayn, 2004; Cooley and Quadrini, 2001). The increased risk factor of many R&D investments and information asymmetry challenges render financing for innovation more challenging than other types of financing. The overall impact of financing constraints on innovation investments is non-negligible: Brown et al. (2009) find financial factors to play a substantial role in explaining trends of R&D.

The financing challenges tend to be particularly important for smaller firms (see Hall, 2002, and Hall and Lerner, 2010, for surveys). This is notably the case as they have fewer internal resources to commit to investing in innovation while external credit is difficult to obtain as they often have low collateral and short credit histories. Credit constraints due to weaknesses in the financial sector have also been identified to hold back smaller firms from engaging in productivity-enhancing investments (Beck and Demirguc-Kunt, 2006; Fafchamps and Schündeln, 2013). Weakly developed financial markets likely operate even more to the disadvantage of small firms as fewer viable projects will be funded and, in a context of weak enforcement, banks are even more likely to provide support to larger clients to reduce lending risks (Tybout, 2000).

Third, access to a knowledge and skills networks is also critical as "standing on the shoulders of giants" matters for advancing research and knowledge (e.g. Scotchmer, 1991; Arthur, 1997). The ability of firms to connect to knowledge networks will facilitate developing R&D investment projects (e.g. Baptista and Swann, 1998; Leiponen, 2005). Geographic clustering encourages such spillovers by permitting the rapid flow of technical information between producers operating near one another, and also by enhancing information flow between suppliers, producers, traders, and others connected to the cluster. Effectively two of the three explanations for positive agglomeration externalities put forward by Marshall (1920) refer to local information and knowledge spillovers and a skilled local labour pool (the third is the local supply of non-traded inputs). Given that one of the major characteristics of developing countries is their weak technological base, technological spillovers can be crucial elements for industrial development. Moreover, firms' own "absorptive capacities" will also matter to reap benefits from knowledge networks. However, while a threshold level of "absorptive capacities" is likely critical (Girma, 2005) there are opportunities for external networks to substitute for internal knowledge capacities particularly for smaller firms.

Effectively to the extent that economies of scale arise, small firms stand to benefit more from external geographically close knowledge networks than larger businesses (Nieto and Santamaria, 2010). That is because larger businesses can, if needed, internalize more of the knowledge production (as they have greater scale) and have larger opportunities to tap into external knowledge networks as a way to substitute for missing knowledge networks in close proximity to their location. Small firms are, in consequence, more likely to be at a disadvantage if the regional context does not offer a sufficient knowledge and skills base (e.g. Visser, 1999) due to a lack of scale and risk-bearing capacities to provide the full set of inputs needed for engaging in innovations. Observations from successful clusters such as Silicon Valley have suggested that the geographical proximity of small firms critically strengthens their innovation performance in particular (Saxenian, 1994).

The overview provides a series of factors that are likely strongly differential across firms. We will test the extent to which these different factors effectively drive heterogeneous impacts of liberalization on firms' decisions to invest in R&D.

3. Industrial liberalization policies in India: A natural experiment

3.1. Identifying impacts of liberalization policies

The extent to which market conditions and in particular those arising in developing countries drive firms' innovation performance is an empirical issue, which, in many ways, is challenging to identify. A major factor and challenge is the possibility of reverse causality – it is well known that political economy factors can affect liberalization with those most likely to benefit being among their strongest defenders. This would hinder identification substantially as positive effects would rather be due to selection rather than to liberalization. Another factor that renders identification difficult is that if firms anticipate reforms, as is often the case as reforms are pre-announced by political parties, then firms likely adjust their actions pre-empting reforms. In this case impacts cannot be identified. Thus, identification will ideally require a quasi-natural experiment where liberalization is introduced unexpectedly so as to provide no opportunities for lobbying. Moreover, in order to test to what extent potential heterogeneous effects are driven by business opportunity rather than scale, we would seek to cover a variety of different business contexts and markets. It is for these reasons that we rely on the dismantling of “License Raj” across industries to identify the effect of the changing the industrial regulatory environment on firms' innovation patterns. The focus on India also provides for a variety of different business contexts – across different Indian states – to explore to what extent unequal opportunities affected firms’ decision to innovate.

3.2. The dismantling of India’s “License Raj”

India’s industrial liberalization policies of the mid-1980-1990 period provide an interesting case for studying the heterogeneous impacts on firms’ innovation performance as they substantially but unexpectedly changed the business environment firms faced compared to the period from the 1950s to the mid-1980s.

During that time period the “License Raj”, a system established in India’s “Industries Development and Regulation Act” of 1951, was in place. This industrial regime was very restrictive as firms were required to obtain an official license from the central government to operate. The license specified not only if the firm was allowed to operate but also the amount of output that the firm was able to produce during the specific period of the license. The government enforced this license through the effective control of the quantity of raw materials (like fuel and coal) that were assigned to each firm (Chari, 2009). This protectionist industrial regime was part of the economic program aimed at the development of the domestic market and industrialization favouring state-owned companies and small private firms. Kochhar et al. (2006) shows that the policies under the “License Raj” resulted in small-sized private firms in manufacturing; in 1990 the average manufacturing Indian firm was more than ten times smaller than the average manufacturing firm in the United States. Beyond costs imposed by not exploiting scale effectively, firms had limited incentives to invest and, to the extent that scale matters for innovation, this likely affected their innovation activities.

Steps to liberalize industries were implemented fully in 1991. The first industrial reform was applied by Rajiv Gandhi in 1985 and consisted in dismantling the “License Raj” in a small number of industries by exempting them from licensing requirements for capacity expansion (Chari, 2011).[8] No plans were set regarding the possible future liberalization of additional industries particularly with the change of government in 1989. The substantial wave of liberalization took place in 1991 in the context of India’s balance-of-payment crisis. As part of structural reform plans defined by the IMF, industrial licenses were removed completely in 1991 for a more substantial number but only a selection of industries.[9] The list of these industries is presented in the Appendix. These 1991 reforms were implemented shortly after the government of Rao was established, which took place after the

[8] This included producers in printing and publishing, leather and leather producers, inorganic heavy chemicals, soaps, cosmetics and glycerine, certain rubber and plastic producers as well as producers of cement.
[9] See the policy objectives stated by the Indian Government on the “Statement on Industrial Policy” on the 24 July 1991. The reasons why the license system was maintained in a few industries is for “security and strategic concerns, social reasons, problems related to safety and over-riding environmental issues, manufacture of products of hazardous nature and articles of elitist consumption”. (page 5, http://dipp.nic.in/English/Policies/Industrial_policy_statement.pdf)

assassination of Rajiv Gandhi. It is, therefore, highly improbable that certain firms/industries anticipated the reform and lobbied either in favour or against the dismantling of the "License Raj" (Aghion et al., 2008; Alfaro and Chari, 2013).

If the government had targeted specific firms/industries in the 1991 plan of industrial liberalization, then we would expect changes in industrial licensing status to be correlated with initial firm performance. Table 1 shows the results of an OLS estimation from regressing firm characteristics in 1989 on the variation in the industrial licensing status across industries between 1989 and 1992, the year after the industrial reform was introduced. However, the correlation is insignificant for all variables. These results confirm previous findings of Aghion et al. (2008), Topalova and Khandelwal (2011) and Bas and Berthou (2013) among others who also show that there is no relationship between deregulation and pre-reform sales growth. Aghion et al. (2008) also point out that there is no apparent observable industry characteristics that might have affected the government choice of industries that were deregulated relative to those that were not. The arbitrary character of this decision reduces possible selection concerns one might raise regarding this particular liberalization episode. The 1991 delicensing reforms in India are, therefore, a suitable quasi-natural experiment for the purposes of our analysis.

