Intellectual Property Regimes and Wage Inequality*

Sourav Bhattacharya† Pavel Chakraborty‡ Chirantan Chatterjee§

February 2021

Abstract

We use The Patents (Amendment) Act, 2002 in India as a quasi-natural experiment to identify the causal effect of higher incentives for innovation on a firm's compensation structure. We find that stronger intellectual property (IP) protection has a sharper impact on the demand for managerial skill for technologically advanced firms. Firms that were a-priori above the industry median (in terms of technology adoption, more so for R&D expenditure) witness a rise in the share of managerial compensation by 1.3–8.3% higher than the rest. This effect is completely driven by firms between 5–8th decile with no effect on firms below the median or at the very top of the technological ladder. This observed "snail-shape" in the firms' response to the IP shock is rationalised in a model where firms within an industry compete for patents by investing in managerial inputs. The observed increase in wage inequality can partly be attributed to a stronger performance pay for high-tech firms. Associatedly, high-tech firms invested more in technology adoption, started to produce more product varieties at higher quality, and filed for more product patent claims.

JEL classifications: D21, D23, L23, O1, O34

Keywords: Intellectual Property Regimes, Wage Inequality, High-tech and Low-tech firms, Managerial Compensation, "Snail-shape", Patent Race

---

*This paper was previously circulated as "Intellectual Property Rights and Firm Structure". We have significantly benefited from discussions with Samuel Asher, Pulapre Balakrishnan, Natarajan Balasubramanian, Richard Baldwin, Benjamin Balsmeier, Sanjay Banerji, Justus Baron, Daniel Bennett, Nicolas Bloom, Eric Bond, David Brady, Guillermo Caruana, Sisir Debnath, Mercedes Delgado, Ravi Dharwadkar, Mark Duggan, Mukesh Eswaran, John Firth, Fabian Gaessler, Dietmar Harhoff, Steve Haber, David Hsu, Olena Ivus, Ravi Jagannathan, Tarun Jain, Rajshri Jayaraman, Chad Jones, Brian Kovak, Tapas Kundu, Margaret Kyle, Ed Lazear, Marv Lieberman, Anirban Mitra, Andreas Panagopoulos, Elena Pastorino, Vishwanath Pingali, Ivan Png, Yi Qian, Josh Rauh, Daniel Rubinfeld, Juan-Pablo Rud, Kamal Saggi, Mariko Sakakibara, Henry Sauermann, Jagadeesh Sivadasan, Andreas Stegmann, Neil Thompson, Andrew Toole, John Van Reenen, Michael Ward, Heidi Williams, Jasper de Winter, and Rosemarie Ziedonis as well as seminar participants at Indian Institute of Management, Calcutta; Indian Statistical Institute, Calcutta; Indian Statistical Institute, New Delhi; Indian Institute of Management, Ahmedabad; Centre for Studies in Social Sciences, Calcutta; Indian School of Business, Hyderabad; Ashoka University; USPTO; CEMFI; Jawaharlal Nehru University; University of Birmingham; Royal Holloway University of London; ESMT Berlin; Max Planck Institute of Innovation and Competition, Munich; University of Crete; Syracuse University; University of Texas, Arlington; Vanderbilt University; Anderson School of Management, UCLA; Hoover Institution Economic Policy Lunch Workshop and conference participants at JIRICO 2016; 12th Annual Conference on Economic Growth and Development, New Delhi; 12th Annual European Policy for Intellectual Property Conference; 6th Annual Searle Center Research Roundtable on SSOs and Patents, Northwestern University; 1st World Bank-Bank of Italy conference on "Building Human Capital for 21st Century Jobs"; XXVIIth Annual Conference on Contemporary Issues in Development Economics; 17th International Industrial Organization Conference, 2019; 3rd UC Riverside India China Workshop; WEAI Annual Conference, 2019; 46th EARIE Annual Conference, 2019. Chatterjee wishes to acknowledge ICICI Bank Chair in Strategic Management at IIM Ahmedabad and the National Fellow Program at Hoover Institution, Stanford University for supporting this research.

†Indian Institute of Management Calcutta, Diamond Harbour Road, Joka, Kolkata 700104, India; email: sourav@iimcal.ac.in

‡Department of Economics, Management School, Lancaster University, LA1 4YX, UK. Email: p.chakraborty1@lancaster.ac.uk

§Business Policy & Economics, Indian Institute of Management, Ahmedabad, Vastrapur, Ahmedabad, Gujarat 380015, India; 2019-2020 Visiting Fellow and 2018-2019 Campbell and Edward Teller National Fellow; email: cc201819@stanford.edu or chirantanc@iima.ac.in

1 Introduction

How do incentives for innovation affect wage inequality? We study how the imposition of stronger Intellectual Property Rights (IPR), brought about by a landmark legislation, **The Patents (Amendment) Act, 2002**, affected the compensation structure of the Indian manufacturing firms. The main highlight of this Act was to change the existing IP regime from process to product patents. The Act also significantly broadened the scope for the implementation of the TRIPs complying IPR regime that India was committed to adopting.[1] In effect, by significantly increasing the cost of imitation, the Act provided stronger incentives to innovate. We study how a large cross section of Indian manufacturing firms responded to this Act in terms of changes in compensation structure.[2] To the best of our knowledge, our work is the first to look at how a change in IPR affects wage inequality.[3]

India's patent policy started to shift towards greater protection of intellectual property rights as a result of the emergence of Trade Related Intellectual Property Rights (TRIPs, hereafter) in the WTO (after 1995). India got a 10-year transition period to implement a TRIPs-compliant IPR regime, but during this period there were several inconclusive rounds of discussion in the Indian parliament due to opposition from various sections of the political establishment (Reddy and Chandrashekaran, 2017). Eventually, in June 2002, the Indian parliament passed the second amendment to the 1970 Act known as The Patents (Amendment) Act, 2002 (Act 38 of 2002).[4] According to the Controller General of Patents, Design and Trademarks, Govt. of India, The Patents (Amendment) Act, 2002, replaced the earlier patent rules implemented by the 1970 Act.[5] This legislation proposed a new definition of the term "invention", introduced product patents in all fields of technology, increased the term of patents from 14 to 20 years (complying with TRIPs),[6] limited the scope for the government to use patented inventions, and streamlined the process of patent grant. This act ended the earlier policy uncertainty and provided the necessary impetus to firms to make the fixed investments in new technology to harness the benefits of the new IP regime. **Panel A** of **Figure 1** demonstrates a sharp increase in investments in technology adoption (sum of R&D expenditure and technology transfer) by a large sample of Indian manufacturing firms. For an average Indian manufacturing firm, investments in technology

[1] It additionally introduced the "Bolar" exception, inspired by the US law exempting manufacturers from infringement if they develop products, conduct research and submit test data for regulatory purposes. A joint parliamentary committee was constituted which submitted a report to the lower house of the Indian parliament; while its research was thorough, political circumstances ensured that the 2002 bill faced lesser difficulties than the earlier legislation and thus The Patents (Amendment) Act, 2002 was enacted. Three years later India was able to push this second legislation further with the addition of 3(d), the compulsory licensing provision, and implemented The Patents (Amendment) Act, 2005 to comply with all the provisions of TRIPs (see Chatterjee et al., 2015 for more details on 3(d)).

[2] By compensation structure we mean total labour compensation of firms. In our case, compensation is equal to wages plus incentives. Sometimes, we use compensation and wages interchangeably in the paper; however we mean the same thing.

[3] Kamal and Lovely (2013) looks at the effect of China's WTO accession, in particular the effect of the implementation of TRIPs on formation of joint ventures.

[4] This Act came into force on 20th May 2003 with the introduction of the new Patent Rules, 2003 by replacing the earlier Patents Rules, 1972.

[5] http://www.ipindia.nic.in/history-of-indian-patent-system.htm

[6] Before implementation of TRIPs, there was no global standard that patents must last for 20 years or more.

trebled within 4 years after the imposition of the new patent law.

Given this as a background, we analyse firms' response to this change in IP regime (in terms of technology investments) in three different dimensions of compensation structure: (i) relative demand for managers vis-a-vis non-managers measured as managers' share of total firm compensation, (ii) heterogeneity in this demand in terms of distribution of firms' technological investments, and (iii) share of performance pay in managerial compensation. We employ PROWESS, a comprehensive database of Indian manufacturing firms which reports detailed labour compensation, divided into managerial and non-managerial components (Chakraborty and Raveh, 2018), details of technology spending like R&D investment, technology transfer etc. as well as other firm characteristics on a panel basis. The panel format of the data enables us to have a dynamic specification in which technological investments and other firm decisions can potentially affect demand for managers.

Our main aim in this study is to establish a causal link between innovation incentives and compensation structure for both within and between firms. One contribution of our work is to identify a suitable quasi-natural experiment that enhances firms' expected returns to innovation. We therefore use the change in the Indian IPR policy as an instrument for innovation.

Due to stronger patent protection, firms invest in a whole range of activities that are intensive in managerial talent: research, conceptualization and development of new products, branding and marketing the product and so on (Teece, 1986, 1996). Existing processes are also pushed closer to the technological frontier through use of more R&D expenditure, technology transfer, import of capital goods, etc. All these tasks can present firms with more complex problems, and this can possibly raise the value of managers as problem-solvers (Garicano, 2000). Therefore, an increase in the returns to innovation raises the relative value of managers over non-managers (Acemoglu et al., 2006). Crucially, due to the complementarity between managerial talent and technological capital as innovation inputs, we expect firms already ahead in the technological ladder to have larger gains from investing in managers.[7] Our benchmark hypothesis is that the increase in wage inequality between managers and non-managers due to the IPR shock would be higher in technologically advanced firms.

We start by dividing firms into two groups, 'high-tech' and 'low-tech' based on their stock of technological capital before the Act of 2002, following Aghion et al. (2005) and Branstetter et al. (2006). We classify a firm as high-tech, if a firm's average expenditure on R&D and technology transfer between 1990-2001 as a share of GVA (gross value-added) is greater than the median in the corresponding industry.[8] Our main dependent variable is relative demand for managers, defined as the share of the total firm compensation

[7] Aghion et al. (2017) find that a positive export shock raises innovation more for productive firms. We have a similar result where innovative effort is more likely to be successful for more productive firms.

[8] We also define 'high-tech' by using R&D expenditure and technology transfer separately. Results are completely driven by the former showing that innovation rather than adoption of outside technology is the main cause behind increase in demand for managerial skills.

being paid to managers. We employ a difference-in-differences approach, considering the high-tech as the treatment group and the low-tech as the control group.[9] We interpret the difference in response to the Act of 2002 between the two groups in terms of relative demand for managers as the impact of the policy change. We find a remarkably persistent, statistically significant and economically meaningful positive effect of The Patents (Amendment) Act, 2002 on the relative demand for managers. Our benchmark estimations indicate that The Patents (Amendment) Act, 2002 led to an increase in the share of managerial compensation of the high-tech vis-à-vis the low-tech firms by 1.3–8.3%. In other words, we find a sharp heterogeneity in firms' response to the IPR shock: the firms that were a-priori technologically advanced at the time of the reform had significantly larger increase in both dimensions (intensive and extensive margins) relative to the technologically backward firms. Our finding leads to the implication that imposition of a stronger IP regime increases wage inequality between firms.

While our baseline measure of technology investment includes both R&D expenditure and technology transfer, we show that our effects can be ascribed almost entirely to R&D expenditure alone. This is line with a change from process to product patents which is likely to raise the relative value of direct innovation through R&D over technology transfer (including transfer of know-how, process modification or reverse engineering). Hu et al. (2005) classifies innovation into R&D and imitation, where they use a broad definition of imitation which would encompass the activities we think of as technology transfer in the current context.

In order to interpret the difference in response as a causal effect, we make the identifying assumption that the two groups would have exhibited similar trends in absence of the policy change. **Panel B** of **Figure 1** plots normalized technology adoption expenditure for our sample of Indian firms for the period 1990-2006[10] by dividing into high-tech and low-tech firms. The graph clearly shows similar trends for high-tech and low-tech firms before the adoption of the patent reform but quite the opposite after. The technology adoption expenditure for the high-tech firms doubled between 2002 and 2006, whereas for low-tech firms it shows the opposite.

Figure 2 plots the normalized average share of managerial compensation in total compensation for the high-tech and low-tech firms. It shows that while there was an increasing trend in managers' share of compensation for both types of firms before the reform, the increase after the reform is concentrated only in case of the high-tech firms; there was only a slight increase for the other type.[11] These two diagrams suggest a possible association between patent reform, technology adoption and demand for managers and paves the

[9] We also change our treatment and control group; the results remain the same. More on this in Section 5.1.

[10] Our dataset runs till 2013. But, we choose to restrict our analysis upto 2006 for the following two important reasons: (a) 2008-09 financial crisis. This event may have adverse consequences on compensation across all types of workers and may alter our findings; (b) India got fully integrated to the WTO-TRIPs patent system by the end of 2005. Extending the data for longer time period after 2005 might have confounding effects of the 2002 Act and final implementation in 2005.

[11] We also explicitly show that our treatment (high-tech firms) and control (low-tech firms) group are not on different time trends in the pre-reform period. We use pre-reform data from 1990 to 2001 to estimate differential time trends in outcomes for high-tech and low-tech firms in detail in Section 5.1.

way to provide causal inferences.

Another implicit assumption in our identification exercise is that the Act of 2002 was exogenous to the firms' response. We run several tests to confirm that neither did the firm adjust their demand for managers in anticipation of the reform, nor did the Act come about as a result of the development of high-tech industrial sector and scientific capacity, or due to lobbying of the high-tech firms. We also check whether the Act of 2002 was a result of other prior events that might be related; effect of such events is found to be indistinguishable from zero.

An important caveat is that our main finding (increase in demand for managers) is driven entirely by firms in the 5–8th decile, i.e., there is no statistically significant effect of the IPR policy change on firms below median or at the very top of the technological ladder. Since the change in relative demand for managers plotted against technology investment is zero below median, strong for marginally big firms before again becoming zero, we say that firms' response to the IP law is "snail-shaped".[12] This is similar to what Aghion et al. (2005) find in terms of the effect of competition on innovation: inverted-U shape. Such shape also holds for other outcome variables like the absolute number of managers and the average compensation of managers. Even after dividing the industries into high-tech (such as pharma) and low-tech (such as textiles), the snail-shape persists in both these groups.

Second, prevalence of the snail-shape effect across industries hints that competition between firms for winning patents is a major driver of demand for managers. We have already mentioned the role of complementarity between managerial input and technological capital (Garicano, 2000; Bresnahan et al., 2002) in driving innovation productivity. But if demand for managers drive a firm's internal structure in entirety, then one would expect the most technologically advanced firms to have the largest demand for managers. The observed hump-shaped pattern hints at an externality between firms, and we hypothesize that this externality operates through the patent race channel. The returns to innovation are largely rents from patents, and firms within the same industry or selling similar product lines compete for patents. A strengthening of IP laws raises the value of patents and induces an increase in demand for managers differentially for firms within an industry.

To explain why a strengthening of IP laws may affect the demand for managers in a non-monotonic way, we present a simple model. In the model, firms compete for a patent and each firm's probability of winning the patent depends on its innovation effort. Innovation effort of a firm depends on two complementary inputs: managers and capital. The model asks how the demand for managers would increase for firms with various levels of capital stock, as the value of obtaining a patent increases. The model captures the intuition that firms with very high capital stock have lower incentive to expand demand for managers as they are already ahead in competition, and those with low capital stock have no incentive since they are too far behind. The

[12] The snail-shape is due to the fact that it is predicted to be zero below a cut-off and hump-shaped above. Please refer to Section 6.2.2 for further discussion.

"marginally big" firms thus exhibit the strongest demand for managers. Formally, the model demonstrates that (i) firms with capital stock below a threshold do not engage in innovation and thus exhibit no response to the IP shock, and (ii) among the firms above the threshold, the expansion in demand for managers is hump-shaped. This model provides rational foundations for the snail-shape observed in the data.[13]

A large body of evidence, both in management and economics, demonstrates that the compensation scheme a firm chooses is a crucial determinant of a firm's ability to innovate. We find that the technologically advanced firms use sharper incentives to motivate managers as a result of the reform. There is considerable debate in the literature about how and whether incentives motivate innovation and creativity (Holmstrom, 1989). Earlier work (e.g., Teece, 1996; Amabile, 1996) suggests that high-powered incentives stifle creativity and innovation, whereas current literature (e.g., Manso, 2011; Ederer and Manso, 2011; Azoulay et al., 2011) focus on forms of long-term incentive mechanisms that motivate innovation. In our case, we find that increased incentive pay is necessitated by the particular way that IP reform affects innovation incentives. A strong IP regime induces patent races, which reward not just the innovation but also the time to innovate. Motivating quicker innovation requires aggressive managerial incentives.