4. Overview of the data

4.1. Data used for the analysis

Our empirical analysis is based on the Prowess database by the Centre for Monitoring the Indian Economy (CMIE).[10] Our final sample contains 16,404 observations with on average yearly information for 1,600 manufacturing firms for the period 1989-1999. Firms with missing information on any of the control variables are excluded.[11] The companies account for more than 70 per cent of the economic activity of India's formal industrial sector (Topalova and Khandelwal, 2011). Collectively, the companies covered in Prowess account for 75 percent of all corporate taxes collected by the Government of India. The database is, thus, representative of India's formal businesses. The data have been used in several studies (Topavola and Khandelwal, 2010; Goldberg et al., 2010; Bas and Berthou, 2012, 2013; Alfaro and Chari, 2013). The Prowess dataset is the only firm-level data of India that has a panel dimension and allows studying the dynamic of growth within firms over time. It provides quantitative information on sales, capital stock, consumption of raw material and energy, compensation to employees (wage-bill), expenditures on R&D and ownership group (private, state-owned or foreign owned), financial statements such as assets, profits and year of incorporation of the firm, location of the firm, main industry at the 5-digit NIC industry classification from India.

[10] The CMIE is an independent economic centre of India that provides services of primary data collection through analytics and forecasting. Further information can be found at http://www.cmie.com/.

[11] Unreported tests which are available from the authors upon request show that the exclusion does not create undue biases.

There are two main advantages of the Prowess dataset relative to other firm level datasets on Indian firms.[12] The first advantage is that the Prowess dataset is the only representative panel firm-level data for Indian firms in the manufacturing sector. This nature of the dataset allows investigating the dynamic effects of the industrial liberalization on firm performance. The second advantage is that the dataset reports detailed information that are relevant for studying innovation choices such as R&D investments at the firm level. It also allows computing total factor productivity, which we estimate using the Olley and Pakes (1996) methodology.

A few caveats are important and necessary to highlight. First, firms are under no legal obligation to report to the data collecting agency. In particular, the dataset does not provide information on the smallest firms. Thus, the dispersion of firm performance and heterogeneous effects of industrial reforms might be even greater than what our analysis can assess. Second, this dataset does not distinguish the type of qualification of workers. There is no information on the number of employees or on the type of workers activity. There is only information on the wage-bill.

We rely on the “Statement on Industrial Policy” of India in 1991 to identify the industries that have been delicensed in that year. This statement describes in the Annex I and II the list of industries to be reserved to the public sector and the list of industries for which industrial licensing continue to be compulsory after the industrial reform of 1991.[13] Appendix A presents the list of these industries. The remaining industries were liberalized in 1991 or in 1985. In the empirical study, we exclude from the analysis the five industries that were delicensed in 1985.

Finally, we use data from the Reserve Bank of India to measure state-level GDP and credit expenditures.

4.2. Data exploration: A few empirical facts

Before analysing the relationship between India’s industrial liberalization and firms' decision to innovate, this section provides a first inspection of the data.

Empirical fact 1: A significant increase in private R&D investments and in the number of firms engaged in R&D activities coincides with the dismantling of the “License Raj”. The biggest increase in the share of innovating firms occurred just after the industrial reform and only in industries that were liberalized.

During the period of the “License Raj” firms’ innovation and technology performance was much lower than in the post-liberalization period. R&D investments have grown quickly in India’s private manufacturing sector during the nineties. In 1995 the private investment in R&D across all manufacturing firms in the Prowess dataset was 14 times greater than in 1990. The growth of R&D

[12] The other firm level data available for India is the Annual Survey of Industries (ASI). However, there is no information on innovation expenditures at the firm level in the ASI.
[13] The “Statement on Industrial Policy” of India in 1991 is available in: http://dipp.nic.in/English/Policies/Industrial_policy_statement.pdf.

investments was driven by a substantial increase in the number of innovating firms, which increased from 3 per cent at the end of the 1980s to 27 per cent in 1999. For this reason, our empirical analysis focuses on the decision of firms to invest in R&D. It is worth noting that the biggest increase in the share of innovating firms occurred just after the industrial reform and only in industries that were liberalized (Figure 1). The share of innovators remains almost constant in industries that were not affected by the industrial reform. Such private sector trends were also accompanied by comparable trends in public investments in innovation.[14]

Empirical fact 2: Firms investing in R&D are on average larger, have higher capital stock, a greater wage-bill, and are more profitable and productive than firms that do not invest in R&D. This fact might point to lower returns from or higher costs of R&D investments for firms lacking those characteristics, including for smaller and less efficient firms.

Table 2 presents an innovation premia analysis with each specification giving correlations of a series of firm characteristics and firms' R&D investment status. These control for industry and year fixed effects. Results show that even within an industry there are substantial differences across innovators and non-innovators in that innovators have a series of positive and significant characteristics. These results are in line with the existing theoretical and empirical evidence on the characteristics of innovating firms – whether as determinants or outcomes of innovation activities (e.g. Bustos, 2011; Bas, 2012; Doraszelski and Jaumandreu, 2009; Griffith et al., 2006 a, b).

Empirical fact 3: The share of firms investing in R&D increased much more substantially in the period following the delicensing among larger and more productive firms. The share among the highest quartiles increased most.

Figure 2 shows the share of R&D investors for different groups of firms categorized by the initial size and productivity distribution. The data show that in the period prior to liberalization only a small share of firms invested in R&D. There were only minor differences across groups with respect to size and none with respect to TFP. A decade later, however, the share of R&D investors had increased substantially and those changes proved to be much larger for the top 3 quartiles with the top group having highest overall increments.

Empirical fact 4: The percentage point changes in firms' propensity to innovate after delicensing differ for firms located in states with more or less advanced business environments. It is in least advanced business environments that the difference in increments between the least and most productive businesses is largest.

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[14] The Ministry of Sciences and Technology from India reported public investment in R&D was ten times higher in 1995 relative to the levels in 1980. Between 1990 and 1996, the average investment in technology from all public agencies has increased by 69 per cent with some strategic agencies that attaint more than 100 per cent (as e.g. the Defence Research and Development Organization and the Department of Space).

Figure 3 reports percentage point changes in the share of firms who invested in R&D over the 10-year period from 1990-1999 across different size and productivity quartiles separately for firms operating in Indian states with high and low GDP. Those point increases are larger for firms of higher size and productivity across both states. Interestingly, however, the difference in increments differs by business environment with a much larger gap in least developed business environment. This might be because in such contexts larger businesses are at a greater advantage by being able to cover sunk costs more easily compared to smaller businesses. These simple statistics thus point to potentially complementary effects of the business environment on firm performance.

Overall, these empirical facts suggest that industrial liberalization might be associated to the expansion of the number of firms that invest in R&D. Moreover, the effects of this reform might differ according to the firms' initial production capacity or alternatively to different impacts due to alternative business environments faced by firms. The next section presents the empirical strategy to identify the effects of industrial liberalization on firms' R&D decision taking into account these empirical features of the data.

5. Estimation strategy

5.1. Baseline equation

The quasi-natural experiment of the dismantling of the "License Raj" as described above allows applying a difference-in-difference methodology. The treated group corresponds to firms producing in 3-digit NIC industries where the production licenses were completely removed in 1991 and the control group is formed by firms producing in those industries that were not affected. This methodology consists in exploiting the variation over time of the reform of industrial licensing across different industries to identify impacts on their decision to invest in R&D. This is a similar framework to the one applied by Aghion et al. (2008) at the industry level and results in the following baseline estimation model:

$$\mathrm{R\&D}_{\mathrm{i,s,t}} = \alpha_0 + \beta_{\mathrm{D}} \mathrm{D}_{\mathrm{s,t}} + \beta_H H_{s,t} + \beta_x \mathrm{X}_{\mathrm{i,t}} + \mu_{\mathrm{i}} + \nu_t + \mathrm{e}_{\mathrm{i,s,t}} \qquad (1)$$

where $R\&D_{i,s,t}$ takes the value of one if firm *i* producing in 3-digit NIC industry *s* invested in R&D in year *t*. $D_{s,t}$ captures the dismantling of the "License Raj". $H_{s,t}$ is the Herfindahl index, a control variable for the level of industry concentration at the 3-digit NIC industry level. The vector $X_{i,t}$ includes a series of firm level variables that control for observable firm characteristics. These include, following the theoretical and micro-level empirical literature on firms' R&D decisions (Aw et al., 2008; Doraszelski and Jaumandreu, 2009, Griffith et al., 2006b), i) the profit ratio of the firm, ii) firm size measured by the wage-bill and iii) firm age. Appendix Table 1 provides detailed information on how different variables are computed. We also add year-fixed effects to control for macro-economic shocks affecting all manufacturing industries in the same way (ν_t). Importantly the specification also includes, differently from Alfaro and Chari (2013), firm fixed effects to control for unobserved firm heterogeneity (μ_i).

By including firm-fixed effects, the coefficient of interest, β_D, captures the differential effect across industries and over time of industrial deregulation on within-firm innovation decision. A positive (negative) significant coefficient would imply that firms producing in 3-digit NIC industries that have been deregulated have a higher (lower) likelihood to innovate relative to firms producing in industries that are still under the license system. It is important to note that the inclusion of firm fixed effects allows controlling for time-invariant firm characteristics, which might have impacts on firms' R&D investment decisions.

We estimate equation (1) as well as all subsequent equations using a linear probability model in our estimation[15] and apply standard errors that are clustered at the 3-digit industry level to correct for autocorrelation across errors within industries.

5.2. Identifying heterogeneous effects of industrial liberalization on firms' innovation strategies

This section extends the empirical strategy to take into account the possible heterogeneous effects of industrial liberalization on firms' R&D decisions depending on initial firm performance:

$$\mathrm{R\,\&\,D}_{i,s,t} = \alpha_0 + \beta_{DP} \mathrm{D}_{s,t} \,\mathrm{x}\, \mathrm{P}_{i,t0} + \beta_x \mathrm{X}_{i,t} + \eta_{s,t} + \mu_i + \mathrm{e}_{i,s,t} \qquad (2)$$

where $\mathrm{P}_{i,t0}$ is a variable of firms' initial sales or TFP levels. The term β_{DP} will then capture the differential impacts of delicensing with respect to firms' size and their efficiency. Note that the initial firm performance variable is excluded from the estimation since it is controlled for with firm fixed effects. Differently from equation (1) in this specification we can also to control for industry-year shocks affecting each 3-digit industry differently over time by including industry-year fixed effects ($\eta_{s,t}$). This is an advantage for this specification as it allows capturing all the reforms that took place in India in the 1989-1999 period and that might affect industries differently over time including trade and FDI liberalization policies. Therefore, neither our indicator of delicensing ($D_{s,t}$) nor the Herfindahl index ($H_{s,t}$) need to be included as part of this specification. The specification exploits varying changes across industries and over time in the industrial reform with the firms' initial sales and TFP.

Moreover, in order to assess effects of delicensing across different parts of the distribution we include in the previous specification interaction terms between quartiles of initial firm sales distribution and the industrial reform indicator variable. This approach follows Bustos (2011) and Bas and Berthou (2013) among others. Equation (2) is modified to take into account the non-linear effects of industrial liberalization on firms' innovation decisions in the following way:

[15] Robustness results reported in Panel A of Table 4 show that our results are maintained for alternative econometric models.

$$\mathrm{R\,\&\,D}_{\mathrm{i,s,t}} = \alpha_0 + \sum_{J} \beta_{j,s}\ \mathrm{D}_{\mathrm{s,t}}\ \mathrm{x}\ \mathrm{Q}_{\mathrm{j,i,t0}} + \beta_x\ \mathrm{X}_{\ \mathrm{i,t}} + \eta_{\mathrm{s,t}} + \mu_{\mathrm{i}} + \mathrm{e}_{\mathrm{i,s,t}} \qquad (3)$$

where $Q_{1,i,t0}$ corresponds to the first quartile of initial size (TFP) distribution that represents the smallest firms and $Q_{4,i,t0}$ corresponds to the largest ones. Note that this specification includes firm fixed effects that are collinear with firms' initial performance quartiles, which are excluded from the estimation.

5.3. The role of business conditions

We extend our analysis to test to what extent the different market conditions described above affect overall and heterogeneous impacts of liberalization by exploiting state- and industry-level variations. Relying on state- and industry-level variables of market imperfection in the years prior to delicensing instead of firm-level variables of financial access and technological inputs allows us to deal directly with the potential endogeneity concerns between these firm characteristics, firms' initial size and R&D decisions.

First, we exploit the diversity in business opportunities across India's 21 states and explore the impacts of differential opportunities by estimating equations (1) and (3) for states with above- and below-median performance in each of the three cases. We use i) state-level GDP per capita as a measure of economic development to capture a variety of business framework conditions, ii) the ratio of credit over GDP by state as a measure of financial development and iii) the number of patents as a measure of knowledge prior to the liberalization reforms. It is important to note that the different samples are only weakly correlated allowing identification of the impacts of differential business conditions on firms' R&D decisions. We use data from the Reserve Bank of India for the year prior to the 1991 reforms. Appendix Table 1 provides additional details.

Second, as an additional test of the relevance of financial development and access to knowledge, we adopt an alternative approach and explore, in the case of financial development, the extent to which heterogeneous effects hold differentially for firms operating in industries that are more dependent on financing than others. For this analysis, we rely on the standard measure used in the literature of external dependence in US manufacturing industries proposed by Rajan and Zingales (1998) and updated by Braun (2002) and Braun and Larrain (2005). If financial development conditions are a binding factor behind differential effects, we would expect them to hold for those industries that rely more substantially on financing but not for others. We estimate equation (3) separating the sample into industries with greater and weaker reliance on financial resources. We adopt the same approach for the question of knowledge splitting the sample into industries that rely more or less on knowledge-intensive inputs. For the access to technological inputs at the industry level, we rely on the measure of differentiated and homogeneous goods proposed by Rauch (1999). If knowledge played a role in such effects, we would again expect those effects to hold more strongly for industries that rely more on knowledge than for others.