Additionally, we use two Bartik-type instruments: (a) we define an industry (we did this both at the 2- and 4-digit level) based on their patent intensity (before the reform). We match the patent data from the Indian Patent Office (IPO) with our firm level data using the names of the firms as the only matching indicator in absence of any other unique identifier.[14]; (b) we change the definition of our high-tech and low-tech firms using a binary index of IP sensitivity (based on patents, trademark or copyrights) following the 4-digit NAICS (North American Industrial Classification System) code in the US as used by Delgado et al. (2013).[15] Although, we do not find any effect in case of the former definition, but our benchmark result (increase in demand for managers for high-tech industries) remains the same for the IP-sensitivity definition.

The finding that more IP sensitive industries have a larger response provides further confirmation that the observed effect is indeed driven by the way the Act of 2002 brought about a change in the property rights over innovation. Importantly, observe that the between-industry effect is not as robust as the within-industry effect. This, coupled with the fact that the snail-shape was observed separately for high-tech as well as low-tech industries, points to patent races within firms in the same industry as the main channel through which the Act of 2002 led to an increase in wage inequality between and within firms.

The effect of the 2002 Patent Act on the demand for managerial skill could also be a result of the omitted

[13] The model makes several simplifying assumptions, as it is the simplest framework that delivers the snail-shape present in the data. We assume a competitive market for managers. We also assume that managers engage only in innovation. All these assumptions can be generalized and the main outcome will still hold. Please refer to Section 4 for details.

[14] We would like to point out here that the firm level patent data comes from a different dataset with no unique matching identifier with our firm level dataset. We use a simple algorithm and manual matching methods to match across these two datasets. And, we could only be able to match around 30-35% of our firm level data to the patent data. Therefore, it will be difficult to conclude anything constructively based on the analysis of the Indian patent data.

[15] We describe this in detail in Section 6.3.

variable problem.[16] We check for the effects of all other possible contemporaneous channels such as trade reforms, other forms of globalization (import competition), skill intensity, management technology, expansion in ICT, labour regulation, institutional quality, financial development, etc. Our estimates show that even though there are a number of complementary channels that are at work, such as skill intensity, IT capital, management technology, state level labour laws, etc. the benchmark result does not change.[17]

Overall, our findings suggest that stronger patent rights leads to an increase in inequality of two different kinds: (i) the technological gap between high-tech and low-tech firms increases; and (ii) between-firm wage inequality increases. And, the increase in both these types of inequality is driven by competition among firms within the same industry. Aghion et al. (2005) while investigating the relationship between competition and innovation highlights similar kind of inequality, where the average technological distance between the technological-leaders and -laggards increases with competition.

The paper contributes to several strands of literature. First, we complement the relatively new and growing literature on how different kinds of innovation activities (R&D adoption/patent filings) can induce inequality within firms, across states, etc (Bøler, 2016; Aghion et al., 2019; Aghion et al., 2018a; Aghion et al., 2018b; Kline et al., 2019). Contextually, our results are similar to Kline et al. (2019). But, we complement them on a few important aspects. Kline et al. (2019) analyzes how patent applications induces worker compensation using a new linkage of US patent applications to US business and worker tax records. Results show that inventors capture a higher share of patent-induced operating surplus. However, they do not find any quality upgrading or selection bias in workforce composition.

In contrast, we use a quasi-natural experiment in terms of an IP reform to show that higher incentives to innovation induces managerial gains both for middle and top level managers providing evidence that gains to innovation extend beyond inventors to workers with different roles that might be attached to the innovation. Our results also show that the increase in the demand for managers is driven by between-firm inequality in terms of adoption of innovation inputs, especially in-house R&D expenditure; whereas Kline et al. (2019) shows that innovation outputs like patent applications drives within-firm inequality. Our aggregate results are completely driven by firms belonging to the 5–8th decile, whereas we do not find any such evidence in Kline et al.'s (2019) study which we believe is a new finding in the literature that extends Kline et al. (2019). The effect on increase in compensation in our study is driven by increase in incentive pay, whereas there is no direct evidence of such in Kline et al. (2019). Finally, our results point out towards a strong quality upgrading mechanism with selection bias in workforce composition.

In a similar context, Bøler (2016) uses a R&D tax credit scheme in Norway to demonstrate that innovation

[16] We also check for a placebo using data only on pharmaceutical firms. The result confirms two different things: first, the IPR reform was sudden; there was no expectation of it to be implemented in 2002 and our aggregate results is not driven by this sector which was exposed to this debate on process and product patents in the WTO.

[17] We also address other possible econometric concerns, such as zeros on the left-hand side. In addition, we look at what happened to the non-managerial side as well.

significantly increases the demand for skilled workers and the increase in demand is due to a change in within-firm skill-biased productivity growth. Aghion et al. (2019) uses data (patent filings) on US states to show that top income inequality is (at least partly) driven by innovation. Aghion et al. (2018b) shows similar evidence for Finnish firms. We complement this literature by analyzing how wage inequality changes because of a shift in the innovation policy.

Second, we also add to the existing literature on how changes in external environment affect the firms' internal organization, such as technology adoption (Bresnahan et al., 2002; Galor and Moav, 2000), communication technology (Garicano, 2000, Garicano and Heaton, 2010), globalization (Guadalupe and Wulf, 2010; Caliendo and Rossi-Hansberg, 2012; Keller and Olney, 2017; Caliendo et al., 2017; Chakraborty and Raveh, 2018), etc. and demand for managers/skilled workers. In a similar context, a significant portion of the literature argues that technological adoption raises the employment shares or relative demand for skilled workers over unskilled workers (Caroli and Van Reenen, 2001) or managers over workers (Lee and Shin, 2017). However, all the studies related to innovation and demand for skilled workers establish a correlation, while we show a causal relation between innovation and relative demand for managers. In our case, this causal interpretation comes from an exogenous change in innovation policy.

Third, our work also closely relates to the recently burgeoning literature that examines management as an input to the firm production function explaining productivity differences in firms within and across countries (Bloom and Van Reenen 2007; Syverson 2011; Bloom et al., 2012; Bloom et al., 2013; Bender et al., 2018).

Fourth, our finding that a change in IPR regime significantly reallocate resources across firms hint towards a capital-skill complementarity channel. It has a parallel in the literature on trade-induced skill-biased technical change (Acemoglu, 2003; Michaels et al., 2014; Autor et al., 2017), particularly in developing economies (Amiti and Cameron, 2012; Raveh and Reshef, 2016; Maloney and Molina, 2016). In a similar context, Ugur and Mitra (2017) maps the qualitative and empirical evidences to report that the effect of technology adoption on employment is skill-biased and more likely to be observed when technology adoption favours product as opposed to process innovation. Vashisht (2017) examines the impact of technology on employment and skill demand for the Indian manufacturing sector and demonstrates that adoption of new technology has increased the demand for high skilled workers. This finding is consistent with ours, as we show that higher technology adoption, due to change in innovation policy, leads to demand for more managers.

Fifth, we contribute to the debate on whether sharp incentives lead to greater innovative output. Holmstrom (1989) identifies the difficulties in motivating innovative effort. Teece (1996) and Amabile (1996) hold that sharp incentives may be inimical to innovation. Empirical work by Lerner and Wulf (2007) and Kline et al. (2019) finds that innovation is associated with long term (rather than short term) incentives. On the contrary, we uncover strong evidence that technologically-advanced firms provide sharper incentives as a result of the IPR shock.

Sixth, there is small and scattered literature on the effect of IPR on income inequality. In a theoretical setup, Parello and Spinesi (2005) show that increased legal protection from patent infringement allows firms to move up the quality ladder faster, thereby increasing the relative value of skilled labour vis-a-vis unskilled. Relatedly, there exists another set of papers, both theoretical and empirical, which looks at the effect of IPR on income inequality (Adams, 2008; Chu and Peng, 2011; Saini and Mehra, 2014).

Finally, the paper relates to the effect of IPR reform on innovative activities of countries, industries, firms and other industry/firm characteristics (see for example, Glass and Saggi (2002) on foreign direct investment and Ivus (2010) on high-tech exports). The effect of an IPR reform on innovation performance has been addressed at multiple levels: country (Park and Lippoldt, 2004; Chen and Puttitatun, 2005; Branstetter et al., 2006; Qian, 2007), industry-firm (Sakakibara and Branstetter, 2001; Allred and Park, 2007; Yang and Maskus, 2009; Lo, 2011). We extend and complement this literature by looking at the effect of an IPR reform on between-firm dimensions of management and organization. In addition, it also contributes to the literature on the effect of the specific 2002 IPR reform in India.

The paper is organized as follows. The next section lays out the details of the reform. We provide details about the data, in Section 3. Section 4 sketches our theoretical model. The empirical strategy and exogeneity of the reform is discussed in Section 5. In Section 6, we report our results, showing the effect of higher incentives to innovation on demand for managers through higher technology adoption and how does it vary across firms' distribution of technology investments. We discuss other complementary channels, types of firms which drive our results in Section 7. The last section discusses our results and concludes.

2 Institutional Background

The pre-1990s intellectual property regime in India was governed by the The Indian Patent Act, 1970, which was aimed at preventing foreign monopolies.[18] Section 5 of the Act states that, in the case of inventions (a) claiming substances intended for use, or capable of being used as food or as medicine or drug, or (b) relating to substances prepared or produced by chemical processes (including alloys, optical glass, semi-conductors and inter-metallic compounds), no patent shall be granted in respect of claims for the substances themselves, but claims for the methods or processes of manufacture shall be patentable. Although it seems, in view of the above two conditions, that apart from these three sectors, product patents were granted in other sectors

[18] The Patent Act of 1970 was partly based on the recommendations of Patent Enquiry Committee (1948-50) and the Ayyangar Committee (1957-59), which made two major observations: (i) the Indian patent system has failed to stimulate and encourage the development and exploitation of new inventions for industrial purposes in the country; and (ii) foreign patentees were acquiring patents not in the interests of the domestic economy but with the objective of protecting an export market from competition of rival manufacturers. The reports also concluded that the foreigners held 80-90% of the patents in India and were exploiting the system to achieve monopolistic control of the market (Ramanna, 2002).

before 2002, but there were significant restrictions to those (Reddy and Chandrashekaran, 2017).[19] Such as, a lot of items apart from the chemical sector also involve significant use of chemical processes, such as textiles and leather, the term of patents was only 5-7 years while the international standard was 20 years, government could use patented inventions to prevent scarcity or in national emergencies, costs of patent litigation were significantly higher in absence of proper facilities, etc. Therefore, such a system only allowed domestic firms to imitate foreign products with a slightly different process, thus expropriating value from investment in product innovation made by foreign firms. The 1970 Patent Act soon started facing international resistance as discussions on free trade started getting linked to IPR (Chaudhuri, 2005).

In 1991, India ran into its much-discussed balance-of-payments (BOP) crisis and turned to International Monetary Fund (IMF) for assistance. The IMF conditioned its assistance on the implementation of a major adjustment program that included several liberalization steps and becoming a member of the World Trade Organization (WTO). In 1994, India signed the Marrakesh Agreement and agreed to be bound by TRIPs. It enabled India to get a 10-year moratorium period (1995-2005) to transition to a stronger, TRIPs-compliant IPR regime which would respect product patents (for details, see Chaudhuri, 2005). This transition had several hiccups with uncertainty around the implementation of the new regime. As we explain below, the uncertainty cleared only by 2002, and this provides us the structural break that we exploit in our study.

India's initial transition started with the failed The Patents (Amendment) Ordinance, 1994 which was tabled by a weak coalition government, amending The Indian Patent Act, 1970. It allowed for a 'mailbox' provision through which firms could file product patent applications which would be reviewed on a priority basis as and when India amended its patent laws to comply with TRIPs. However, uncertainty remained about the exact time frame of this transition. Simultaneously, The Patents (Amendment) Bill, 1995 was introduced in the Parliament to enforce the ordinance.[20] As per Indian law, a bill must be passed by both houses of the parliament. While the Upper House passed it, the Indian parliament was dissolved due to ideological differences between members of the ruling coalition once the bill was in the lower house of the parliament. The Patents (Amendment) Bill, 1995 automatically lapsed leaving the uncertainty around IPR transition alive.

The United States filed a complaint against India to the Dispute Settlement Board (DSB) of the WTO in 1996 for failing to abide by the TRIPs.[21] India lost this case, despite an appeal, with the U.S. further bolstered by an European Community complaint. India then negotiated with the U.S. to amend its patent

[19] We use pharmaceuticals, chemicals and food products sectors as an placebo to show that the increase in managerial compensation was much higher in these sectors than others.

[20] In Indian constitutional law, ordinances are valid for only six months from the day of promulgation, or six weeks from the day Indian Parliament reconvenes after the ordinance is promulgated.

[21] See: World Trade Organization, Chronological list of disputes cases, available at https://www.wto.org/english/tratop_e/dispu_e/dispu_status_e.htm and World Trade Organization, India — Patent Protection for Pharmaceutical and Agricultural Chemical Products, WT/DS50/1, available at https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds50_e.htm.

law by April 1999.[22] Finally, in order to honour this commitment made to the DSB, India implemented The Patents (Amendment) Act, 1999 despite civil society concerns. This amended Act had the provision for filing of applications for product patents in the areas of drugs, pharmaceuticals and agrochemicals, though the applications were only to be reviewed after 31st December, 2004.[23] However, this Act came as a compromise in what was still an uncertain environment around patent policy and was basically a post factum of the failed Patent (Amendment) Bill, 1995. It failed to encourage much innovation.

Throughout the nineties, patent policy in India was subject to a political tug-of-war. While a large section of the INC (Indian National Congress, the ruling party during the first half of the decade) had been sympathetic to liberal patent laws, there was stiff resistance from the opposition as well as parts of INC. In April 1993, a parliamentary committee tasked to study the draft proposal by Arthur Dunkel on Uruguay round of GATT documented the strong unwillingness of India to comply with TRIPs,[24] although its recommendations were rejected by the ordinance of 1994. The BJP (Bharatiya Janata Party), after coming to power in 1998, abandoned its opposition and adopted a pro-patent position. By the turn of the millennium, a majority within both the BJP and the INC favoured a more liberal patent policy.[25] By this time, a domestic constituency had also emerged in support of the patent reform. The support occurred at different levels: first, the impact of liberal ideas regarding economic reforms slowly led to a more westernized notion of IPR; second, by this time a more 'modern', professionally managed and technologically advanced segment of industry had developed in India; third, top Indian research and scientific institutes (e.g., Council of Scientific and Industrial Research, CSIR) felt that they could benefit from patents rather than publications (Ramanna; 2002; Choudhury and Khanna, 2014).[26]

Overall, our detailed discussion of the events prior to the implementation of the 2002 Act suggests that there was a significant amount of uncertainty in transitioning to a stronger IPR regime, which essentially cleared up with The Patents (Amendment) Act, 2002 (Reddy and Chandrashekaran, 2017). We utilize this Act as a quasi-natural experiment to understand how the change in the intellectual property rights regime affects a firm's compensation structure. We conduct a variety of exogeneity checks (explained in detail in Section 4.1) to ensure that we address any confounding impact of potential ex-ante industry or firm level changes that may have influenced the 2002 IPR reform.

[22]Dispute Settlement Body, India - Patent Protection for Pharmaceutical and Agricultural Chemical Products - Reasonable period of time for implementation of the DSB's recommendations, WT/DSB/M/45 (Jun. 10, 1998), at 16.

[23]Further, the applicants could be allowed Exclusive Marketing Rights to sell or distribute these products in India, but subject to fulfilment of certain conditions.

[24]India, Rajya Sabha, Parliamentary Standing Committee on Commerce, DRAFT DUNKEL PROPOSALS at 46 (December 14, 1994)

[25]For details, see 'Parties undecided on Patents Bill', Economic Times, December 21, 1998; 'BJP Eases Stand on Swadeshi Plank, Backs Government Policy', Deccan Herald, January 5, 1999; 'Congress Support to Ensure Passage of Patents Bill', Economic Times, December 23, 1998.

[26]ASSOCHAM (Associated Chambers of Commerce and Industry) also gave a written submission to the Committee on the need for phased introduction of product patents in India and pointed out that it was of the view that to attract increasing flow of foreign direct investment, it is important for India to strengthen the patent system. This will ensure higher interaction in R&D as well as flow of foreign capital.

3 Dataset

We exploit a dataset of Indian manufacturing firms drawn from the PROWESS database, constructed by the Centre for Monitoring the Indian Economy (CMIE). The dataset has previously been used by Khandelwal and Topalova (2011), Ahsan and Mitra (2014) and Chakraborty and Raveh (2018), among others. The dataset accounts for more than 70% of the economic activity in the organized industrial sector, and 75% (95%) of corporate (excise duty) taxes collected by the Indian Government (Goldberg et al., 2010). All variables are measured in Millions of Indian Rupees (INR), deflated to 2005 using the industry-specific Wholesale Price Index, and are outlined in **Appendix A** (Data). **Table 1** presents descriptive statistics for the relevant variables.