6. Results

6.1. Impacts of industrial liberalization on firms' R&D investment decisions

This section presents the baseline results on the relationship between industrial liberalization and firms' R&D decisions. Columns (1) to (4) of Table 3 present the results of the estimation of the linear probability model presented in equation (1) using a within-firm estimator. The estimates in column (1) show that the coefficient on the delicensing measure is positive and significant. This result suggest that firms producing in industries affected by the dismantling of the production licenses (the treated group) are more likely to invest in R&D over the period 1989-1999 relative to firms producing in industries were the licenses were not removed (the control group). Higher levels of industry concentration, as measured by the Herfindahl index, are positively correlated with firms' R&D investments. Our coefficient of interest on the delicense measure is robust and stable to the inclusion of these firm level controls suggesting that firm performance measures that determine the decision to innovate are not picking up the effect of industrial liberalization. Columns (2) to (4) introduce several firm level variables that control for observable firm characteristics varying over time that may affect firms' R&D decisions. We find that firms with larger profits have a greater probability of investing in R&D (column 2). Firm age is negatively correlated with firms' R&D investment decision (column 3) while the reverse is the case for firms' wage-bill. The estimated coefficient implies that industrial liberalization increases firms' probability to invest in R&D by 9.2 per cent for the average firm over the period. These results are in line with the findings in the literature for the impact of industrial liberalization on firm and industry performance in India (Aghion et al., 2008; Harrison et al., 2013).

Regarding heterogeneous impacts in terms of initial size (based on sales) and productivity (based on TFP), our results indicate substantial heterogeneous effects with delicensing having a positive effect for larger and more productive firms. Columns (5) and (7) of Table 3 present the estimates of equation (2). The coefficient on the interaction term is positive and significant in both specifications. Columns (6) and (8) of Table 3 present results for equation (3). The estimates suggest that industrial liberalization increases the incentives to invest in innovation for initially larger and more productive firms (fourth quartile), while it decreases those incentives for smallest and least productive firms (first and second quartile). Firms with highest initial sales and productivity increased their probability of investing in R&D by 14 per cent, while the smallest firms reduced their likelihood to innovate by around 8 per cent and the least efficient by about 14 per cent.

6.2. Robustness

This section presents a series of sensitivity tests of the previous results, which are reported in Panels A to C of Table 4.

First, we consider alternative econometric specifications to estimate firms' R&D decisions using probit and conditional logit models. In the previous estimations, we rely on a linear probability model with firm fixed effects to estimate the determinants of firms' decision to innovate. The advantage of this linear probability model relative to alternative specifications to model firms' R&D choices is that it allows capturing unobservable firm characteristics that do not vary over time using a within-firm estimator. However, this model assumes that the likelihood of innovating varies linearly with changes in independent variables. This assumption is not required for the probit model which assumes a non-linear relationship between industrial liberalization and the probability of investing in R&D. For each firm, there exists a threshold level that determines whether the firm innovates or not. The probit model assumes that the unobservable threshold level that determines firms' R&D decision is normally distributed. Thus, we explore if our findings are robust to using a probit model. Since due to the incidental parameters problem, the probit model cannot be consistently estimated with firm fixed effects, we estimate a probit model with random fixed effects. Columns (1) to (5) of Table 4 present the marginal effects for the probit estimations. The coefficient of interest on delicensed is positive and significant confirming the previous results (column 1). Column (2) and (4) confirm industrial liberalization has a stronger effect for initially larger and more productive firms. Column (3) and (5) validate the non-linear effects of industrial liberalization found in the previous estimations. For this specification, firms in the third and fourth quartile of the initial size and TFP distribution benefitted mostly from the dismantling of the “License Raj”. As expected, this coefficient is now much higher than the one in the previous specification since the time-invariant unobserved heterogeneity is only taken into account in the linear probability model.

Another alternative econometric specification to estimate a binary outcome model of the determinants of firms' innovation decision is a logistic regression. We present in columns (6) to (10) of Panel A of Table 4 the marginal effects after a conditional logit model with firm fixed effects. The conditional logit estimator relies on the sample of firms that change their R&D status at least once over the period. The number of observations is then highly reduced since this specification excludes firms that do not innovate and those that invest in R&D during the whole period, but it allows controlling for unobservable firm characteristics that do not vary over time. Overall, the results of these alternative econometric specifications confirm the previous findings on the effect of industrial liberalization on firms’ R&D decisions.

Second, we present evidence on the effect of industrial liberalization on the intensive margin of R&D investments. If industrial reform affects firms’ R&D decision, we expect that removing the production licenses also enhances the level of investment in R&D.[16] We rely then on an OLS estimation with firm fixed effects regressing R&D intensity (the ratio of R&D investments over total sales) on the industrial delicense measure. Column (1) shows that the coefficient of interest on the delicense measure is positive and significant for the baseline specification. This implies that industrial

[16] We also verified that our results are not driven by sample selection. All the estimations are robust and stable when we focus on the sample of firms that is present during the whole period 1990-1999. These results are available upon request.

liberalization increases the share of R&D investments within-firm over time. Interacting R&D intensity with initial firm sales and TFP levels confirms that heterogeneous effects also arose for the levels of R&D investments, as shown in Columns (2) and (4) of Panel B of Table 4. We also find that firms in the higher quartiles were more positively affected than those in the lowest quartile based on initial sales (column 3) while results for TFP point in the same direction but were not significant (column 5).

Finally, we test evidence for alternative approaches to assessing initial firm heterogeneities. First, columns (1) and (2) of Panel C of Table 4 show results for impacts of delicensing on R&D where initial size is measured by the wage-bill instead of firm sales. These results confirm our main findings with stronger impacts on firms with a higher initial wage bill and strong positive effects for the largest quartile. Second, we test whether our results are robust to using alternative thresholds of initial sales distribution such as above and below the median initial sales, or for low (below the 33rd percentile), medium (between the 33rd and the 66th percentiles) and high (above the 66th percentile). Results presented in Columns (3) and (4) of Panel C of Table 4 confirm this to be the case.

6.3. Disentangling the impacts of business conditions

This section reports results exploring impacts of the three enabling factors for firm R&D discussed in section 2 on overall impacts of liberalization on firms' decisions to undertake R&D investments and in particular on whether they were drivers behind heterogeneous impacts of liberalization.[17]

Table 5 reports results that explore whether different levels of economic development affect results as a rough proxy for institutional and business framework conditions. Columns (1) and (2) suggest that overall the impacts of liberalization on R&D investment decisions were positive both in more and less developed Indian states. However, we find differences across the two samples regarding heterogeneous impacts as indicated by Columns (3) and (4) for initial sales and (5) and (6) for TFP. We find that significant positive effects for the highest quartile in sales and TFP hold only in states with low economic development, i.e. in these states benefits accrue disproportionately to the largest firms. This supports the hypothesis that economic conditions matter in particular for heterogeneous impacts of liberalization.

Table 6 explores the extent to which the second key factor, financial development, drives effects. Columns (1) and (2) show that delicensing led to increased R&D investments by both firms in states with more and less financially developed sectors. We find positive average improvements.

[17] One concern regarding results reported in this section might be a high level of correlation across states regarding their economic and financial development as well as the level of patenting. This would render identification of specific explanatory factors impossible. However, we find that correlations to be sufficiently low (economic development measured by GDP is correlated with patent intensity at 0.4 and with financial development at 0.19, while patent intensity and credit ratio are correlated at 0.26) to allow distinguishing across the different contexts. The industry-level evidence supports conclusions further.

Evidence on heterogeneous effects suggests that the largest size quartile is much more likely to benefit only in states with low financial development. These results, however, are not maintained if we use TFP instead. In order to test whether our results effectively relate to financing opportunities for firms, we split our sample across industries with high versus low financial dependence. Columns (7) to (10) report results showing significant positive effects for industries with high dependence for the highest quartiles. This supports evidence on the role of financing conditions as an explanation of heterogeneous impacts of licensing on R&D investment decisions.

Finally, Table 7 explores the extent to which the knowledge and skills base drives impacts. Columns (1) and (2) show that aggregate effects are positive significant in different contexts independently of whether they are located in a state with stronger or weaker patenting, a proxy we use as an indicator of the available geographic knowledge base. Columns (3) and (4) indicate for sales and Columns (5) and (6) for TFP that effects are much more substantially unequal for firms in environments with low knowledge base – where potentially the capacity of larger firms to get such knowledge from other (internal or external) sources will make the critical difference. Columns (7) to (10) explore how effects differ across industries with different degrees of reliance on knowledge inputs, while we find the coefficient to be larger for high-reliance industries, we find positive effects for the largest quartiles also for industries relying less on those.

Overall, the results suggest barriers to firm operations in less developed economic environments, limited access to knowledge conditions and financing drive unequal effects of delicensing. This points to potentially suboptimal allocation of R&D investments across initially differently sized and differently productive firms as complementary costs seem to have affected differential impacts of delicensing. It is worth noting that our results do not, however, contradict the hypothesis that initially larger and more productive firms stand to benefit more from liberalization due to benefits of scale: results reported in Table 8 show a significant positive relationship between firm size and productivity on R&D investment decisions in the different business environments. Rather we document that both factors are at play, a dimension that is critical for policy as implications are rather different pointing to the importance of addressing business conditions for broader participation in innovation activities even from an efficiency perspective.

7. Conclusion

This paper investigates the impacts of an industrial liberalization policy, the dismantling of the "License Raj" in India, on firms' decisions to undertake R&D investments. Our results show that while the initially largest and most productive firms were more likely to invest in R&D in response to these policy reforms, the smallest and least productive firms were less likely to do so. We also show that disadvantageous business conditions magnify heterogeneous impacts: the initially largest and most efficient firms only benefitted disproportionately where business conditions were characterized by substantial shortcomings. This suggests that liberalization might effectively have provided opportunities for a wider group of more innovators if complementary policies had been in place providing access to finance, skills and/or knowledge as well as better business framework conditions. Since shortcomings in the business conditions in many developing countries are often substantial, these complementary policies are critical if liberalization is to lead to maximum returns. Otherwise liberalization efforts are likely to fall short of potential benefits they could offer in terms of strengthening national innovation capacities.

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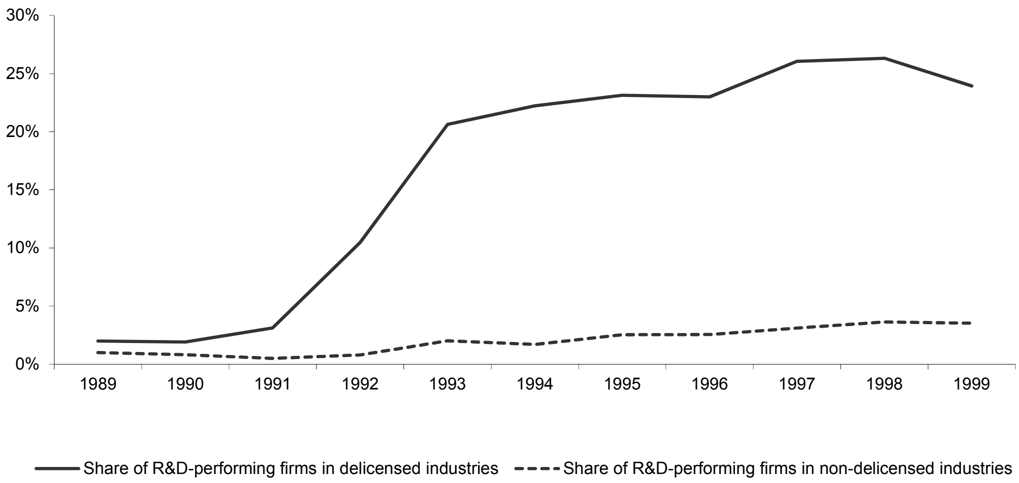
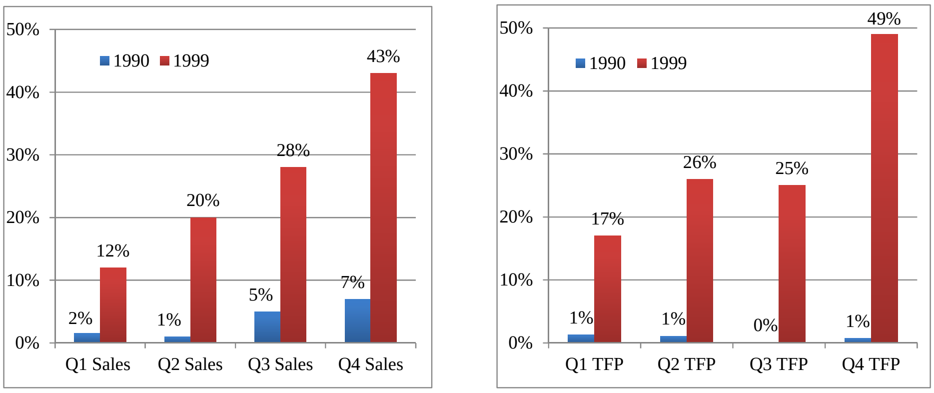
Figure 1: The share of R&D-performing firms in delicensed vs. non-delicensed industries



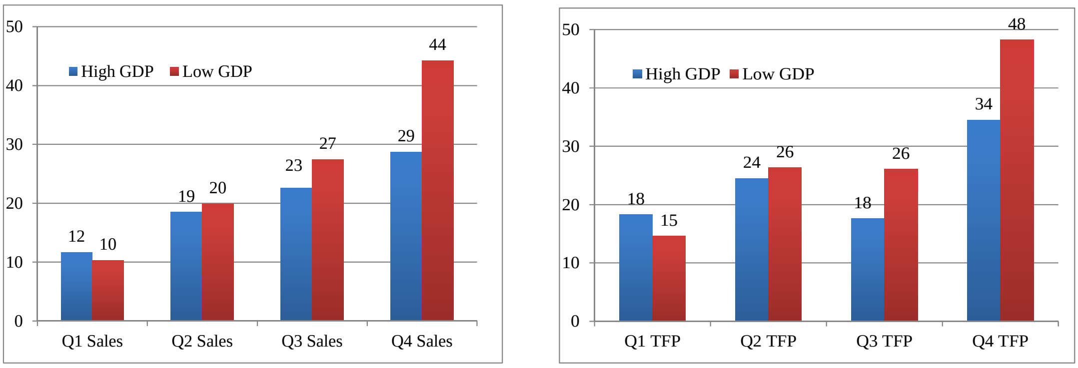
Note: Delicensed industries include industrial machinery; computers, peripherals, storage devices and communication equipment; commercial vehicles and automobile ancillaries; textiles, garments and yarn; cosmetics, toiletries, soaps and detergents; fertilizers; metal products; vegetable oils and products; aluminium and its products as well as other metal products, electronics, leather products and chemicals. Non-delicensed industries include industries producing mineral products; electronic aerospace and defence equipment; hazardous chemicals, lubricants, drugs and pharmaceuticals, industrial explosives; processed/packaged foods, refineries, refractories, sugar, tobacco products; other non-metallic mineral products; motor cars and other transport equipment; other leather products and paper. The industries that were delicensed in 1985 are excluded.
Source: Authors' calculation from Prowess dataset.