The database contains information on approximately 27,400 publicly listed companies, all within the organized sector, of which almost 11,500 are in the manufacturing sector.[27] It reports direct measures on a vast array of firm level characteristics including sales, exports, imports, production factors employed, gross value added, assets, ownership, products produced, and others. The dataset covers both large and small enterprises; data for the former types is collected from balance sheets, whereas that for the latter ones is based on CMIE's periodic surveys of smaller companies.

PROWESS has several features that makes it particularly appealing for the purposes of our study as compared to other available sources, such as the Indian Annual Survey of Industries (ASI), for instance. First, unlike other sources, the PROWESS data is in effect a panel of firms, enabling us to study their behavior over time; specifically, the (unbalanced) sample covers 108 (4-digit) manufacturing industries that belongs to 22 (2-digit) larger ones,[28] at the National Industrial Classification (NIC) level over the period of 1990-2006.

Second, our classification of firms into high- and low-tech categories are based on the technological investments done by the firms, especially in the pre-reform period. This classification is the key in our case as it explains the differential effect of the reform on the changes in managerial compensation. PROWESS reports detailed information on technology investments which is also absent in ASI. The information on technology adoption, divided into R&D expenditure and royalty payment on technical know-how (i.e., technology transfer), is mandatory as per section 217 of the Companies Act.[29] We aggregate the expenditures on R&D as well as on technology transfer, to represent the total technology adoption expenditure for any given firm.

Third, the feature of the dataset upon which our study is based, is that it disaggregates compensation

[27] While placed according to the 4-digit 2008 National Industrial Classification (NIC) level, firms are reclassified to the 2004 level to facilitate matching with the industry level characteristics. Hence, all industry level categorization made throughout the paper are based on the 2004 NIC classification.

[28] In terms of composition, approximately 20% of the firms in the dataset are registered under the Chemical and Pharmaceutical industries, followed by Food Products and Beverages (13.74%), Textiles (10.99%) and Basic Metals (10.46%).

[29] As per section 217(1)(e), the information shall be attached to every balance sheet laid before a firm in the Annual General Meeting, in a report by its board of directors.

data by managers and non-managers, with a further decomposition of compensation to wages and bonuses. Additionally, the managers are divided into two groups: directors and executives.[30] The non-managers are defined as those who do not manage other employees.

A key related issue is regarding the accuracy and consistency of the data. Chakraborty and Raveh (2018) compares the compensation data for 20 randomly selected firms (representing both relatively large and small ones) from PROWESS with that of those reported in the annual reports and finds that the correlation is higher than 0.99. We implicitly assume that there is consistency in the definition of managers across firms.[31]

The data set provides a large variation across firms and industries in the compensation of managers compared to non-managers, which enables us to better understand how they react to IPR reform. For instance, the average share of managerial compensation in total labour compensation across 2-digit industries for the period of 1990-2006 goes from a low of approximately 1.5% to a high of around 9% (Chakraborty and Raveh, 2018). The variation is also observed when measuring changes (in managerial compensation) over time; averaging annual changes over the same period, we observe that while in some industries the average annual rate of change is around 10%, in others it can get as high as 200%. Such variation will be more prominent when the data translates to the firm level.

4 Theory

Before getting on with using the data for our empirical estimations, we provide a simple model in this section to illustrate how firm demand for managers respond to an IP shock, as a function of its capital stock. The model is built on the following basic premises. Each firm engages in two activities: regular output production and innovation. Innovation is produced by managers while regular output is produced by workers, and capital stock is a complementary input in both processes. We assume that innovation performance is driven by manager-capital complementarity. There are many sources of such complementarity, e.g., knowledge spillover, size/scale effects and so on, but we do not formally model the process of innovation. The returns to innovation performance (or equivalently, innovative effort) are determined by a patent race: those with higher effort have a higher likelihood of obtaining the patent. The patent race introduces an externality across firms: the marginal product of managers depends on one's own capital stock as well as on the innovation effort of all other firms. The demand for managers is determined in Nash equilibrium of the patent race game between firms. The change from process to product patent is modelled as exogenous an increase in

[30] While there is scope for subjective interpretation of this distinction by firms, it does not affect our analysis, where we consider the aggregate of Executives and Directors. Directors are defined as managers without executive powers, as opposed to executives who do possess such responsibilities. Executives include, for instance, the CEO, CFO, and Chairman, whereas Directors may include positions such as Divisional Managers.

[31] There is scope for some subjective interpretation of this distinction by firms, when providing data. However, all firms included in the analysis are listed in the Mumbai Stock Exchange, and hence are subject to the same corporate governance and reporting regulations including the said definitions, which mitigates this concern to a large extent. Moreover, our results on managers as a single group do not get affected by such issues. In addition, we use firm fixed effects which will absorb this kind of unobserved heterogeneity.

the value of the patent: we are interested in the firms' response to this shock.

We find that the demand for managers follow a "snail-shape", zero below a cut-off and hump shaped above it. In other words, only firms with capital stock above a threshold participate in the patent race. Among these firms, the demand for managers is largest for an intermediate level of capital stock. Firms with lower capital stock have lower marginal productivity of managers due to manager-capital complementarity. Firms with very high capital stock are already far ahead in competition and the marginal increase in probability of obtaining the patent by expanding managerial workforce is low. This non-monotonicity in demand for managers is obtained due to the patent race externality. If demand were driven only by manager-capital complementarity, then it would be strictly increasing in capital stock.

In the following section, we present the model and results. The detailed analysis, proofs and derivations are presented in **Appendix C**.

4.1 Model

In a certain industry, there are n firms denoted by $j = 1, 2, ...n$.[32] Each firm engages in two activities: producing a regular output and innovation. As a simplification, we assume that there are two types of outputs: the regular output X_j and the innovative output Y_j. There are three kinds of inputs: managers (M), workers (L) and capital (K). In the short run, the stock of capital is given, and a firm j is parameterized by its capital stock k_j. We assume that $k_1 > k_2 > k_3 > .... > k_n > 0$.

We think it is reasonable that managers are more important for producing innovation and workers for producing the regular output. To capture this in a tractable way, we posit the following production functions for the two kinds of outputs. The regular output X is produced only with workers and capital, and the production function for firm j is $f_j(L, K) = L_j^a K_j^b$, where $0 < a < 1$ and $0 < b < 1$ are constants. The market for regular output is competitive, and the price of X is p.

For the innovative output, the firms are engaged in a patent race. The value of the patent is v, and a firm obtains the patent with a probability which depends on its "innovative effort" $q_j \geq 0$ through a contest function. We assume the simplest functional form: the probability that firm j obtains the patent is $\frac{q_j}{\sum_i^n q_i}$. The innovative effort q_j of a firm depends on the number of managers $m_j \geq 0$ employed and the amount of capital stock k_j. We therefore assume that $q_j = \gamma m_j k_j^\alpha$ where $\gamma > 0$ and $0 < \alpha \leq 1$. The expected value of innovative output Y_j is

$$\frac{m_j k_j^\alpha}{\sum_{i=1}^n m_i k_i^\alpha} v$$

While the literal interpretation is that each firm obtains the patent of value v with probability proportional to its innovative effort q_j, this model is also consistent with the interpretation that each firm obtains a share of the prize v in proportion to q_j.

[32] We need a finite number of firms since this is a game theoretic model.

In the short run, the firm j, given capital stock k_j,chooses the number of workers $L_j \geq 0$ and managers $m_j \geq 0$ to maximize

$$\pi_j = \frac{m_j k_j^\alpha}{\sum_{i=1}^n m_i k_i^\alpha} v + pL_j^a k_j^b - zL_j - wm_j$$

where z is the wage rate for workers and w is that for managers. We implicitly assume that no firm has market power in the market for managers and workers.

The optimal number of workers for firm j is given by $L_j^* = \left(\frac{z}{p} k_j^b\right)^{\frac{1}{1-a}}$, which we write as Ak_j^β, where $A > 0$ and $\beta > 0$.

There are two challenges to finding the optimal number of managers m_j^*. First, m_j^* is determined by the Nash equilibrium of the patent race game. Therefore, a firm's choice of managers depends on the other firms' choices. Second, we have to ensure that the number of managers is non-negative.

At this point, we introduce a definition: a firm is said to be **active** if $m_j^* > 0$ and **inactive** if $m_j^* = 0$. An inactive firm does not engage in innovation ($Y_j = 0$) and only produces the regular output.

The first order condition of the patent race game is as follows.

$$\frac{\partial \pi_j}{\partial m_j} = \frac{k_j^\alpha \left[\sum_{i \neq j}^n m_i k_i^\alpha\right]}{\left(\sum_{i=1}^n m_i k_i^\alpha\right)^2} v - w \tag{1}$$

The Nash equilibrium is given by the conditions

$$\frac{\partial \pi_j}{\partial m_j} \leq 0 \text{ and } m_j \frac{\partial \pi_j}{\partial m_j} = 0 \text{ for all } j.$$

While we furnish the detailed analysis in the appendix, here we provide the steps to the solution. First we solve the first order conditions without taking into account the non-negativity constraint on m_j. This gives us the solution to the unconstrained game

$$\widetilde{m}_j^n = \left(\frac{v}{w}\right) \left(\frac{\frac{1}{k_j^\alpha}}{\frac{1}{n-1} \sum_{i=1}^n \frac{1}{k_i^\alpha}}\right) \left(1 - \frac{\frac{1}{k_j^\alpha}}{\frac{1}{n-1} \sum_{i=1}^n \frac{1}{k_i^\alpha}}\right)$$

Define an index which is an *inverse* measure of the firm's capital stock,

$$d_j^n \equiv \frac{\frac{1}{k_j^\alpha}}{\frac{1}{n-1} \sum_{i=1}^n \frac{1}{k_i^\alpha}}$$

Note that $d_1^n < d_2^n < ... < d_n^n$. Notice that $d_j^n > 0$, but there is no guarantee that $d_j^n < 1$, since the denominator is divided by $n - 1$ and not n.

As a solution to the unconstrained game, we have $\widetilde{m}_j^n = \left(\frac{v}{w}\right) [d_j^n (1 - d_j^n)]$. Observe that this value can be negative for firms with low capital stock. We now have to determine the set of *active* firms.

We observe next that if a firm $j > 1$ is active in equilibrium, the firm $j - 1$ must also be active. Therefore, the set of active firms constitute the top end in terms of capital stock, down to a cut-off. Suppose the set of firms $\{1, 2, ...t\}$ are active for some arbitrary $t \leq n$. For an active firm $j \leq t$, denote the index d_j^t as

$$d_j^t \equiv \frac{\frac{1}{k_j^\alpha}}{\frac{1}{t-1}\sum_{i=1}^{t}\frac{1}{k_i^\alpha}}$$

In this case, it is easy to see that the demand for managers in each active firm is $\left(\frac{v}{w}\right) d_j^t \left(1 - d_j^t\right)$. Clearly, this requires that $d_j^t < 1$ for all active firms $j = 1, 2, ..t$. This condition is satisfied as long as $d_t^t < 1$, or the smallest active firm employs a positive number of managers. The equilibrium set of active firms is $T = \arg\max_t\{d_t^t < 1\}$.

The following proposition formally presents the optimal choice of managers.

Proposition 1 *Denote by T the maximum value of t such that $d_t^t < 1$. The unique Nash equilibrium choice of managers is given by $m_j^* = \left(\frac{v}{w}\right) d_j^T \left(1 - d_j^T\right)$ for $j = 1, 2, ..T$ and $m_j^* = 0$ for $j > T$.*

Proof. In appendix. ■

The two important features of this equilibrium are : (1) firms with lower than a threshold capital stock (k_T) do not employ managers for innovation, and (2) the demand for managers among the active firms at first increases and then decreases in capital stock. To see the second part, note that the maximum value of $d(1 - d)$ occurs at $d = \frac{1}{2}$. Therefore, m_j^* is concave and maximized for the value of j such that d_j^T is closest to $\frac{1}{2}$.

This gives us our snail-shape in the demand for managers: firms lower than a threshold capital stock employ $m_j^* = 0$ and above the threshold, demand for managers is hump-shaped (inverse U). Of course, all that the result says is that the distribution is *potentially* snail-shaped, and we need sufficient variation in the distribution of capital stock to avoid extreme trivial cases.

Before going to the next section, we make a comment about the model. In the production function, we have assumed that labour is needed only for regular output and managers only for innovation. This is obviously a simplification, and it allows us to solve the model in closed form. More importantly, it also delivers the result that there are firms that do not engage in innovation but produce only the regular output. A more realistic specification that would lead to the same outcome would be that both the outputs use all three inputs (managers, labour and capital), and innovation is more sensitive to managerial input than is the regular output. Moreover, there are non-concavities in innovation, and a minimum threshold of managerial input is required to produce innovation. Inactive firms employ managers less than that threshold, and their demand for managers is therefore not affected by a change in the size of the prize.

4.2 Empirical implications

Now we turn to the empirical counterpart of our result. In the data, we look at the share of managers' compensation in the total compensation. The compensation for managers in firm j is wm_j^* and that for workers is zL_j^*. Thus, the variable of interest is

$$C(k_j) = \frac{wm_j^*}{wm_j^* + zL_j^*},$$

where m_j^* is given by Proposition 1 and $L_j^* = Ak_j^\beta$.

What we can identify is how $C(k_j)$ changes with v. The natural experiment we consider – an exogenous shift from process to product patent – has the effect of raising the returns to innovation or raising v in terms of our model. Our empirical hypothesis is presented in the following result.

Proposition 2 *Assume that $C(k_j) < \frac{1}{2}$ for all j.*[33] *The change in $C(k_j)$ with respect to v, i.e., $\frac{dC(k_j)}{dv}$, is zero for $j > T$ and positive for $j < T$. Moreover, for $j < T$, $\frac{dC(k_j)}{dv}$ is hump-shaped: $\frac{dC(k_j)}{dv}$ is maximized for the firm j with d_j^T closest to $\frac{\alpha+\beta}{2\alpha+\beta}$.*

Proof. In appendix ■

For the purpose of intuition, note that since m_j^* is linear in v, the rate of change of managerial demand, i.e., $\frac{dm_j^*}{dv}$ has the same shape as m_j^* as a function of k. The proof consists of showing that $C(k_j)$ will inherit the same properties as m_j^* as long as the manager's compensation is less than the worker's wage bill ($C(k_j) < 1/2$). This assumption is satisfied in our data for practically every firm in the dataset.

Our empirical strategy consists of two exercises. In the benchmark exercise, we break up each industry into firms with above median capital stock (high-tech firms) and those with below median capital stock (low-tech firms). Recall that the theory predicts that there is some T such that $\frac{dC(k_j)}{dv} = 0$ for $j > T$ and $\frac{dC(k_j)}{dv} > 0$ for $j < T$. In this specification, we take T to be the median firm. Therefore, the high-tech firms (the above-median firms) have a positive $\frac{dC(k_j)}{dv}$ while the low-tech firms (the below-median firms) have $\frac{dC(k_j)}{dv} = 0$. We estimate the difference in the average value of $\frac{dC(k_j)}{dv}$ between the high-tech and low-tech firms. This difference is estimated as our "interaction term" and is loosely referred to as the effect of the shock.

In the second exercise, we try to establish the snail-shaped graph of $\frac{dC(k_j)}{dv}$. We break up the firms in the sample into deciles and estimate the average $\frac{dC(k_j)}{dv}$ in each decile. In this case, we expect the value of $\frac{dC(k_j)}{dv}$ to be zero in the low deciles, increase in the middle deciles and then again go down in the high deciles. We do this exercise separately for various industry groups. We indeed find that the threshold T is

[33] This is also confirmed by the data we use. An average firm pays around 2% of their total labour compensation towards managers. Even a firm in the 99th percentile and above (of the size distribution) pays their managers about 30% of their total labour compensation.

around the median: for the first five deciles, the effect is not distinguishable from zero. Typically, the effect is positive for the sixth to eighth decile and again vanishes in the tenth decile, providing us evidence for the snail-shape.

5 Empirical Strategy

Higher incentives to innovation induce firms to demand more managerial skill to maximize innovation potential, and can be more pronounced for technologically advanced firms. We study this phenomenon using the Patents (Amendment) Act, 2002 as an instrument for innovation to analyze its effect on the share of managerial compensation in total labour compensation for manufacturing firms in India. We use a difference-in-differences approach following Branstetter et al. (2006, 2011) controlling for other firm and industry level characteristics and other simultaneous policy changes that might affect the outcome of interest using the following specification:

$$\begin{aligned}\left(\frac{Mcomp}{Tcomp}\right)_{it} &= \alpha_i + \alpha_t + \alpha_{jt} + \beta_1(IPR_{02} \times HighTech_{i,90-01}) + \\ &\quad X_{ijt} + firmcontrols_{it-1} + \epsilon_{it}\end{aligned} \tag{2}$$

where, i indexes an individual firm, j the firm's industry group, and t the year. $Mcomp$ denotes the total managerial compensation, whereas $Tcomp$ is the total labour compensation of a firm. So, the dependent variable measures the share of managerial compensation in total labour compensation of a firm. IPR_{02} is the post-IPR reform dummy variable, which takes a value of 1 for years on and following the imposition of The Patent (Amendments) Act, 2002. In particular, IPR_{02} takes 1 for the years 2002-2006.

An intellectual property rights reform raises the incentives to invest both in R&D and technology transfer. On the other hand, managerial skill is a strong complement to technological inputs (Garicano, 2000). Therefore, the firms that already have higher level of technology at the time of the reform, would demand more managers than those which are technologically less advanced. Acemoglu et al. (2006) argues that for countries which are closer to the technology frontier, selection of high-skilled managers becomes crucial as managerial skill is important for innovation.

To study whether such is the case at the firm level, i.e., whether a change in patent regime affects firms' demand for managers differentially, we divide the firms into two groups based on their investment in technology adoption before the reform. Firms are defined as 'high-tech' firms or 'treated' group in our estimation if the average GVA (gross value-added) share of technology adoption (sum of R&D expenditure and royalty payment for technical know-how) for the years before the reform (1990-2001) is greater than the median of the industry to which the firms belongs. We assign these firms a high technology use dummy,

$HighTech_{i,90-01}$, equals to 1. For the rest of the firms, $HighTech_{i,90-01}$ equals 0, which serves as 'control' group in our estimations.[34]

Table 2 compares high-tech and low-tech firms before and after the 2002 IP reform on various characteristics, such as technology adoption, managerial compensation, capital employed, trade (exports and imports) and sales. We calculate the mean share of these observable characteristics over the gross value-added (GVA) of a firm. For an average high-tech and low-tech firm, the differences across these characteristics before the implementation of the Act were to the tune 1–30%; this increased to 30–300% after the reform.

Typically, one expects the experiment to affect only the treatment group and not the control group. While there is no a priori reason for the control group not to be affected by the Act of 2002, in a later section we find that the control group is indeed unaffected by the Act. In section 6.2.2, we examine the effect of the IP policy shock on different deciles of firms and demonstrate that the effect on the bottom five deciles cannot be statistically distinguished from zero. In Section 6.3.1, we perform the same exercise with a different choice of treatment group. We classify our data according to IP-sensitivity of industries following the definitions provided in Delgado et al (2013), and obtain the same results.

Our key variable of interest is the interaction term $IPR_{02} \times HighTech_{i,90-01}$ (or its coefficient β_1). It measures the differential response of the high-tech and low-tech firms due to the IPR shock in terms of demand for managers. In other words, β_1 measures between-firm inequality in terms of demand for managerial workers. We expect its sign to be positive.

Note also that both types of firms are similarly affected due to the reform; the reform provides all firms the same incentives to innovate. This means that the effects we document are only due to the differential behavioural responses of these two types of firms. Our identification strategy is based on two assumptions. First, the behavioural responses of firms should not affect the timing and/or the occurrence of the reform, or simply that the reform is exogenous. Second, both types of firms should have had similar trends in terms of the demand for managers before the reform, on average. We later provide evidence in support of these two assumptions.

X_{ijt} is a vector of firm and industry characteristics which are likely to impact a firm's managerial compensation. For example, following Chakraborty and Raveh (2018), we use both input and output tariffs at the industry level to control for trade reforms initiated by the Govt. of India during the 1990s. We also specifically control for product market competition effect (both for domestic and export market), skill-intensity, management technology, IT expenditure, productivity, labour regulations, institutional quality, financial development, etc. We also include three firm level controls ($firmcontrols$) in all our specifications:

[34] While it is true that this is not a perfect control group that we could use in the estimations, given the nature of the reform, it is difficult to find a group of firms, which is exogenous to the change in intellectual property regime. Given the circumstances, this is the best we could use as all other sectors are also simultaneously impacted by other reforms (e.g., trade reforms). Using any other sector, say agriculture, would have been more exogenous to the reform, but the behavioural pattern of the agricultural sector is completely different from that of services and may bias the results in a different manner.

age of a firm (older firms may have a more established structure and culture; controlling for age would take care of the potential differences in the flexibility of undertaking organizational reforms), amount of capital employed as a share of total gross value-added (higher capital intensity may also raise the demand for managers significantly) and assets (larger firms may have greater management needs). We use assets and capital intensity in $(t-1)$ period. α_i and α_t are time-invariant firm and year fixed effects, respectively.

While estimating the above equation, we carefully control for other simultaneous reforms, such as delicensing of industries (which happened during the 1990s), any unobservable possible tax incentives for R&D, corporate governance reforms[35], etc. that may affect the share of managerial compensation in a firm. Those, if not controlled for can bias our outcomes. To control for these unobserved policy changes (or any other change in the economic environment affecting all firms), we use α_{jt} – industry-year trends. We interact a firm's industrial classification at NIC 5-digit level (most disaggregated level of industrial classification) with year trends to control for other simultaneous policy reforms that may affect our dependent variable. We also replace the industry-year trends with industry-year fixed effects at various (industrial classification) levels, but the results do not change.

However, one should still be careful in interpreting the basic estimates as conclusive evidence of the causal effect of the IPR reform on the differential demand for managers between high-tech and low-tech firms because of the following three reasons: (a) omitted variable bias, (b) differential time trends; and (c) reverse causality. We address the former by sequentially adding various firm and industry characteristics and its interaction with the $HighTech_{i,90-01}$ dummy to our baseline specification. As for the latter ones, we first show that the two groups of firms are not on different time trends in the pre-reform period and secondly, managerial compensation or any other feature that is closely associated with the demand for managers did not influence the IPR reform through a series of exogeneity checks explicitly in the following sections.

5.1 Were the High-tech and Low-tech firms on Different Pre-Reform Time Trends?

We now take a cue from Abramitzky and Lavy (2014) and show that our treatment (high-tech firms) and control (low-tech firms) group were not on different time trends in the pre-reform period. We use pre-reform

[35] There were a couple of crucial changes in the realm of corporate governance reforms that took place around the implementation of The Patents (Amendment), Act, 2002: (i) exogenous changes in the Clause 49. The Clause 49 reform required firms to change the composition of their board of directors – specifically, at least 50% of the board had to consist of independent directors; and (ii) in 2002 the Securities and Exchange Board of India (SEBI) (Amendment) Act, 2002 replaced the earlier SEBI Act, 1992 to enlarge the Board of Directors of firms and transparent functioning of the Indian capital market. All these changes can induce a large number of firms to consistently report the compensation of the managers (especially, the top managers). However, we argue that is not the case. First, looking at **Figure 2** closely, it can be noticed that it is not only after 2002 that we observe a sharp rise in the share in managerial compensation; it was also during mid-1990s. If it had been only for the corporate governance reforms and nothing else, then we would have seen only a secular trend before 2002 and no spike. Chakraborty and Raveh (2018) show that the increase in the share of managerial compensation during the 1990s is due to the trade reforms undertaken by India. Second, even though the reform for the Clause 49 was adopted by SEBI in 2000, it was only in late 2002, SEBI constituted a committee to assess the adequacy of current corporate governance practices, and based on the recommendations of this committee, the Clause 49 came into operation on 1 January 2006.

data from 1990 to 2001 to estimate differential time trends in outcomes for high-tech and low-tech firms. Results are reported in **Table 3**. First, we estimate a constant linear time trend model while allowing for an interaction of the constant linear trend with the $HighTech_{i,90-01}$ dummy. Second, we estimate a model where we replace the linear time trend with a series of year dummies (for the pre-reform period) and include in the regression of each of these time dummies with the $HighTech_{i,90-01}$.

The estimates from columns (1) and (2) suggest that there is a time trend in the managerial compensation used, but this trend is identical for high-tech and low-tech firms. The estimated coefficient on the interaction of the time trend and year dummies with the $HighTech_{i,90-01}$ dummy is practically zero in all the cases. We also note that some of the interaction terms in column (2) are positive and others are negative, thereby lacking any consistent pattern. We, therefore cannot reject the hypothesis that all the interaction terms are jointly equal to zero. We conclude that both groups of firms were on a similar time trend of demand for managers in the 11 years prior to the reform.

Next, in column (3), we run a placebo test with detailed estimates of the timing of changes in share of managerial compensation. We follow Branstetter et al. (2006) and adopt the following methodology. We use an ex-ante ex-post approach to prove that The Patents (Amendment), Act 2002 is not endogenous. In other words, the estimation examines if there were any anticipatory effects of the reform. It could be possible that some of the high-tech firms were lobbying for the implementation of a stronger IPR regime to reap higher benefits and started reorganizing the firm structure accordingly. This could have increased the share of managerial compensation of the firms before the reform and post-2002 increase was just a mere continuation. We argue such is not the case.

The $IPR_{02}(t-4)$ dummy is equal to one for all years that predate the 2002 Patent Act by four or more years and is equal to zero in other years, and the $IPR_{02}(t+4)$ dummy is equal to one for all years at least four years after the IPR reform and zero during other years. The other reform dummies are equal to one in specific years and zero during other years. There is no dummy for the year of the ban; the coefficient of the other reform dummies estimates relative to that year. The results indicate that the coefficients on the dummies for years prior to The Patents (Amendment) Act, 2002 fails to show any evidence of a significant movement in the demand for managers prior to the reform when estimated relative to the preceding year. For example, the coefficient on the $IPR_{02}(t-4)$ show that the managerial compensation of a high-tech firm is negative and insignificant prior to the reform relative to the concurrent effect of the reform, which is $IPR_{02} \times HighTech_{i,90-01}$. The coefficient of the interaction term for the years after the reform are large, positive and significant. Thus, the timing of changes is consistent with a shift in activities that follows the enactment of the reform; the coefficients are positive, significant and increases over time.

5.2 Exogeneity of The Patents (Amendment) Act, 2002

Another crucial issue regarding our identification strategy is to establish that the timing of the 2002 IPR reform as exogenous, at least with respect to the activities of the Indian manufacturing firms. It might be the case that the high-tech firms lobbied for the The Patent (Amendment) Act, 2002 in order to reap any substantial benefits from it. So, to test for potential lobbying effect on the 2002 reform, we ran some further checks following Khandelwal and Topalova (2011) in **Table 4**. In particular, we test whether the interaction of high-tech dummy and reform dummy is correlated with important pre-reform (pre-2002 but post-1999) industry characteristics, which may have influenced the 2002 reform. If this were the case, one should expect current share of managerial compensation to predict future implementation of the IPR reform due to the influence of the high-tech firms. In order to understand, we use the following regression[36]:

$$IPR_{02} \times HighTech_{i,90-01} \quad = \quad \alpha_i + \alpha_{jt} + \delta_1 \pi_{it} + firmcontrols_{it-1} + \epsilon_{it} \qquad (3)$$

π_{it} is a vector of characteristics that can possibly influence the reform. It includes share of managerial compensation (a larger share of managers may influence the industry lobbyists to put pressure on the Govt. to adopt more stronger intellectual property rights), capital intensity (this captures whether more capital intensive firms/industries are instrumental in driving the reform), technological adoption (firms may have set up R&D centres anticipating the reform, and therefore might lobby for the reform), consultancy fees (domestic) for technical know-how (a crude proxy for lobbying expenditure: where firms can pay more to the local R&D institutes to lobby for stronger patent protection), share of skilled workers (a highly skilled work force may also push for reforms in order to reap benefits from higher incentives to innovation), and average factory size (this captures the ability of producers to organize political pressure groups to lobby for stronger patent rights regime). All the pre-reform characteristics are measured as an average for the years 2000 and 2001.[37] These results are presented in columns (1) − (6). The coefficients indicate no statistical correlation between the complementary effect of technology adoption and 2002 IPR dummy and any of the industry characteristics. The above analysis leads us to the conclusion that the delays, debates and dilemmas regarding IPR in the previous decade had meant that firms did not commit to changing their internal organization. For all practical purposes we can treat the Act of 2002 as exogenous regarding changes in firm organization.

[36] We have also used the following equation for robustness check: $IPR_{02} = \alpha_i + \alpha_{jt} + \delta_1(\pi_{it} \times HighTech_{i,90-01}) + firmcontrols_{it-1} + \epsilon_{it}$. And, the results are similar. We do not find any association between any key firm or industry characteristics driving the reform.

[37] Results are similar if we change the time period to 1990-2001.

6 Results

6.1 First Order Effects

Before we go to our main results on the effect of the IP reform of 2002 on the wage inequality of Indian manufacturing firms, we aim to understand the first order effects of the reform. In particular, we discuss three issues: (a) reallocation of productive factors from low-tech to high-tech firms (b) between-firm responses to the change in IP law in terms of product variety and product quality, and (c) the effect on patenting activity. We present our results in **Table 5**.

Columns (1) – (3) show significant evidence of between-firm reallocation of productive factors in terms of R&D expenditure, transfer of technology (we use royalty for technical know-how as an indicator), and capital employed. High-tech firms spend significantly more on R&D, technology transfer and employ more capital as a result of the change in IP law.[38] Garicano (2000) explicitly shows that changes in production technology is significantly associated with changes in organizational design, especially in terms of demand for managers. These reallocation of productive factors across firms also point towards a capital-skill complementarity channel that may be at work. Our estimates show that the 2002 IP reform led to about 90% more increase on R&D expenditure for high-tech firms. In case of technology transfer and capital employed, the numbers are 22 and 28%, respectively.

We now estimate the effect of change in the IP law on the product scope, which we define as the number of product varieties produced by a firm. The implementation of product patent filings should have a positive effect on the number of product varieties produced, especially for the high-tech firms. Column (4) shows that the change in the IP law increases the number of products produced by the high-tech firms by about 3% more than that of low-tech firms. Next, we utilize firm-product-year level data to explore the effect of stronger patent laws on product quality in column (5).[39] We follow de Loecker et al. (2016) and calculate the price of a product as an indicator for quality.[40] Our estimate shows that there is a significant increase, following the IP reform, in the relative difference in product quality between high-tech and low-tech firms. This is consistent with the idea in Parello and Spinesi (2005) that stronger IPR allows firms to move up the quality ladder.

Lastly, we investigate whether the Patents (Amendment), Act 2002 have any effect on a firm's patenting activity. The time period between the imposition of the 2002 Act and the end of our sample period is not long enough (just four years) to understand whether IP reform has actually led to an increase in product

[38] A couple of recent survey papers (Williams, 2017 and Sampat, 2018) show how patent laws significantly affect research investments.

[39] Note that the number of observations go up significantly as we use firm-product-year level data for this column rather than firm-year level.

[40] We closely follow the methodology proposed by de Loecker et al. (2016) to estimate the coefficients of the production function. We use these estimates to calculate prices at the firm-product level. The main advantages of using this method are: (a) allows for multi-product production function; (b) overcomes bias in revenue based production function estimates by using information on quantities of products; (c) accounts for unobserved input allocations and firm specific input prices.

patents earned by a firm. As a proxy, we look at whether the Act induced firms to file for more product patent claims after 2002 or not.

To do so, we utilize data from patent filings by Indian manufacturing firms with the Indian Patent Office (IPO). Firm innovative activity data comes from the EKASWA database assembled by the Patent Facilitating Centre (PFC) of the Department of Science and Technology, Govt. of India. EKASWA contains all domestic patents published between January 1994 and early 2011. For our purpose, we restrict the data till 2006. Our analysis focuses on the patent claim by a firm, segregated into product and process claims. Due to the absence of an unique identifier between the firm level balance sheet and firm level patent data, the main problem in matching these two dataset consists in matching assignee in the patents to firm names.

To match assignee names to firm names, we rely on a combination of an automated matching algorithm and extensive manual checking of the (un) matched data. We search through every patent claims with the keywords 'product' and 'process' claims to classify it as a product or process claim filing. With this, we are able to match only around 30-35% of our firm level data to the patent data. Therefore, the results we present here might be a lower bound of the true effects of the Patent Act, 2002 on the claims of patents filed in India.

Column (6) uses share of product claims in total patent claims filed by an Indian manufacturing firm with the IPO. Due to prevalence of higher proportion of zeros in the dependent variable, we use Binomial regression for our estimation. Our variables of interest, $IPR_{02} \times HighTech_{i,90-01}$ is positive and significant. It means that the high-tech firms are filling for more product claims in their patent filings as compared to low-tech firms in the post-2002 period. Our estimate points out that an average high-tech firm files for 54% more product claims in post-2002 period than a low-tech firm.

Overall, we find that the strengthening of patent law induces a quality-upgrading mechanism. High-tech firms now adopt more technology, produce more products at a higher quality, and file for more patents.[41]

6.2 Benchmark

We now report our main findings under three main heads: relative demand for managers, heterogeneity in such responses, and incentive provision.