Figure 2: R&D-performing firms by initial size and TFP quartiles, in 1990 and 1999



Source: Authors' calculation from Prowess dataset.

Figure 3: Percentage change in the share of firms that invested in R&D over 1990-1999 by initial size and TFP quartiles



Source: Authors' calculation from Prowess dataset.

Table 1: Exogeneity

	Dependent variables:				
	Sales (*it*)	TFP (*it*)	Profit ratio (*it*)	Wage bill (*it*)	R&D intensity (*it*)
	(1)	(2)	(3)	(4)	(5)
Δ Delicense in 1989-1992	0.382	-0.008	-0.186	-0.588	0.000
	(0.366)	(0.135)	(0.179)	(0.728)	(0.000)
Observations	611	611	611	611	611
R-squared	0.12	0.39	0.13	0.07	0.03

Note: The dependent variables in each column are the initial firm-level outcomes in 1989. The table shows the coefficients on changes in industrial liberalization status of industries between 1989 and 1992 from firm-level regressions of initial firm characteristics controlling for 2-digit industry fixed effects. Firm-level variables are expressed in logarithms except for the ratio of R&D expenditures over total sales. Heteroskedasticity-robust standards errors clustered at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: R&D premia

	Dependent variables:				
	Sales *(it)*	Capital *(it)*	Wage bill *(it)*	Profit *(it)*	TFP*(it)*
	(1)	(2)	(3)	(4)	(5)
R&D *(it)*	1.266***	1.216***	1.504***	0.013***	0.513***
	(0.027)	(0.029)	(0.029)	(0.002)	(0.012)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	16,404	16,377	16,404	16,404	15,763
R-squared	0.25	0.25	0.27	0.06	0.17

Note: Each specification gives OLS estimates and includes 3-digit NIC industry and year dummies. Each of the dependent variables is expressed in logarithms. Firm TFP is computed using the Olley and Pakes (1996). Heteroskedasticity-robust standards errors clustered at the 3-digit industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Main results: Impacts of delicensing on firms' R&D decisions

	Dependent variable: R&D *(it)*							
	Baseline				Interactions with sales		Interactions with TFP	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Delicense *(t-1)*	0.087**	0.085**	0.093**	0.092**				
	(0.042)	(0.042)	(0.042)	(0.042)				
Delicense *(t-1)* * Initial sales					0.080***			
					(0.010)			
Delicense *(t-1)* * Q1 Initial sales						-0.085*		
						(0.044)		
Delicense *(t-1)* * Q2 Initial sales						-0.074*		
						(0.043)		
Delicense *(t-1)* * Q3 Initial sales						0.019		
						(0.045)		
Delicense *(t-1)* * Q4 Initial sales						0.136***		
						(0.047)		
Delicense *(t-1)* * Initial TFP							0.118***	
							(0.018)	
Delicense *(t-1)* * Q1 Initial TFP								-0.139***
								(0.044)
Delicense *(t-1)* * Q2 Initial TFP								-0.033
								(0.044)
Delicense *(t-1)* x Q3 Initial TFP								0.025
								(0.044)
Delicense *(t-1)* x Q4 Initial TFP								0.139***
								(0.051)
Profit ratio *(t-1)*		0.011***	0.011***	0.010***	0.005	0.005	0.006*	0.006*
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Age *(t-1)*			-0.105***	-0.144***	-0.095***	-0.098***	-0.091***	-0.096***
			(0.031)	(0.028)	(0.022)	(0.023)	(0.032)	(0.031)
Wage-bill *(t-1)*				0.033***	0.036***	0.039***	0.055***	0.055***
				(0.010)	(0.010)	(0.011)	(0.014)	(0.013)
Herfindhal index *(t-1)*	0.122***	0.119***	0.117***	0.117***				
	(0.044)	(0.044)	(0.043)	(0.043)				
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes				
Industry-year fixed effects					Yes	Yes	Yes	Yes
Observations	16,404	16,404	16,404	16,404	16,207	16,207	14,031	14,031
R-squared	0.20	0.21	0.21	0.21	0.28	0.28	0.29	0.29

Note: Heteroskedasticity-robust standards errors clustered at the 3-digit industry level. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Robustness tests
Panel A: Alternative econometric specification

	Dependent variable: R&D $_{(it)}$									
	Probit model					Conditional logit				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Delicense $_{(t-1)}$	0.658***					1.287***				
	(0.131)					(0.461)				
Delicense $_{(t-1)}$ * Initial sales		0.151***					0.346***			
		(0.030)					(0.113)			
Delicense $_{(t-1)}$ * Q1 Initial sales			-0.357**					0.583		
			(0.171)					(0.617)		
Delicense $_{(t-1)}$ * Q2 Initial sales			0.099					0.765		
			(0.151)					(0.502)		
Delicense $_{(t-1)}$ * Q3 Initial sales			0.599***					1.202**		
			(0.147)					(0.479)		
Delicense $_{(t-1)}$ * Q4 Initial sales			1.261***					1.568***		
			(0.151)					(0.480)		
Delicense $_{(t-1)}$ * Initial TFP				0.103*					0.474***	
				(0.058)					(0.179)	
Delicense $_{(t-1)}$ * Q1 Initial TFP					-0.283					0.339
					(0.175)					(0.611)
Delicense $_{(t-1)}$ * Q2 Initial TFP					0.240					1.272**
					(0.163)					(0.540)
Delicense $_{(t-1)}$ * Q3 Initial TFP					0.430***					1.359***
					(0.163)					(0.522)
Delicense $_{(t-1)}$ * Q4 Initial TFP					1.168***					1.445***
					(0.165)					(0.500)
Firm level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm random effects	Yes	Yes	Yes	Yes	Yes					
Firm fixed effect						Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,404	16,207	16,207	14,031	14,031	5,998	5,998	5,998	5,647	5,647
Log likelihood	-4842	-4842	-5073	-4842	-4842	-1486	-1486	-1486	-1361	-1361

Note: Firm control variables are the same as those reported in table 3. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Robustness tests
Panel B: Using R&D intensity as dependent variable

	Dependent variable: R&D intensity $_{(it)}$				
	(1)	(2)	(3)	(4)	(5)
Delicense $_{(t-1)}$	0.002***				
	(0.001)				
Delicense $_{(t-1)}$ * Initial sales		0.001**			
		(0.000)			
Delicense $_{(t-1)}$ * Q1 Initial sales			0.001		
			(0.001)		
Delicense $_{(t-1)}$ * Q2 Initial sales			0.001*		
			(0.001)		
Delicense $_{(t-1)}$ * Q3 Initial sales			0.002**		
			(0.001)		
Delicense $_{(t-1)}$ * Q4 Initial sales			0.002**		
			(0.001)		
Delicense $_{(t-1)}$ * Initial TFP				0.001***	
				(0.000)	
Delicense $_{(t-1)}$ * Q1 Initial TFP					-0.001
					(0.001)
Delicense $_{(t-1)}$ * Q2 Initial TFP					0.000
					(0.001)
Delicense $_{(t-1)}$ * Q3 Initial TFP					0.000
					(0.000)
Delicense $_{(t-1)}$ * Q4 Initial TFP					0.001
					(0.001)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes				
Industry-year fixed effects		Yes	Yes	Yes	Yes
Observations	16,404	16,207	16,207	14,031	14,031
R-squared	0.01	0.01	0.01	0.05	0.05