6.2.1 Managerial Compensation

We now present our benchmark results from estimating equation (1) in **Table 6**. We use managerial share of total compensation as a measure of demand for managerial skill in the intensive margin, for the period 1990-2006, as our outcome of interest. We provide different specifications by varying the fixed effects (firm, year, industry-year and so on) as well as the level of aggregation while always controlling for the age (including

[41] We also look at the effects on sales (divided into domestic and exports) of firms. Revenues from both domestic and exports increases for high-tech firms. However, the increase in total sales is significantly driven by domestic sales.

a quadratic term), ownership and size of a firm. We find that in each of these specifications, the coefficient of the interaction term $IPR_{02}\times\ HighTech_{i,90-01}$ is positive, highly significant across specifications (1.3% – 8.3%). In other words, the increase in the demand for managers in the intensive margin is due to the differences in the high-tech and low-tech firms.

Although endogenous, we start by using a simple and continuous indicator of technology adoption in column (1). We use share of technology adoption in gross value-added of a firm, $TechAdop/GVA$, and interact with IPR_{02}. Our estimate is significant and positive; increase in technology adoption as a result of the IP reform in 2002 induces a positive effect on the share of managerial compensation in a firm. Columns (2) – (5) use $IPR_{02} \times HighTech_{i,90-01}$ as the variable of interest by controlling for industry-year trends (column (2)), industry-year fixed effects at 2-digit (column (3)), 3-digit (column (4)), and 4-digit (column (5)).

In column (6), we use simple Average Treatment Effect of the Treated (ATT), which measures the difference in mean (average) outcomes between the units assigned to the treatment (high-tech firms) and control (low-tech firms) group, respectively. We match firms based on age, ownership and size. Our estimates suggest that the 2002 IPR reform increases the relative demand for managers gap between high-tech and low-tech firms by 1.7% at the mean, which is the same as the estimate from our OLS regressions. In column (7), we use a 2SLS method. In the first stage, we regress technological investments of a firm on the change in the patent policy or The Patents (Amendment) Act, 2002 and use the residuals as an instrument in the second stage to estimate the effect of IP reform on managerial compensation. Our identification strategy works well with the patent policy significantly affecting the technological investments of a firm – first stage is positive and significant with the F-Stat (strength of the instrument) well above 10.

In column (8), we additionally interact the $HighTech_{i,90-01}$ with year dummies to control for the pre-trends that may have a strong influence in our results. We use the following regression equation:

$$\begin{aligned}\left(\frac{Mcomp}{Tcomp}\right)_{it} &= \alpha_i + \alpha_t + \alpha_{jt} + \beta_1(IPR_{02} \times HighTech_{i,90-01}) + \\ &\quad \alpha_t \times HighTech_{i,90-01} + firmcontrols_{t-1} + \epsilon_{it} \qquad (4)\end{aligned}$$

Even when controlling for pre-trends, our coefficient of interest is still positive and significant. **Panel A** of **Figure 3** plots coefficients (β_1s) from equation (2) for the share of managerial compensation.[42] The plotted coefficients illustrate that the difference between the high-tech and low-tech firms in terms of the share of managerial compensation is not significantly different from zero before the patent reform of 2002 except for

[42] We have used 2002 as the reference period when plotting the coefficients. The results or the figure is unaltered with the change in the reference period. For example, if we set the coefficient to 0 just before the treatment (in 2001), the result does not change qualitatively.

the years 1995 and 1996.[43] In other words, the share of managerial compensation rises differentially for high-tech firms after 2002. In particular, it took a sharp rise in the year following the implementation of the IPR reform and continued to increase further thereafter.

One might argue that the timing of the 'bump' around 1995-1996 roughly coincides with India's signature of the Marrakesh agreement or the WTO, which binds it to the TRIPs regime. Chakraborty and Raveh (2018) using the same dataset shows that this increase in the demand for managers is due to drop in input tariffs, as a result of the trade reforms in India during the 1990s, which led to higher adoption of imported capital goods. This is also shown in our exercises in **Table 3** − the interactions between the year trends before 2002 with $HighTech_{i,90-01}$ does not produce any significant estimates suggesting that there is no categorical difference between the high-tech and low-tech firms in terms of demand for managers. This particular concern will be more clear in the next couple of estimations.

A key argument that we make in the paper is that firms that are already ahead in the technological ladder may have larger gains from investing in innovation. And, Acemoglu et al. (2006) shows that a similar argument can be made in case of a country. Following Hu et al. (2005), we explore this further by distinguishing between direct innovation through R&D expenditure and technology transfer both of which we observe in the data. Currently, we lump these two things together into our 'technology adoption' measure. We repeat column (8) in columns (9) and (10) by redefining the $HighTech_{i,90-01}$ as $HighTech^{R\&D}_{i,90-01}$ and $HighTech^{TechTran}_{i,90-01}$, respectively. $HighTech^{R\&D}_{i,90-01}$ takes a value 1 if the mean GVA share of R&D expenditure of a firm is greater than the median GVA share of R&D expenditure of the corresponding industry (to which the firm belongs). Similarly for $HighTech^{TechTran}_{i,90-01}$ in case of technology transfer. The estimated coefficients show that the entire effect of the change in patent policy on managerial compensation is due to R&D investments by a firm and not technology transfer.

Next, similar to column (8) we plot the coefficients of our estimation from column (9) in **Panel B** of **Figure 3**. The estimated coefficients clearly shows that when we use $HighTech^{R\&D}_{i,90-01}$ instead of $HighTech_{i,90-01}$ the 'bump' around 1995-1996 disappears completely and the β_1s are significant only for the years after 2002. This points out that the 'bump' around 1995-1996 can possibly be explained by technological transfer and not R&D expenditure (which is the key element behind the difference in the demand for managers between high-tech and low-tech firms).

The above result clearly explains the mechanisms at place. Our results in **Table 5** show that firms invest in R&D about three times more than that of technology transfer as a result of the 2002 IP reform. This increase in innovation (in-house innovation or R&D expenditure) by the high-tech firms rather than absorption of foreign technology significantly drives the demand for R&D managers in order to innovate more products. And, this subsequently led to increase in demand for other managers involved with the

[43] Although there is a slight upward jump after 1999, but the coefficient is still not significantly different from zero.

innovation process, such as marketing managers. Overall, higher R&D expenditure which signals toward greater innovation efforts led to the increase in wage inequality across firms with different technological ability.

We now check for the robustness of our results in **Table 7**. We start by controlling for total compensation at the firm level in column (1) as one of the controls to consider our coefficient of interest to be a relative-wage effect. It would also help control for omitted demand-side factors at the firm level. Using this additional control does not change our benchmark result. A basic worry with an interaction term like this $IPR_{02} \times HighTech_{i,90-01}$ could be that it is not $HighTech_{i,90-01}$ but some other omitted factor correlated with $HighTech_{i,90-01}$ that is driving firms' response to the Act. In order to potentially control for that, we interact IPR_{02} with firm fixed effects and a key firm characteristic (sales) in columns (2) and (3), respectively. Adding these interaction terms do little to change our benchmark result; it remains robust.

For all our estimations, we use data from the pre-reform period to divide firms into $HighTech$ and $LowTech$. This could potentially be problematic because R&D and royalty payments are likely subject to the same unobservables as is managerial compensation. This approach therefore could potentially renders the treatment group assignment endogenous. In order to control for such events, we use pre-sample data to define which firm belongs to which group. In other words, we use a definition of $HighTech$ where it takes value 1 if the mean of the GVA share of R&D expenditure and royalty payments is greater than the industry median of the firm for the years 1990-1996. Therefore, column (4) now runs the same regression, but for the years 1997-2006. Our benchmark estimate does not change qualitatively; it remains positive and significant at 1% level. Column (5) changes the time period from 1990-2006 to 1990-2005. The reason for doing so is that 2005 is a crucial year when India finally complied with the TRIPs agreement and this could influence the outcome of interest. Reducing the time period also does not affect our benchmark finding. Next, in column (6) we exclude firms which are too close to the median to show that the median cut-off that we use to divide the firms into two groups is not correlated with our findings. Our result portray that dropping firms close to median also does not alter how change in IPR policy influences managerial compensation.

Column (7) controls for the entry and exit of firms. Goldberg et al. (2010) argues that the exit rate of firms in case of Indian registered industrial sector is very low – around 5-7%. However, it could still affect our results. Suppose TRIPs compliance had the following effect: "treated" firms in the lower tail of the top of half of the technology adoption distribution (say between 50th and 60th percentiles) were "competed out" of the market in 2003, say. That is, they did not survive the first year following enactment of The Patents (Amendment) Act, 2002 because they were no longer competitive with more nimble/more productive surviving firms within their respective industries. Then the data for the attriting firms is missing, while the data for the surviving firms remain in the dataset. The latter firms are higher performing, and will have better outcomes on average than the firms that exited (had they not attrited). If such selective attrition/survival is not accounted for in the analysis, this pattern will tend to overstate the effect the Act, all else equal. Our point estimate shows that such is not the case.[44]

Column (8) uses an alternate definition of control and treatment group. Recall that the 1970 Patent Act had provisions for filing of product patents in all, but food, pharmaceuticals, and items manufactured with chemical processes without any other provisions compatible to TRIPs. Using this provision, we now only focus on sectors which did not any have product patents before. In other words, we exploit the food, pharmaceuticals, and chemical sector as the treated group and other manufacturing sector as the control group. Since the changes in terms of patent laws was the most in these three sectors, we expect a higher effect in returns to the managerial skills for these sectors than the rest.[45] The estimate shows our hypothesis to be true; the price for managers in these sectors went up by 0.7% more than the other sectors.

Since our dependent variable is a ratio, estimating zero-valued variables with OLS may produce biased estimates. So, we use a Poisson Pseudo-Maximum Likelihood (PPML) (Silva and Tenreyro, 2006) in column (9) to control for such. PPML estimates the coefficients in terms of percentage changes and the dependent variable does not need to follow a Poisson distribution or be integer-valued (it can be continuous).[46] As the point estimate demonstrates, the 2002 IPR reform continues to induce significant increase in the relative share of managerial compensation.[47]

Another crucial issue regarding our identification strategy is to establish that the timing of the 2002 IPR reform as exogenous, at least with respect to the price of managers in the Indian manufacturing firms. It may be that the previous IPR amendment bills or acts, say the one in 1999 led the firms to start demanding for managers anticipating the implementation of a stronger amendment act in the next few years and this influenced the differential effect on managerial compensation between high-tech and low-tech firms. And, this could be utilised by the big firms or multinationals to pressurize Govt. of India to impose a stronger intellectual property rights regime to create a certain kind of monopoly power over some products, which can reap them higher benefits. While we cannot completely rule out these alternative explanations, we can examine their plausibility more carefully. To understand, whether such is the case or not, we control for whether the 1999 Patent Act has any proactive effect on the share of managerial compensation. In other words, we examine if the observed effect of 2002 reform sustains, when we introduce the 1999 reform. Column

[44] Additionally, we explicitly control entry and exit of firms in our sample (results available on request). We define entry as an indicator variable, which is equal to 1 for the first year as a firm enters our sample (except the initial year). We also define exit as a dummy, which takes a value 1 when a firm exits our sample (except 2006) and is never observed again during the period of analysis. Our benchmark result continues to hold.

[45] Although there are problems associated using such a categorization highlighted in Section 2 in details, such as spillover effects of chemical processes in other sectors.

[46] We estimate the standard errors using Eicker-White robust covariance matrix estimator.

[47] We also aggregate our dependent variable ($Mcomp/Tcomp$) and $HighTech_{i,90-01}$ to the industry level (formally, $HighTech_{i,90-01}$ is replaced by $HighTech_{j,90-01}$, where j denotes an industry). An industry is categorized as $HighTech_{j,90-01}$ if its average technological expenditure for the period 1990-2001 is greater than the median technological or innovation expenditure of the whole of manufacturing sector. The motivation to do this is to check whether the differential effect holds between these different types of industries as well. The results suggest that the 2002 IPR reform also led to larger increase in demand for managers in high-tech industries. In other words, our benchmark result is also robust to this kind of aggregation.

(10) introduces the 1999 reform dummy IPR_{99} and its interaction with the $HighTech_{i,90-98}$ dummy. We define IPR_{99} as a time dummy, which takes a value 1 for the years 1999-2001. $HighTech_{i,90-98}$ takes a value 1 if the average technological adoption expenditure of a firm between the years 1990 and 1998 is greater than the median technological expenditure of the industry to which the firm belongs. We do this to understand whether a firm, which was a high-tech before the 1999 Act, raised its demand for managers because of the 1999 reform and the 2002 reform was nothing but an additional push. We fail to find any evidence of such kind; the interaction term is indistinguishable from zero.[48]

Lastly, two possible concerns that could influence the results: (a) the way the 'managers' are defined. Our results show returns to innovation are higher for managers, but not specific to any kind of managers, such as R&D managers. It might be difficult to understand whether these gains are accruing to the researchers or not. In order to potentially address this problem, we utilize a unique feature of the data where we can divide the consortium of managers into top and middle level managers. Researchers or the R&D workers in any firm generally belong to the mid level management rather than top level. **Table B1** of **Appendix B** estimates the equation (1) but by dividing the total managerial compensation into top and middle. Our estimates show that the change in the IP policy raises return for both the top and middle managers.

(b) our result simply captures increased returns to R&D workers and researchers due to stronger IP regime. In this reasoning, a higher share of R&D workers are possibly designated as managers in high-tech firms (compared to low-tech firms). Note that since we classify firms as high-tech and low-tech at the industry level and the share of R&D workers classified as managers should not vary within a given industry, it is unlikely that our interaction term is a proxy for returns to R&D workers. In addition, as argued before we think that the innovation process involves a range of activities from R&D to branding and selling the product and hence should affect managers all along the work chain (Teece, 1986, 1996).

We also use total number of managers (extensive margin)[49], absolute managerial compensation, and average managerial compensation as dependent variables in **Table 8**. Our coefficient of interest continues to be positive and significant across all dimensions of the demand for managers. Columns (1) and (2) perform the same analysis for demand for managers in the extensive margin by treating the total number of managers as the outcome variable. The interaction term or the between-firm effect is positive and significant. In particular, our results show that at the extensive margin, the reform caused the high-tech firms to employ around 4.7% – 4.9% more managers than the low-tech firms at the mean. Columns (3) – (4) substitutes total

[48] Our estimate of IPR_{02} on the share of managerial compensation is also consistently positive and significant across different specifications suggesting that there is also a direct or within-firm effect of the IP reform. However, we do not report it or consider to be a part of our results, as it is difficult to distinguish the effect of IPR_{02} from year effects.

[49] PROWESS provides names of the managers at the top and middle management level. We count the names to calculate the number of managers in a firm across different years. We note that the names of the managers belonging to the middle management are not as consistently reported as top management. So, when we match the data (with the number of managers across both management levels and compensation), the number of observations drop significantly. However, that is not the case with only the top management. If we use only the top management data, then the number of observations rise significantly and our result continues to hold.

managers by absolute managerial compensation. As the coefficients demonstrate, substitution of dependent variable does not alter our benchmark finding. While the extensive margin considers the effect of IPR on "quantity" of managers employed, columns (5) and (6) looks at the average "price" of managers to test whether there is a quality versus quantity trade off. We now treat the average compensation of managers, obtained by dividing the total compensation with the number of managers, as dependent variable in a firm. The estimate is positive and significant.

In **Table B2** of **Appendix B**, we perform a set of similar exercises for non-managerial employees.[50] We find that, in terms of non-managerial share of total compensation, the interaction term $IPR_{02} \times HighTech_{i,90-01}$ is negative. Moreover, while there is no significant effect of IPR on average compensation, there is a positive effect on employment. This result further strengthens our intuition that there is indeed a capital-skill complementarity at play. We explore this in more detail later in Section 6.5.

Combining all the results, we infer that the 2002 IPR reform in India did increase managers' value to the organization more for the high-tech firms than the low-tech. On the other hand, while the same reform led to an increase in non-managerial employment, their share of compensation went down since their average wages remained virtually unchanged across the economy. In a somewhat similar context, Vashisht (2017) finds that adoption of new technology has increased the demand for high-skilled workers at the cost of intermediary skills, leading to the polarization of manufacturing jobs in India. These results may suggest that technology has reduced the routine task content of manufacturing jobs in India (Garicano, 2000).[51]

6.2.2 Heterogeneity in Firms' Response

Although our results consistently show that a change in innovation regime significantly increases the difference between the high-tech and low-tech firms in terms of demand for managerial workers, but cannot seem to answer two important questions: (a) is the control group unaffected by treatment? (b) which type of firms are actually driving the results?