Note: Firm control variables are the same as those reported in table 3. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Robustness tests
Panel C: Using alternative approaches to assess heterogeneous effects

	Dependent variable: R&D $_{(it)}$			
	Using interactions with initial wage		Alternative quantiles	
	(1)	(2)	(3)	(4)
Delicense $_{(t-1)}$ * Initial wage-bill	0.086***			
	(0.009)			
Delicense $_{(t-1)}$ * Q1 Initial wage-bill		-0.019		
		(0.039)		
Delicense $_{(t-1)}$ * Q2 Initial wage-bill		-0.013		
		(0.040)		
Delicense $_{(t-1)}$ * Q3 Initial wage-bill		0.038		
		(0.043)		
Delicense $_{(t-1)}$ * Q4 Initial wage-bill		0.180***		
		(0.050)		
Delicense $_{(t-1)}$ * Low sales			-0.079*	
			(0.040)	
Delicense $_{(t-1)}$ * Medium sales			0.001	
			(0.045)	
Delicense $_{(t-1)}$ * Large sales			0.113**	
			(0.049)	
Delicense $_{(t-1)}$ * Low TFP				-0.113**
				(0.047)
Delicense $_{(t-1)}$ * Medium TFP				-0.003
				(0.043)
Delicense $_{(t-1)}$ * Large TFP				0.126**
				(0.048)
Firm-level controls	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects				
Industry-year fixed effects	Yes	Yes	Yes	Yes
Observations	16,404	16,404	16,207	14,031
R-squared	0.22	0.21	0.27	0.30

Note: Firm control variables are the same as those reported in table 3. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: The impact of economic development on heterogeneous effects across firms

	Dependent variable: R&D $_{(it)}$					
	States at different levels of economic development					
	High GDP	Low GDP	High GDP	Low GDP	High GDP	Low GDP
	(1)	(2)	(3)	(4)	(5)	(6)
Delicense $_{(t-1)}$	0.174***	0.247***				
	(0.023)	(0.045)				
Delicense $_{(t-1)}$ * Q1 Initial sales			-0.123	-0.056		
			(0.088)	(0.051)		
Delicense $_{(t-1)}$ * Q2 Initial sales			-0.110	-0.053		
			(0.093)	(0.040)		
Delicense $_{(t-1)}$ * Q3 Initial sales			-0.033	0.056		
			(0.094)	(0.044)		
Delicense $_{(t-1)}$ * Q4 Initial sales			0.052	0.185***		
			(0.091)	(0.059)		
Delicense $_{(t-1)}$ * Q1 Initial TFP					-0.259**	-0.074**
					(0.100)	(0.037)
Delicense $_{(t-1)}$ * Q2 Initial TFP					-0.140	0.023
					(0.100)	(0.043)
Delicense $_{(t-1)}$ * Q3 Initial TFP					-0.079	0.071*
					(0.100)	(0.041)
Delicense $_{(t-1)}$ * Q4 Initial TFP					0.014	0.199***
					(0.102)	(0.059)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,699	8,705	7,597	8,610	6,515	7,516
R-squared	0.13	0.19	0.27	0.33	0.29	0.35

Note: Firm control variables are the same as those reported in table 3. “High GDP” (“Low GDP”) regressions show results for the set of Indian states with above-(below) median GDP in 1989. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: The impacts of financial development on heterogeneous effects across firms

	Dependent variable: R&D $_{(it)}$									
	Financial development at state level						Industries' financial dependence			
	High	Low	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Delicense $_{(t-1)}$	0.349***	0.253***								
	(0.082)	(0.062)					-0.015	-0.107*		
Delicense $_{(t-1)}$ * Q1 Initial sales			-0.084	-0.043			(0.045)	(0.054)		
			(0.064)	(0.076)			-0.014	-0.101		
Delicense $_{(t-1)}$ * Q2 Initial sales			-0.093	-0.012			(0.057)	(0.067)		
			(0.068)	(0.072)			0.081	-0.020		
Delicense $_{(t-1)}$ * Q3 Initial sales			0.009	0.063			(0.063)	(0.064)		
			(0.076)	(0.068)			0.198**	0.103		
Delicense $_{(t-1)}$ * Q4 Initial sales			0.119	0.183**			(0.076)	(0.058)		
			(0.074)	(0.074)						
Delicense $_{(t-1)}$ * Q1 Initial TFP					-0.114*	-0.119			-0.098**	-0.167**
					(0.060)	(0.071)			(0.039)	(0.078)
Delicense $_{(t-1)}$ * Q2 Initial TFP					-0.016	-0.018			-0.003	-0.024
					(0.071)	(0.072)			(0.061)	(0.068)
Delicense $_{(t-1)}$ * Q3 Initial TFP					0.026	0.051			0.055	0.024
					(0.065)	(0.075)			(0.076)	(0.065)
Delicense $_{(t-1)}$ * Q4 Initial TFP					0.165**	0.152**			0.179**	0.130
					(0.074)	(0.074)			(0.080)	(0.071)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes							
Industry-year fixed effects			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,340	8,064	8,277	7,930	7,195	6,836	8,607	7,208	7,619	6,079
R-squared	0.22	0.17	0.33	0.27	0.35	0.29	0.28	0.27	0.30	0.29

Note: Firm control variables are the same as those reported in table 3. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: The impact of access to knowledge on heterogeneous effects across firms

	Dependent variable: R&D *(it)*									
			Patenting at the state level				Industry reliance on differentiated knowledge inputs			
	High	Low	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Delicense *(t-1)*	0.268***	0.319***								
	(0.063)	(0.076)								
Delicense *(t-1)* * Q1 Initial sales			-0.091	-0.067			-0.078	-0.074		
			(0.113)	(0.048)			(0.077)	(0.065)		
Delicense *(t-1)* * Q2 Initial sales			-0.076	-0.059			-0.073	-0.056		
			(0.127)	(0.036)			(0.082)	(0.059)		
Delicense *(t-1)* * Q3 Initial sales			0.014	0.040			0.049	0.014		
			(0.123)	(0.040)			(0.091)	(0.051)		
Delicense *(t-1)* * Q4 Initial sales			0.073	0.177***			0.159	0.134**		
			(0.121)	(0.050)			(0.095)	(0.052)		
Delicense *(t-1)* * Q1 Initial TFP					-0.211	-0.102***			-0.136*	-0.125*
					(0.142)	(0.032)			(0.070)	(0.067)
Delicense *(t-1)* * Q2 Initial TFP					-0.115	0.017			-0.014	-0.031
					(0.138)	(0.041)			(0.077)	(0.058)
Delicense *(t-1)* * Q3 Initial TFP					-0.050	0.074*			0.059	0.016
					(0.136)	(0.038)			(0.072)	(0.061)
Delicense *(t-1)* * Q4 Initial TFP					0.018	0.209***			0.156*	0.147**
					(0.139)	(0.054)			(0.089)	(0.066)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes								
Industry-year fixed effects			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,856	11,548	4,792	11,415	3,982	10,049	7,445	8,583	6,609	7,287
R-squared	0.18	0.20	0.32	0.29	0.35	0.31	0.30	0.25	0.31	0.28