To answer these two questions and better understand how relative demand for managers change with technology adoption, we carry out some additional estimations by dividing the firms into quintiles and deciles in **Table 9**. In essence, we now test our **Proposition 2**. We start by dividing firms into quintiles; columns (1) − (3) use quintile regressions. A firm belongs to 1st quintile if the average GVA share of technology adoption of a firm falls below 20th percentile of the corresponding industry of the firm on and/or before 2001, so on for others. Our estimates clearly show that the change in the IPR regime in 2002 does not affect demand for managers in the firms for the first two quintiles in any way, with some weak effect for

[50] We note that PROWESS provides very limited data (only for about 250 firms) on the number of employees in a firm. We do not claim that results from using such limited data can be generalized, but gives a rough idea of what happened on the non-managerial side of the firms.

[51] We also estimated a trend break model following Burgess and Pande (2005) to control for the differential time trends that may affect the outcome variable(s) in **Table B3** (**Appendix B**). Post-trend effects are significantly different from pre-trends establishing the fact that trend does not influence our benchmark result.

3rd quintile of firms. The firms that are most strongly affected belong to the top two quintiles, which are basically the firms above the median. The quintile results indicate that the choice of our control group is statistically sound, i.e., the low-tech firms (i.e., the firms below the median in terms of technology adoption) do not respond to the change in IP law.

To establish the phenomenon more clearly, we now divide the firms into deciles in columns (4) – (6). A firm belongs to 1st decile if the average GVA share of technology adoption of a firm falls below 10th percentile of the corresponding industry of the firm on and/or before 2001, so on for others. The decile estimates confirm that there is no effect for firms below the median , i.e., the first five deciles. In addition, the decile estimates indicate that the effect increases in size as a firm's technology adoption increases, but only till 8th decile. The effect vanishes again for the top decile or the biggest of the firms. In other words, the change in the IPR law or competition for innovation induces the marginally big firms or firms belonging from 5–8th decile to invest more in technology adoption and therefore demand more managers. To put it differently, our coefficients point towards a certain 'snail-shaped' effect of the change in the IP law – there is zero effect till 4th decile (which is the median), following which where the effect rises as we go up the size distribution, and then it vanishes again for the 9th decile.

Columns (7) and (8) breaks down the industries into high-tech (e.g., pharma, nuclear coke, petroleum, etc.) and low-tech (e.g., textiles, leather, beverages, etc.) based on the average technology adoption expenditure of those sectors and compare it with the median of the entire manufacturing sector. We continue to find evidence of snail-shaped effect in both the low- and high-tech sectors. Demand for managerial input/skills increase for firms above the median, except the highest or 9th decile. This tells that the snail-shaped effect is not entirely driven by high-tech, and presumably higher wage sectors. This is further evidence that the patent race across firms within an industry is creating the snail-shape.

We also check for the extensive margin of the effect using managerial employment in column (9); we find similar non-monotonic shape. Lastly, in column (10) we check for the value of managers using average managerial compensation. Our estimates show that the average managerial compensation increases for firms below the median as well; the effect runs from 2nd to 8th decile. Overall, these results point out that the IPR reform significantly increased the value of managers over non-managers, especially for firms above the median (but not 9th decile).

Figure 4 plots the coefficient estimates for each of the deciles with respect to column (6) of **Table 9**.[52] Since the coefficients below the median are not significantly different from zero, we treat them as zero; as for the others above the median, they are as per the regression estimates. The graph shows the snail-shape clearly; no effect for below-median and 9th decile firms and highest for marginally big firms.[53]

[52] Similar pattern follows if we do it separately for high-tech and low-tech industries.

[53] In another robustness check, we drop firms, which are greater than 90th percentile of the total assets of the industry to which the firm belongs. Our baseline coefficient does not change, suggesting similar kind of intuition.

The above heterogeneity among firms in the response to the IP regime change is indicative evidence that the firms' response to the change in IP law is driven through a patent race channel. We have already noted the various sources of manager-capital complementarity in innovation (knowledge spillover, scale/size effects and so on). In absence of externalities between firms, one would expect such complementarity would lead to an increasing relationship: firms with higher technological capital would exhibit a larger increase in demand for managers. The observed non-monotonicity indicates the presence of an externality.[54]

This externality comes from the fact that typically, several firms within an industry or the same product line, say, dyes, compete for a patent, and the firm earliest to successfully innovate obtains the patent. Therefore whether a firm wins a patent or not depends not only on its own investment in innovation but also that of the other firms it is competing with. This idea follows a long line of work on R&D and patent races (Kamien and Schwarz, 1976; Loury, 1979; Dasgupta and Stiglitz, 1980; Reinganum, 1989; Dixit, 1987; Baye and Hoppe, 2003). The change from a process patent to a product patent regime in effect raises the value of the patent.[55]

The likelihood of successfully obtaining the patent depends on both managerial input and technological capital, and these two factors are complementary in producing innovation. Firms with low capital stock have relatively low productivity of managers and therefore little demand for managers. At the other end, firms with very high capital stock are already far ahead in competition and the marginal increase in probability of obtaining the patent by expanding managerial workforce is low. The demand for managers is strongest for marginally big firms which (a) have large enough capital stock so that managerial input is highly productive, and (b) obtain relatively larger increase in winning probability by hiring more managers. This intuition is captured in the formal model we present in Section 4.

6.2.3 Wages and Incentives

Our empirical and conceptual exposition so far indicates that the positive impact of the 2002 IPR reform on the relative demand for managers is driven only by firms above the median, but below the top decile. The change in patent law has virtually no effect for the low-tech firms. In this sub-section, we now examine the components of the managerial compensation to better understand the sources of the change.

There is a considerable debate in the literature about the role of performance incentives in motivating innovation. Holmstrom (1989), Teece (1996) and Amabile (1996) indicate that short-term performance incentives may not be conducive to generate effort towards innovative activities. Lerner and Wulf (2007)

[54] Firms in the 9th decile are supposedly the big multinationals, which are already ahead in the competition. Implementation of stricter or new patent laws in India has little incentive for them to change their organizational structure significantly. They file for product patents elsewhere when product patents are not recognized in India.

[55] An alternate hypothesis that the snail-shape is consistent with is that the large firms have optimal internal organization but the others are not. A more competitive IP regime forces the other firms to reorganize, and this reorganization is stronger for the firms that are largest within this set of firms that do not already have the optimal organization. However, this does not seem to be the whole story as we later show that even after contolling for management quality, our results persist (see Section 6.5 for details).

and Kline et al. (2019) point out the value of long term incentives for innovation. We, however, find an increase in incentive share of pay especially for high-tech firms.

We disaggregate the compensation into wages and incentives and present the results in **Table 10**. We define as incentive pay, a part of compensation reported, as the following heads: (a) benefits or perquisites; (b) bonuses and commission; (c) contribution to provident fund; and (d) contribution to pension, whereas wages are considered to be the pre-determined component of the total compensation received by the employees. Column (1) examines managers' share of total wage, $Mwages/Twages$; and column (2) uses managers' share of total incentive pay, $Mincentives/Tincentives$, as the outcome of interest in Equation (1).

Notice first that the coefficient of the interaction term in column (1) is negative, and the same in column (2) is positive and highly significant. Therefore, differences between high-tech and low-tech firms in terms of demand for managers is only due to the difference in share of incentives. High-tech firms are paying 3.2% more incentives to their managers as a result of the IP reform. In columns (3) and (4), we use wages and incentives (of all managers) as a share of total compensation; the results do not change qualitatively.

This result is consistent with empirical findings elsewhere that a positive external shock (e.g., trade liberalization) brings about an increase in managerial compensation through an increase in incentive pay (Cunat and Guadalupe, 2009; Chakraborty and Raveh, 2018). Our result that incentive driven increase is concentrated in high-tech firms is also reminiscent of the conclusion in Acemoglu et al. (2006) that firms closer to the technological frontier provide sharper incentives to their managers.

Figures 5 and **6** plot the coefficients of the difference between high-tech and low-tech firms for managerial wages and incentives, respectively. Both the figures imitates our empirical finding. In case of wages (**Figure 5**), the coefficient drops after the reform, hinting that the difference between the managerial and non-managerial wages reduces after the 2002 patent reform. Whereas, in case of incentives (**Figure 6),** it is the opposite. The difference started increasing the year after the implementation of the reform and it became distinctly different from 0.[56]

6.3 External Validity: Alternate Definitions of Our Treatment Group and IPR Shock

6.3.1 Disaggregating Industries Based on Intellectual Property (IP) Classification of NAICS

Until now, we divide our sample of firms based on their technological knowledge within an industry. We now change our intra- to inter-industry classification based on IP intensity of industries. This is based on patents, trademark or copyrights of industries at the 4-digit level as developed by Delgado et al. (2013). We use two approaches – high-IP products and high-IP clusters. We start with the former.

The high-IP product list is primarily based on 4-digit NAICS code with above average IP intensity in the

[56] It might seem to be some sort of increasing trend after 1997 or from 1998 onward, but none of the coefficients are significantly different from zero till 2002.

US.[57] To define the high-IP group of products, Delgado et al. (2013) matches the NAICS industries to the COMTRADE product categories at SITC, Rev. 3 (Standard International Trade Classification, Revision 3). We use the International Standard Industrial Classification (ISIC) Rev. 4 to match to the NIC of India.[58] Using this classification, we could match about 50-55% of the industries. Our 'treated' group is now the high-IP intensity industries, which takes a value 1 through out the entire time period of our study. On the other hand, the 'control' group is the low-IP intensity industries, which takes a value 0. The identification of the low-IP industries is also based on the same classification as the ESA-USPTO Report described. Our conjecture is that due to the implementation of the IP-law in 2002, the patentable intensity of the high-IP products would increase multi-fold, so demand for managerial skill would increase more than proportionately in those industries than low-IP intensity industries. Our variable of interest, $IPR_{02} \times HighIP_j$ would capture the relative differences across these two set of industries, where the classification is based on IP intensity of industry j ($HighIP_j$).

Delgado et al. (2013) argues that the classification of the high-IP products/groups are very broad and based on somewhat coarse mapping. Therefore, to further sharpen the analysis, particular sub-categories of high-IP products (e.g., biopharmaceuticals or ICT) is defined. To define subsets of the high-IP product group, a clustering approach is used to create groups (called 'clusters') in such a way that objects in the same cluster are more similar to each other than to those in other groups. In this case, the objects are narrowly defined industries or traded products (NAICS or SITC). The cluster approach allows more refined mapping of related traded products into meaningful groups of high-IP intensity. To do so, they use the industry cluster data from the U.S. Cluster Mapping Project (USCMP; Porter (2003)).[59] Industry clusters are groups of industries related by knowledge, skills, inputs, demand and other linkages in a region (Porter, 2003). The main method in the USCMP of creating these groups is the correlation of employment between industries across regions within the U.S. For example, the computer hardware and software industries are in the same Information and Communication Technology cluster because employment in each industry is strongly co-located.[60] They use the USCMP to assess which clusters have high-patent intensity in the U.S. and then define the high-IP clusters. The (mutually exclusive) clusters with the highest IP intensity are biopharmaceuticals, medical devices, analytical instruments, chemicals, ICT and production technology (PT). We use the same concordance tables as defined above to do match the high-IP clusters with the Indian industrial classification. Our matching percentage increases to around 70–75%. **Table 11** presents

[57] ESA-USPTO Report, U.S. Department of Commerce, 2012

[58] We use UN classification system to match SITC Rev.3 with 2004 NIC 4-digit industries. In addition to the UN system, we also use this classification to duly classify the product categories into high-IP and low-IP products.

[59] Additional information on the USCMP can be accessed at http://www.clustermapping.us/.

[60] Delgado et al. (2013) show that these cluster definitions capture many types of inter-industry linkages discussed in the economies of agglomeration literature. Other clustering and network studies at firm-level focus on specific linkages, such as the technology and market proximity (Bloom et al., 2013). In this case, the goal is to capture meaningful groups of industries (and products) that are highly related among themselves in various dimensions (technology, skills, input-output).

the required results.

Columns (1) – (3) present our estimates from high-IP group classification, whereas columns (4) – (6) do the high-IP cluster analysis. Apart from interactions of industry fixed effects and time trends, we also, in addition, control for the interaction of $HighIP_j$ and year fixed effects in columns (2) – (3) and (5) – (6). We also change the definition of IPR_{02} in columns (3) and (6). In these two columns, it 1 for the year 2002, 2 for 2003, 3 for 2004, and so on. We use it in an increasing order to measure the increasing intensity of the 2002 IPR reform over the years. Our coefficient of interest, $IPR_{02} \times HighIP_j$, across all these different methods remain positive and significant. The estimates show that the 2002 IPR reform led to around 0.1–1.3% difference in the price of managers between low-IP and high-IP intensity groups at the mean.[61]

6.3.2 Patent Protection Index – Ginarte and Park (1997) and Park (2008)

Ginarte and Park (1997) and followed by Park (2008) estimated a patent protection index to facilitate comparisons of patent regimes across countries. The index was constructed at the country level, quinquennially from 1960 to 1990 by Ginarte and Park (1997) and later extended till 2005 by Park (2008). They used a coding scheme applied to national patent laws. The index was estimated based on the examination of the patent laws on these five different categories: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of patent. Each of these categories was given a value ranging from 0 to 1 (for details, see Ginarte and Park (1997)). The weighted sum of these five values then constitutes the overall value of the patent rights index, which ranges from zero to five. Higher values of the index would therefore indicate stronger levels of protection.

For our purpose, we use the values for India for 1990, 1995, 2000, and 2005. We define $Patent_{Index}$ such that it will take similar values for 1990-1994 based on what the index was in 1990. And, so on for other years. We then interact $Patent_{Index}$ with $HighTech_{i,90-01}$ to estimate the effect of higher patent protection on the share of managerial compensation in columns (7) and (8). In doing so, we divide the time period before and after 2002. Our estimates show that the effect on the managerial compensation is completely driven by change in the patent protection index after 2002 and not before.

6.3.3 Patent Intensity

We now change our inter-industry classification to patent intensity of an industry. In practice, we are using a Bartik-type instrument. We use the patent filings data and calculate the average patents filed by an industry (at the 4-digit level)[62] before the reform (for the years 1995–2001). We define $HighPatentIntensity_j$. It

[61] **Table B4** (**Appendix B**) exploits a different dataset. We use plant level data from Annual Survey of India (ASI) for the years 1999 to 2006 and runs the same regression(s) by classifying sectors according to $HighIP_j$. Changing the dataset also does not alter our benchmark finding – returns to managerial skill in sectors with higher IP intensity are significantly more than the others.

[62] We also did it at the 2-digit level and the results are the same.

takes value 1 if the average patent filings of an industry is greater than the median patent filings of the manufacturing industry as a whole. We interact this with IPR_{02} and measure the required effect in columns (9) and (10).

In addition to using interaction of industry fixed effects with year trends or year fixed effects, we also control for the interactions between $HighPatentIntensity_j$ and year fixed effects to control for differential trends between high- and low-patent intensive industries. We do not find any effect of the pre-reform patent intensity on the demand for managerial skill, however, the effect in both the cases is positive. Non-significance of the effect could possibly be due to (a) significantly low matching of the patent to the firm level data (around 30%), and/or (b) the effect is driven by within-industry race for patent filings and not across industries.

Our results using external classification both at the industry and year level gives additional support to our benchmark findings that higher patent protection increased the demand for managers significantly. Importantly, observe that the between-industry effect is not as robust as the within-industry effect. This, coupled with the fact that the snail-shape is observed separately for high-tech as well as low-tech industries, points to patent races within firms in the same industry as the main channel through which the Act of 2002 led to an increase in wage inequality between and within firms.

6.4 Firm Characteristics

We now examine additional heterogeneity in **Table 12** using various firm characteristics to identify the set of firms, which drive the main result(s). We start by dividing the sample into exporters and non-exporters in columns (1) and (2). The coefficients show that the differential response in the demand for managers is significant for both exporters and non-exporters, with the effect significantly higher for the latter group of firms. We believe that this result is due to the fact that to begin with, exporting firms as a group are much more similar in terms of technological expenditure than non-exporting firms.

Next, we divide firms by ownership – domestic and foreign in columns (3) and (4). The interaction effect of $IPR_{02} \times HighTech_{i,90-01}$ is significant for both domestic and foreign firms, with the effect slightly higher for foreign firms. Lastly, in columns (5) and (6) we follow Nouroz (2001) and use the input-output classifications to categorize firms by the end use of their products. The division is made into two groups – intermediate (intermediates, basic and capital) and final (consumer durables and non-durables) goods. The interaction effect is significant for both classes of firms. Overall, our findings show that an IPR shock has an economy-wide effect in comparison to trade or other macroeconomic shocks, where the effect is limited to only a few sections of firms such as exporters (Caliendo and Rossi-Hansberg, 2012).

6.5 Complementary Effects

This section controls for all other possible channels that can simultaneously affect the managerial compensation of a firm by using several controls, alternative techniques, sample and time period in **Tables 13** and **14**. While some of these channels do have significant effects, our primary result remains true and significant in every case establishing the fact that IPR reforms indeed contribute to a higher relative demand for managers for high-tech firms.

Trade Shocks: We start by controlling for all possible trade channels that can concurrently affect managerial compensation and present the results in **Table 13**. Recent research by Caliendo and Rossi-Hansberg (2012) points out that trade significantly affects organizational structure of firms through increase in demand for managers (Cunat and Guadalupe, 2009; Chakraborty and Raveh, 2018). Chakraborty and Raveh (2018) uses the trade liberalization exercise adopted by India during the 1990s to examine its effect on the demand for managers and show that drop in input and not output tariffs significantly explains the rise in the share of managerial compensation for Indian manufacturing firms. We use the same indicators and interact them with $HighTech$ in columns (1), (2) and (3). Our results indicate that both input and output tariffs significantly increased the difference in the demand for managers across high-tech and low-tech firms. However, we do not find any statistically significant effect when we use them jointly.

Cunat and Guadalupe (2009) and Guadalupe and Wulf (2010) show that import and product market competition significantly affects managerial or executive compensation. We use Chinese competition as a proxy for import competition.[63] We follow Chakraborty and Henry (2019) and use China's entry to the WTO in 2001 as a quasi-natural experiment for the possible indicator for Chinese import competition in column (4) to measure such effect.[64] Our variable of interest is $DComp_{IN}^{China} = AvgM01_j^{China} \times WTO_t$.[65] $AvgM01_j^{China}$ is a measure of Chinese competition that an industry faces because of the unilateral liberalization policies pursued by China; it is a 10-year average of the share of imports by industry j for the period 1992-2001. WTO_t is a year dummy variable intended to capture the effect of China's entry into the WTO. It takes a value of 1 for the years following the signing of the WTO agreement by China; $WTO_t = 1$ for the years

[63] India's imports from China increased from around 1% in 1992 to 17% in 2006; the increase in the share is especially sharp between 2001 and 2006, from 5.5% to 17%.

[64] PROWESS does not give any information regarding the trade destinations of the firms. To overcome such a shortcoming, we match the firm-level data from PROWESS with the trade-destination based product level UN-COMTRADE dataset at NIC 2004 4-digit level.

[65] We use the following index:

$$AvgM01_j^{China} = \sum_{1992-2001}\left[\frac{imports_{jt}^{China}}{imports_{jt}^{Total}}\right]$$

$$= \sum_{1992-2001}\left[\frac{imports\ from\ China\ for\ the\ years\ 1992-2001\ for\ the\ industrial\ category\ j}{imports\ from\ World\ for\ the\ years\ 1992-2001\ for\ the\ industrial\ category\ j}\right]$$

2002-2006.

Therefore, $DComp_{IN}^{China}$ provides a measure of the amount of competition faced by Indian firms as a result of China becoming a member of the WTO. In other words, the interaction term provides a clear and exogenous measure of import competition from China and represents a difference-in-differences approach to measure the effect of Chinese import competition. In order to measure the differential effect of the Chinese import competition on the managerial compensation, we interact $DComp_{IN}^{China}$ with our $HighTech_{i,90-01}$ dummy. We fail to find any statistically significant effect of domestic competition from Chinese imports.[66]

Caliendo et al. (2017) argues that participation in export market significantly increases executive compensation. In column (5), we use the share of Chinese imports in total imports of the US to see whether export market competition, $FComp_{IN}^{China}$, has positively affected the demand for managers. We find negative effect of the interaction term with weak significance. Higher participation in the export market closes the gap between high-tech and low-tech firms in terms of demand for managers.

Other Possible Channels: We follow Chakraborty and Raveh (2018) and test for other industry and firm level channels in **Table 14**. We start by testing the potential correlation between relative demand for managers and skilled labour in column (1). We measure the latter using the 3-digit industry level ratio of non-production workers to all employees in an industry, obtained from Ghosh (2014) (1990-2000), and the ASI (2001-2006). The main result continues to hold, suggesting that it is not driven only by increases in the demand for skill. However, our outcome variable of interest and skill intensity appears to be significantly correlated. This suggests that capital-skill complementarity might also be a channel through which demand for managers increased because of higher technology adoption due to the IPR reform.

Column (2) uses management technology and its interaction with $HighTech_{i,90-01}$ dummy as an additional control. We use data on management technology from World Management Survey. It is given for a single year, which is 2004 across all the NIC 2004 2-digit industries. Our estimates point out that management technology of an industry is positively and significantly correlated with the demand for managers, but this is a complementary additional effect with our main variable of interest still positive and significant. Establishment of new factories may create a demand for new managers, as local knowledge is important (Bloom et al., 2010). Therefore, we use an additional related measure: the number of factories and plants at the industry level, derived from ASI. The inclusion of this additional control does little to change our benchmark finding.

Bloom et al. (2013) points out that better managed firms in India have higher productivity. To address this, we control for productivity using Levinshon and Petrin (2003) methodology in column (4). As the results demonstrate, more productive firms demand more managers, but our coefficient of primary interest

[66] We also use an alternate measure of Chinese import competition. We use lagged value of the share of imports from China at 2004 NIC 4-digit level weighted by sales share of those industries. We continue to find no effect of Chinese import competition.

is stable is sign, magnitude and significance.

One can argue that the sudden expansion in Information Technology enabled services (ITES) in early 2000s can explain some of the increased relative demand for managers in the high-tech firms that we ascribe to IP reforms. In order to control for this, we use expenditure incurred by firms towards in-house information technology and consultancy fees for technological upgradation in column (5). We find consultancy fees for technology upgradation to be significantly correlated with the share of managerial compensation. However, the sign and significance of our main channel does not go away.

As highlighted by Bloom et al. (2013), family firms may use their control over the Board of Directors to appoint their family members in several of the managerial positions within the firm and this could increase the managerial compensation. We construct an indicator for family ownership by considering the proportion of shares held by Hindu undivided families[67]. In column (6), we interact the family-ownership indicator with $IPR_{02} \times HighTech_{i,90-01}$ and see whether family firms influence any increase in the share of managerial compensation or not. We do not get any such evidence.

Keller and Olney (2017) suggest that the increase in managerial compensation during a trade shock may be explained by the fact that the top management gets to decide its own pay. In order to check if our results can be explained by the lack of good corporate governance, we use the number of independent directors in the Board of a firm as an indicator of quality of governance. Since most firms started reporting the composition of their boards from 2003-2004 onwards, matching the number of independent directors with our main dataset running from 1990 till 2006 drops around 90% of the observations. In column (7) we report the results from this control. None of the regressors are significant, including our main variable of interest; but the sign of the coefficient does not change. In column (8), we interact the IPR_{02} dummy with the share of product claims in total patent claims, $PClaims/TClaims$, of a firm. As discussed before, we use a firm level patent filings database from IPO and manually match with the firm level dataset. Our matching percentage is not high; we could only be able to match around 30-35% of the data. We do this simple exercise to understand whether there is any sort of positive correlation between patent claims (as a result of the 2002 IPR reform) and demand for managers. If yes, then it will add further support to our conjecture on patent race channel. Our results show that the conjecture is true. We get a positive correlation between the share of product patent claims and share of managerial compensation. However, it is only significant at 12% level. This weak significance could be a result of the lower matching turnout between patent claims and firm level data.

Lastly, we account for a few state level characteristics in columns (9) – (11). Following Bloom and Van Reenen (2010), we control for cross-regional variation in labour market rigidity in India in order to check if the sharper response of high-tech firms to IP reforms appears due to a possible concentration of

[67] The data on family firms is from 2007, as this is the first year for which PROWESS reports such data. We assume that such proportion remained constant over the period 1990–2006.

high-tech firms with more flexible labour market regulations in column (9). We use the postcode for each firm to locate its state/region and match it with our dataset. India is a federal democracy and under the Indian Constitution of 1949, industrial relations is a concurrent subject. This implies that central and state governments have joint jurisdiction over labour legislation. The key piece of central legislation is the IDA 1947, which sets out the conciliation, arbitration and adjudication procedures to be followed in the case of an industrial dispute. The Act was designed to offer workers in the organized sector some protection against exploitation by employers (for details, see Besley and Burgess, 2004).[68] It has been extensively amended by state governments during the post-Independence period. Besley and Burgess (2004) code all 113 such amendments since the Act was passed and designate them as being either "neutral", "pro-worker", or "pro-employer" to investigate how labour regulation impacts economic performance at the state level.[69]

We exploit this variation across Indian states and interact $HighTech_{i,90-01}$ with $LabLaws_s$. $LabLaws_s$ is a dummy variable that equals one if labour laws in a state in which firms' are registered are pro-employer. $LabLaws_s = 1$, when $s =$ Andhra Pradesh, Karnataka, Rajasthan, Tamil Nadu, and Uttar Pradesh.[70] On the other hand, $LabLaws_s = 0$, when $s =$ Gujarat, Maharastra, Orissa, and West Bengal (pro-worker states) and for neutral states Assam, Bihar, Haryana, Jammu and Kashmir, Punjab, Kerala and Madhya Pradesh. All the other variables remain the same as Equation (1) except for the fact that we also add state-year fixed effects to control for other possible unobserved state level characteristics that may influence our outcome variable of interest. Our results show that managers are better paid in states with pro-employer labour regulations.

Other than intellectual property rights, the quality of other institutions of a country including contract enforcement, property rights and shareholder protection are also important factors that could possibly affect the demand for managerial skills and compensation structure. We follow Ahsan (2013), Chakraborty (2016) and use the pendency ratio of high courts as the indicator for quality of institutions.[71] Our assumption here is: the higher is the pendency ratio, the lower is the judicial quality hence quality of institutions. We interact judicial quality, $JudicialQ_{st}$, with $HighTech_{i,90-01}$ and measure the required effect in column (10). We do find that lower the pendency ratio, the higher is the managerial compensation, but the magnitude of the effect is very small. Financial Development can also affect the demand for managerial skills and compensation structure. In column (11), we follow Khandelwal and Topalova (2011) and use credit per capita in 1992 as the measure of financial development. The states above median are classified as having

[68] The Act is comprised of seven chapters and forty sections, specifying the powers of government, courts and tribunals, unions and workers and the exact procedures that have to be followed in resolving industrial disputes.

[69] Although all states have the same starting point, they diverge from one another over time.

[70] This is the classification by Gupta et al. (2009). We also check our results using the classification by Adhvaryu et al. (2013), where the "pro-employer" states are – Andhra Pradesh, Karnataka, Kerela, Madhya Pradesh, Rajasthan, and Tamil Nadu; the result does not vary.

[71] Both these papers use a regional level institutional quality indicator based on Levchenko (2007) and Nunn (2007). They use country level institutional quality indicator based on World Bank Governance Indicators.

high financial development and $FinDev_s$ will take a value 1 for those states.[72] We use an indicator at the initial period of our analysis as this is could be highly correlated with our outcome of interest. Managerial compensation is higher in financially developed states than others. However, in all these three cases our benchmark result continues to be positive and significant.

7 Discussion of Results and Conclusion

We find that the change in intellectual property rights regime in India, as encapsulated in the Patent (Amendment) Act, 2002, had the following effects. The IP reform led to a significant increase, both statistically and economically, in managers' compensation as a share of total labour compensation as well as the employment share of managers. This increase in the relative value of managers is significantly more (1.3% − 8.3%) for firms that were technologically advanced before the reform. And, the effect is consistently significant across various specifications. Disaggregating the total managerial compensation into wages and incentives, we see that it is the share of incentives rather than wages that explains the difference between high-tech and low-tech firms.

Next, we show that all these effects are driven particularly by the marginally big firms; firms belonging to 5–8th decile. The same is true across both high-tech and low-tech sectors. In other words, IPR induces only the firms above the median but below the top decile to adopt more technology and therefore demand for managers. On the other hand, the IPR change does not affect firms below the median. Putting all these together refers to a snail-shape effect. This non-monotonic relation of the demand for managers and technological capabilities of firms' establishes that the observed changes in the demand for managers cannot entirely be explained by technological depth of a firm, but also by patent races ushered in due to the stronger IPR reforms.

Looking at the first order effects, we also find that the 2002 IPR reform led to between-firm reallocation of productive factors (in terms of capital employed, technology adoption). In addition, high-tech firms, as a result of the change in the IP law, started to produce more product varieties at higher quality and filed more product patent claims. All these results hint towards a quality-upgrading mechanism.

Lastly, these effects hold across exporters and non-exporters (higher for non-exporters than exporters), domestic and foreign firms as well as firms producing final or intermediate goods. We now try to reconcile these findings with the related literature and seek to find the channels through which an IPR reform may raise the demand for managers and thereby contribute to wage inequality.

While we measure technological intensity by R&D expenditure and technology transfers, there is a clutch

[72] States above median are: Andhra Pradesh, Chandigarh, Daman and Diu, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Pondicherry, Punjab, Tamil Nadu, and West Bengal. States below the median: Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Bihar, Dadra and Nagar Haveli, Lakshadweep, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Rajasthan, Sikkim, Tripura, and Uttar Pradesh.

of other complementary factors associated with technological advancement (e.g., ICT, management technology, expenditure in physical capital etc.). There is a large literature examining the correlation between these factors with innovation expenditure, organization design and demand for skilled labour (Bresnahan et al., 2002; Burstein et al., 2016; Caroli and Van Reenen, 2001; Guadalupe et al., 2014; Bloom et al., 2014). We find that each of these has an independent effect on the increase in relative demand for managers, which is thus consistent with the large literature on capital-skill complementarity. However, even after controlling for these factors, technology intensity of inputs has a statistically significant effect on share of managerial compensation for high-tech firms.

Acemoglu and coauthors, in a series of papers (Acemoglu et al., 2006; Acemoglu et al., 2007) show that managerial skill is more valuable to firms closer to the technological frontier, and in particular for firms engaged more in innovation than imitation. The IPR reform in India increased the relative value of product innovation over process imitation by introducing monopoly rights over new products. As a result, there was an economywide increase in demand for managers.

Our results showing increase in technology adoption/innovation capabilities as a complement to managerial inputs are consistent with the idea of a firm as a problem solving entity enunciated in Garicano (2000). The production process essentially involves workers solving a flow of problems. Unsolved problems travel up the organizational layers, and a manager's role is to attend to the exceptional problems occurring within his/her span of control. The organizational hierarchy is designed to optimize managers' time and maximize problem solving efficiency. The IPR reform increases the value of new products, and as a firm undertakes more new product development the complexity of the problems faced by the firm increases significantly. Since the production workers (non-managers) are faced with more challenging or exceptional problems, the role of the manager becomes more valuable to the firm. This explains the increase in the demand for managers relative to production workers consequent to the IPR reform. And, this demand increases more than proportionately for firms higher up in the technological ladder.

Between-firm increase in demand for managers is consistent with the idea of IPR reforms inducing patent-races (Branstetter et al., 2006). While product patents increased the gains from product innovation, the firms that were already technologically advanced had a deeper stock of technical knowledge, skills and resources and therefore were at an advantage in such races. Therefore, the expected gains from new product development increased more for firms already ahead in the race.

Our data shows a sharp rise in performance pay especially for high-tech firms while the larger literature provides at best mixed support for short term incentives as a way of motivating innovation (Teece, 1996; Amabile, 1996; Lerner and Wulf, 2007; Kline at al., 2019). On the other hand, similar increase in incentives have been reported due to trade shocks or increased market competition (Cunat and Guadalupe, 2009; Keller and Olney, 2017). We hypothesize that the new IPR regime created a climate of more fierce competition among firms in the race to capture monopoly rights. In this environment, the increase in performance pay was possibly a measure adopted by firms in order to motivate managers to not only engage in innovation but to innovate fast enough to be able to win the patent race. Our result on product varieties, product quality and product claims validate such conjectures. There was a sharp increase in the number of new products introduced, product quality, and product patent claims by high-tech firms. All these results point towards a productivity upgrading mechanism. However, in our case, this is not within-firm but between-firm; more so for the high-tech firms.[73]

Our results are also indicative of the kind of changes a developing economy like India goes through with increasing formalization and integration with the global economy. Given that the TRIPs+ provisions are soon to be implemented in the least developed countries, our results may have implications across these newly IP-acceeding nations. For example, the observed wage inequality between managers and non-managers as well as between high-tech and low-tech firms. Such wage polarization (Cozzi and Impullitti, 2016) appears to be an important economic trade-off associated with globalization of developing economies. Our case presents an opportunity to more carefully examine the effects of IPR on wage inequality across nations like Brazil, Chile, China, etc. using employer-employee dataset to extend our work bringing in more evidence on the welfare effects of IP across the world.

We close this section with a comment comparing the IPR shock with a trade shock. Some of our results like increased demand for managers, higher between-firm wage inequality, sharper incentives, etc. have also been observed elsewhere due to increased competitiveness because of trade shocks. However, while a trade shock typically affects those industries that are engaged in export or import, we find that a change in property rights over innovation affects virtually all sectors of the economy. It is this pervasiveness of impact that underlines the importance of intellectual property as a lever of market power, policy and driver of welfare. But, it may significantly depend on the country characteristics and/or firm heterogeneity.