Note: Firm control variables are the same as those reported in table 3. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Linear interactions testing the impacts of business conditions on heterogeneous effects across firms

	Dependent variable: R&D *(it)*											
	Economic development at state level				Financial development at state level				Patenting at the state level			
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Delicense *(t-1)* * Initial sales	0.062***	0.093***			0.076***	0.086***			0.052***	0.099***		
	(0.015)	(0.015)			(0.010)	(0.016)			(0.013)	(0.014)		
Delicense *(t-1)* * Initial TFP			0.091***	0.136***			0.124***	0.109***			0.081**	0.144***
			(0.027)	(0.023)			(0.022)	(0.026)			(0.030)	(0.018)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,597	8,610	6,515	7,516	8277	7930	7195	6836	4,792	11,415	3,982	10,049
R-squared	0.27	0.33	0.28	0.36	0.33	0.27	0.35	0.29	0.32	0.29	0.34	0.32

Note: Firm control variables are the same as those reported in table 3. Heteroskedasticity-robust standards errors corrected for clustering at the 3-digit NIC industry level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix A: List of industries reserved for the public sector

Statement on industrial policy, New Delhi, 24 July 1991.

PROPOSED LIST OF INDUSTRIES TO BE RESERVED FOR THE PUBLIC SECTOR

1. Arms and ammunition and allied items of defence equipment, Defence aircraft and warships.
2. Atomic Energy.
3. Coal and lignite.
4. Mineral oils.
5. Mining of iron ore, manganese ore, chrome ore, gypsum, sulphur, gold and diamond.
6. Mining of copper, lead, zinc, tin, molybdenum and wolfram.
7. Minerals specified in the Schedule to the Atomic Energy (Control of Production and Use) Order, 1953.
8. Railway transport.

LIST OF INDUSTRIES IN RESPECT OF WHICH INDUSTRIAL LICENSING WILL BE COMPULSORY

1. Coal and Lignite.
2. Petroleum (other than crude) and its distillation products.
3. Distillation and brewing of alcoholic drinks.
4. Sugar.
5. Animal fats and oils.
6. Cigars and cigarettes of tobacco and manufactured tobacco substitutes.
7. Asbestos and asbestos-based products.
8. Plywood, decorative veneers, and other wood based products such as particle board, medium density fibre board, block board.
9. Raw hides and skins, leather, chamois leather and patent leather.
10. Tanned or dressed furskins.
11. Motor cars.
12. Paper and Newsprint except bagasse-based units.
13. Electronic aerospace and defence equipment; All types.
14. Industrial explosives, including detonating fuse, safety fuse, gun powder, nitrocellulose and matches.
15. Hazardous chemicals.
16. Drugs and Pharmaceuticals (according to Drug Policy).
17. Entertainment electronics (VCRs, colour TVs, C.D. Players, Tape Recorders).
18. White Goods (Domestic Refrigerators, Domestic Dishwashing machines, Programmable Domestic Washing Machines, Microwave ovens, Airconditioners).

Note: The compulsory licensing provisions would not apply in respect of the small scale units taking up the manufacture of any of the above items reserved for exclusive manufacture in small scale sector.

Source: Statement on industrial policy, New Delhi, 24 July 1991.
http://dipp.nic.in/English/Policies/Industrial_policy_statement.pdf.

Appendix B: Description of the variables used

Variable name	Description	Mean	Std. Dev.
A. Main variables			
R&D	Indicator takes the value of one if firm i reports positive R&D expenditures in year	0.23	0.42
R&D intensity	Ratio of R&D expenditure over sales of firm i in year t.	0.00	0.02
Delicense	Variable is equal to 1 for 3-digit industry s if the industry is delicensed in 1991 and 0 otherwise. See Appendix A for the full list of delicensed industries	0.79	0.41
Herfindhal index	The index, computed as the square of the market share of all firms at the 3-digit industry level s, captures the degree of sales concentration (in logarithm).	-3.31	0.94
Age of the firm	The age of the firm is computed using the year of incorporation in the Prowess	2.84	0.89
Profit ratio	Ratio of profits after tax over total assets of firm i at time t.	-3.23	1.09
Wage bill	The wage-bill reported by the firm i at time t.	0.65	1.69
B. Interaction variables			
Initial sales	Logarithm of firm i's sales measured in its initial year in the Prowess database.	2.59	1.47
Q1 Initial sales	First quartile of initial sales distribution, where the first quartile corresponds to firms with the smallest sales (in logarithm)	0.19	0.39
Q2 Initial sales	Second quartile of initial sales distribution (in logarithm)	0.25	0.43
Q3 Initial sales	Third quartile of initial sales distribution (in logarithm)	0.27	0.45
Q4 Initial sales	Fourth quartile of initial sales distribution (in logarithm)	0.29	0.45
Initial TFP	Firms TFP measured in the initial year in the Prowess database. Firm TFP is measured relying on the non-parametric methodology developed by Olley and Pakes (1996) (in logarithm).	0.23	0.98
Q1 Initial TFP	First quartile of initial TFP distribution, where the first quartile corresponds to the least productive firms (in logarithm)	0.22	0.41
Q2 Initial TFP	Second quartile of initial TFP distribution (in logarithm)	0.25	0.43
Q3 Initial TFP	Third quartile of initial TFP distribution (in logarithm)	0.26	0.44
Q4 Initial TFP	Fourth quartile of initial TFP distribution (in logarithm)	0.27	0.44
Initial wage-bill	Firms wage-bill measured in the initial year in the Prowess database (in logarithm).	0.24	1.62
Q1 Initial wage-bill	First quartile of initial wage-bill distribution, where the first quartile corresponds to firms with the lowest wage-bill (in logarithm)	0.20	0.40
Q2 Initial wage-bill	Second quartile of initial wage-bill distribution (in logarithm)	0.24	0.43
Q3 Initial wage-bill	Third quartile of initial wage-bill distribution (in logarithm)	0.27	0.44
Q4 Initial wage-bill	Fourth quartile of initial wage-bill distribution (in logarithm)	0.30	0.46
C. State and industry variables			
Economic development at the state level	Indicates Indian states with GDP above/below the median level across all Indian states in the initial year. State GDP data are from the Reserve Bank of India.		
Financial development at the state level	Indicates Indian states with a ratio of credit over GDP that is above/below the median level across all Indian states in the initial year. Data on the ratio of credit over GDP are from the Reserve Bank of India.		
Patenting at the state level	Indicates Indian states with number of patents in the state that is above/below the median level across all Indian states in the year prior to liberalization.		
Financial dependence at the industry level	Indicates industries with external dependence that is above/below the median level across US manufacturing industries based on Rajan and Zingales (1998) and updated by Braun (2002) and Braun and Larrain (2005).		
Differentiated/homogeneous inputs at industry level	These are industries that rely more on differenciated/homogeneous intermediate good inputs. The identification of heterogeneous goods is based on Rauch (1999) and linked to industry input requirements using India's Input-Output tables for 1993.		

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