[73] We also checked for the effect of our main variable of interest, $IPR_{02} \times HighTech_{i,90-01}$, on the productivity estimate of a firm. We use Levinshon and Petrin (2003) methodology to estimate the physical productivity of a firm. We find significant effects of increase in productivity for high-tech firms.

References

Abramitzky, R., Lavy, V., 2014. How Responsive is Investment in Schooling to Changes in Redistributive Policies and in Returns? *Econometrica* 82 (4): 1241–1272

Acemoglu, D., 2003. Patterns of Skill Premia. *The Review of Economic Studies* 70 (2): 199–230.

Acemoglu, D., Aghion, P., Zilibotti F., 2006. Vertical Integration and Distance to Frontier. *Journal of the European Economic Association* 1 (2–3): 630–638

Acemoglu, D., Aghion, P., Lelarge, C., Van Reenan, J., Zilibotti F., 2007. Technology, Information and the Decentralization of the Firm. *The Quarterly Journal of Economics* 122 (4): 1759–1799.

Adams, S., 2008. Globalization and Income Inequality: Implications for Intellectual Property Rights. *Journal of Policy Modeling* 30 (5): 725–735

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and Innovation: An Inverted-U Relationship. *The Quarterly Journal of Economics* 120 (2): 701–728

Aghion, P., Akcigit, U., Bergeaud, A., Blundell, R., Hémous D., 2019. Innovation and Top Income Inequality. *The Review of Economic Studies* 86 (1): 1–45

Aghion, P., Bergeaud, A., Blundell, R., Griffith, R., 2018a. The Innovation Premium to Low-Skill Jobs. *Mimeo*, University of Manchester

Aghion, P., Akcigit, U., Hyytinen, A., Toivanen, O., 2018b. On the Returns to Invention Within Firms: Evidence from Finland. *American Economic Association Papers and Proceedings* 108: 208–212

Aghion, P., Bergeaud, A., Lequien, M., Melitz, M., 2017. The Impact of Exports on Innovation: Theory and Evidence. *Mimeo*, LSE

Ahsan, R. , 2013. Input Tariffs, Speed of Contract Enforcement, and the Productivity of firms in India. *Journal of International Economics* 90 (1): 181–192

Ahsan, R., Mitra, D., 2014. Trade Liberalization and Labor's Slice of the Pie: Evidence from Indian Firms. *Journal of Development Economics* 108 (1): 1–16

Allred, B. B., Park, W. G., 2007. Patent Rights and Innovative Activity: Evidence from National and Firm-level Data. *Journal of International Business Studies* 38: 878–900

Amiti, M., Cameron, L., 2012. Trade Liberalization and the Wage Skill Premium: Evidence from Indonesia. *Journal of International Economics* 62 (2): 277–287

Amabile, T. M., 1993. Motivational Synergy: Toward New Conceptualizations of Intrinsic and Extrinsic Motivation in the Workplace. *Human Resource Management Review* 3: 185–201

—., 1996. *Creativity in Context*. Boulder: Westview Press.

Autor, D., Dorn, D., Katz, L. F., Patterson, C., Van Reenen, J., 2017. The Fall of Labor Share and the Rise of Superstar Firms. *NBER Working Paper No. 23396*, NBER, Cambridge, MA

Azoulay, P., Zivin, J. G., Manso, G., 2011. Incentives and Creativity: Evidence from the Academic Life Sciences. *RAND Journal of Economics* 42: 527–554

Balasubramanian, N., Sivadasan, J., 2011. What Happens when Firms Patent? New Evidence from US Manufacturing Census Data. *The Review of Economics and Statistics* 93 (1): 126–146

Baye, M. R., Hoppe, H. C., 2003. The Strategic Equivalence of Rent-Seeking, Innovation and Patent Race Game. *Games and Economic Behavior* 44 (2): 217–226

Bender, S., Bloom, N., Card, D., Van Reenen, J., Wolter, S., 2018. Management Practices, Workforce Selection, and Productivity. *Journal of Labor Economics* 36 (S1): S371–S409

Besley T., Burgess, R., 2004. Can Labor Regulation Hinder Economic Performance? Evidence from India. *The Quarterly Journal of Economics* 119 (1): 91–134

Bloom, N., Sadun, R., Van Rennen, J., 2010. Does Product Market Competition Lead Firms to Decentralize? *American Economic Review Papers and Proceedings* 100: 434–438

—., 2012. Americans Do IT Better: US Multinationals and the Productivity Miracle. *American Economic Review* 102 (1): 167–201

—., 2017. Management as a Technology? *NBER Working Paper No. 22327*, NBER, Cambridge, MA

Bloom, N., Van Reenen, J., 2007. Measuring and Explaining Management Practices across Firms and Countries. *The Quarterly Journal of Economics* 122 (4): 1351–1408

—., 2010. Why do Management Practices Differ Across Firms and Countries? *Journal of Economic Perspectives* 24 (1): 203–224

Bloom N., Eifert, B., Mahajan, A., McKenzie, D., Roberts, J., 2013. Does Management Matter? Evidence from India. *The Quarterly Journal of Economics* 128 (1): 1–51

Bloom, N., Garicano, L., Sadun, R., Van Reenen, J., 2014. The Distinct Effects of Information Technology and Communication Technology on Firm Organization. *Management Science* 60 (12): 2859–2885

Bøler, E. A., 2016. Technology-Skill Complementarity in a Globalized World, *Mimeo*, Imperial Business School, London

Branstetter, L., Fisman, R., Fritz Foley, C., 2006. Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U.S. Firm-level Patent Data. *The Quarterly Journal of Economics* 121 (1): 321–349

Branstetter, L., Fisman, R., Fritz Foley, C., Saggi, K., 2011. Does Intellectual Property Rights Reform Spur Industrial Development? *Journal of International Economics* 83 (1): 27–36

Bresnahan, T. F., Brynjolfsson, E., Hitt, L. M., 2002. Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-level Evidence. *The Quarterly Journal of Economics* 117 (1): 339–376

Burgess, R., Pande, R. 2005. Do Rural Banks Matter? Evidence from the Indian Social Banking Experiment. *American Economic Review* 95 (3): 780–795

Burstein, A., Morales, E., Vogel, J., 2016. Changes in Between-Group Inequality, Computers, Occupations, and International Trade. *Mimeo*, UCLA

Caliendo, L., Rossi-Hansberg, E., 2012. The Impact of Trade on Organization and Productivity. *The Quarterly Journal of Economics* 127 (3): 1393–1467

Caliendo, L., Monte, F., Rossi-Hansberg, E., 2017. Exporting and Organizational Change. *NBER Working Paper No. 23630*, NBER, Massachusetts, MA

Caroli, E., Van Reenen, J., 2001. Skill-Biased Organizational Change? Evidence from a Panel of British and French Establishments. *The Quarterly Journal of Economics* 116 (4): 1449–1492

Chakraborty, P., 2016. Judicial Quality and Regional Firm Performance: The Case of Indian States. *Journal of Comparative Economics* 44 (4): 902-918

Chakraborty, P., Raveh, O., 2018. Input-Trade Liberalization, and the Demand for Managers: Evidence from India. *Journal of International Economics* 111: 159–176

Chakraborty, O., Henry, M., 2019. Chinese Competition and Product Variety of Indian firms. *Journal of Comparative Economics* 47 (2): 367–395

Chatterjee, C., Kubo, K., Pingali, V., 2015. The Consumer Welfare Implications of Governmental Policies and Firm Strategy in Markets for Medicines. *Journal of Health Economics* 44: 255–273

Chaudhuri, S., 2005. *The WTO and India's Pharmaceuticals Industry: Patent Protection, TRIPs, and Developing Countries.* Oxford University Press, India

Chen, Y., Puttitatun, T., 2005. Intellectual Property Rights and Innovation in Developing Countries. *Journal of Development Economics* 78 (2), 478–493

Choudhury, P., Khanna, T., 2014. Toward Resource Independence—Why State-Owned Entities Become Multinationals: An Empirical Study of India's Public R&D Laboratories. *Journal of International Business Studies* 45 (8): 943–960

Chu, A., Peng, Shin-Kun., 2011. Effect of TRIPs on Growth, Welfare and Income-inequality in an R&D Growth Model. *Journal of Macroeconomics* 33 (2): 276–287

Cozzi, G., Impullitti, G., 2016. Globalization and Wage Polarization. *The Review of Economics and Statistics* 98 (5): 984–1000

Cunat, V., Guadalupe, M., 2009. Globalization and the Provision of Incentives inside the Firm. *Journal of Labour Economics* 27 (2): 179–212

Dasgupta, P., Stiglitz, J., 1980. Uncertainty, Industrial structure and the Speed of R&D. *The Bell Journal of Economics* 11 (1): 1–28

Delgado, M., Margaret, K., McGahan, A. M., 2013. Intellectual Property Protection and the Geography of Trade. *Journal of Industrial Economics* LXI (3): 733–762

de Loecker, J., Goldberg, P. K., Khandelwal, A. K., Pavcnik, N. 2016. Prices, Markups, and Trade Reform. *Econometrica* 84 (2): 445–510

Dixit, A., 1987. Strategic Behavior in Contests. *American Economic Review* 77 (5): 891–898

Ederer, F. P., Manso, G., 2013. Is Pay-for-Performance Detrimental to Innovation? *Management Science* 59 (7): 1496–1513

Galor, O., Moav, O., 2000. Ability-biased Technological Transition, Wage Inequality, and Economic Growth. *The Quarterly Journal of Economics* 115 (2): 469–497

Garicano, L., 2000. Hierarchies and the Organization of Knowledge in Production. *Journal of Political Economy* 108 (5): 874–904

Garicano, L., Heaton, O., 2010. Information Technology, Organization, and Productivity in the Public Sector: Evidence from Police Departments. *Journal of Labor Economics* 28 (1): 167–201

Ghosh, S., 2014. Manufacturing Sector in India: Role of External Economies and Industrial Policy.

Mimeo, Jawaharlal Nehru University

Ginarte, J. C., Park, W. G., 1997. Determinants of Patent Rights: A Cross-national Study. *Research Policy* 26 (3): 283–301

Glass, A. J., Saggi, K., 2002. Intellectual Property Rights and Foreign Direct Investment. *Journal of International Economics* 56 (2): 387–410

Goldberg, P. K., Khandelwal, A., Pavcnik, N., Topalova, P., 2010. Imported Intermediate Inputs and Domestic Product Growth: Evidence from India. *The Quarterly Journal Economics* 125 (4): 1727–1767

Guadalupe, M., Wulf, J., 2010. The Flattening Firm and Product Market Competition: The Effect of Trade Liberalization on Corporate Hierarchies. *American Economic Journal: Applied Economics* 2 (4): 105–127

Guadalupe, M., Li, H., Wulf, J., 2014. Who lives in the C-Suite? Organizational Structure and the Division of Labor in Top Management. *Management Science* 6 (4): 824–844

Holmstrom, B., 1989. Agency Costs and Innovation. *Journal of Economic Behaviour and Organization* 12: 305–327

Hu, Albert G. Z., Jefferson, Gary H., Jinchang Q., 2005. R&D and Technology Transfer: Firm-level Evidence from Chinese Industry. *The Review of Economics and Statistics* 87 (4): 780–786

Ivus, O., 2010. Do Stronger Patent Rights Raise High-tech Exports to the Developing World? *Journal of International Economics* 81 (1): 38–47

Kamal, F., Lovely, M. E., 2013. Evolving Property Rights and Shifting Organizational Forms: Evidence From Joint-Venture Buyouts Following China's WTO Accession. *Working Paper 13-05*, Center for Economic Studies, U.S. Census Bureau

Kamien, M. I., Schwartz, N. L., 1976. On the Degree of Rivalry for Maximum Innovative Activity. *The Quarterly Journal of Economics* 90 (2): 245–260

Keller, W., Olney, W., 2017. Globalization and Executive Compensation. *NBER Working Paper No. 23384*, NBER, Cambridge, MA

Khandelwal, A., Topalova, P., 2011. Trade liberalization and Firm Productivity: The Case of India. *The Review of Economics and Statistics* 93 (3): 995–1009

Kline, P., Petkova, N., Williams, H., Zidar, O., 2019. Who Profits from Patents? Rent Sharing at Innovative Firms. *The Quarterly Journal of Economics* 134 (3): 1343–1404

Lee, S. Y., Shin, Y., 2017. Horizontal and Vertical Polarization: Task Specific Technological Change in a Multi-Sector Economy. *NBER Working Paper No. 23283*, NBER, Cambridge, MA

Lerner, J., Wulf, J., 2007. Innovation and Incentives: Evidence from Corporate R&D. *The Review of Economics and Statistics* 89 (4): 634–644

Levchenko, A., 2007. Institutional Quality and International Trade. Review of Economic Studies 74 (3): 791–819

Levinshon, J., Petrin, A., 2003. Estimating Production Functions Using Inputs to Control for Unobservables. *The Review of Economic Studies* 70 (2): 317–341

Lo, S., 2011. Strengthening Intellectual Property Rights: Experience from the 1986 Taiwanese Patent

Reforms. *International Journal of Industrial Organization* 29 (5): 524–536

Loury, G. C., 1979. Market Structure and Innovation. *The Quarterly Journal of Economics* 93 (3): 395–410

Maloney, W. F., Molina, C. A., 2016. Are Automation and Trade Polarizing Developing Country Labor Markets, too? *World Bank Policy Research Working Paper 7922*, World Bank, Washington DC

Manso, G., 2011. Motivating Innovation. *Journal of Finance* 66: 1823–1860

Michaels, G., Natraj, A., Van Reenen, J., 2014. Has ICT Polarized Skill Demand? Evidence From Eleven Countries Over Twenty-Five Years. *The Review of Economics and Statistics* 96 (1): 60–77

Nouroz, H., 2001. *Protection in Indian Manufacturing.* MacMillan Publishers, MacMillan India Ltd., India

Nunn, N., 2007. Relationship-Specificity, Incomplete Contracts and the Pattern of Trade. *The Quarterly Journal of Economics* 122 (2): 569–600

Qian, Y., 2007. Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment? A Cross-Country Analysis of Pharmaceutical Patent Protection, 1978-2002. *The Review of Economics and Statistics* 89 (3): 436–453

Parello, C., Spinesi, L., 2005. A Schumpeterian Model of Wage Inequality and Intellectual Property Rights Enforcement. *Rivista Di Politica Economica* 95 (5): 151–176

Park, W. G., Lippoldt, D., 2004. International Licensing and the Strengthening of Intellectual Property Rights in Developing Countries. *OECD Trade Policy Working Paper No. 10*, OECD Publishing

Park, W. G., 2008. International Patent Protection: 1960–2005. *Research Policy* 37 (4): 761–766

Porter, M. E., 2003. The Economic Performance of Regions. *Regional Studies* 37 (6–7): 549–578

Ramanna, A., 2002. Policy Implications of India's Patent Reforms: Patent Applications in the Post-1995 Era. *Economic and Political Weekly* 37 (21): 2065–2075

Raveh, O., Reshef, A., 2016. Capital Imports Composition, Complementarities, and the Skill Premium in Developing Countries. *Journal of Development Economics* 118: 183–206

Reinganum, J., 1989. Timing of Innovation: Research, Development and Diffusion. *Handbook of Industrial Organization*, Volume I. Amsterdam: North-Holland, pp. 849–908

Reddy, P., Chandrashekaran, S., 2017. *Create, Copy, Disrupt. India's Intellectual Property Dilemmas.* Oxford University Press, India

Sakakibara, M., Branstetter, L., 2001. Do Stronger Patents Induce More Innovation? Evidence from the 1988 Japanese Patent Law Reforms. *RAND Journal of Economics* 32 (1): 77–100

Saini, S., Mehra, M. K., 2014. Impact of Strengthening Intellectual Property Rights on Income Inequality: An Econometric Analysis. *MPRA Paper No. 75456*. Munich Personal RePEc Archive

Santos Silva, J. M. C., Tenreyro, S., 2006. The Log of Gravity. *The Review of Economics and Statistics* 88 (4): 641–658

Syverson, C., 2011. What Determines Productivity? *Journal of Economic Literature* 49 (2): 326–65

Teece, D. J., 1986. Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy* 15 (6): 285–305

—., 1996. Firm Organization, Industrial Structure and Technological Innovation. *Journal of Economic Behaviour and Organization* 31 (2): 193–224

Ugur, M., Mitra, A., 2017. Technological Adoption and Employment in Less Developed Countries: A Mixed-Method Systematic Review. *World Development* 96: 1–18

Vashisht, P., 2017. Destruction or Polarization: Estimating the Impact of Technology on Jobs in Indian Manufacturing. *ICRIER Working Paper No. 334*, ICRIER, New Delhi

Yang, L., Maskus, K. E., 2009. Intellectual Property Rights, Technology Transfer and Exports in Developing Countries. *Journal of Development Economics* 90 (1): 231–236

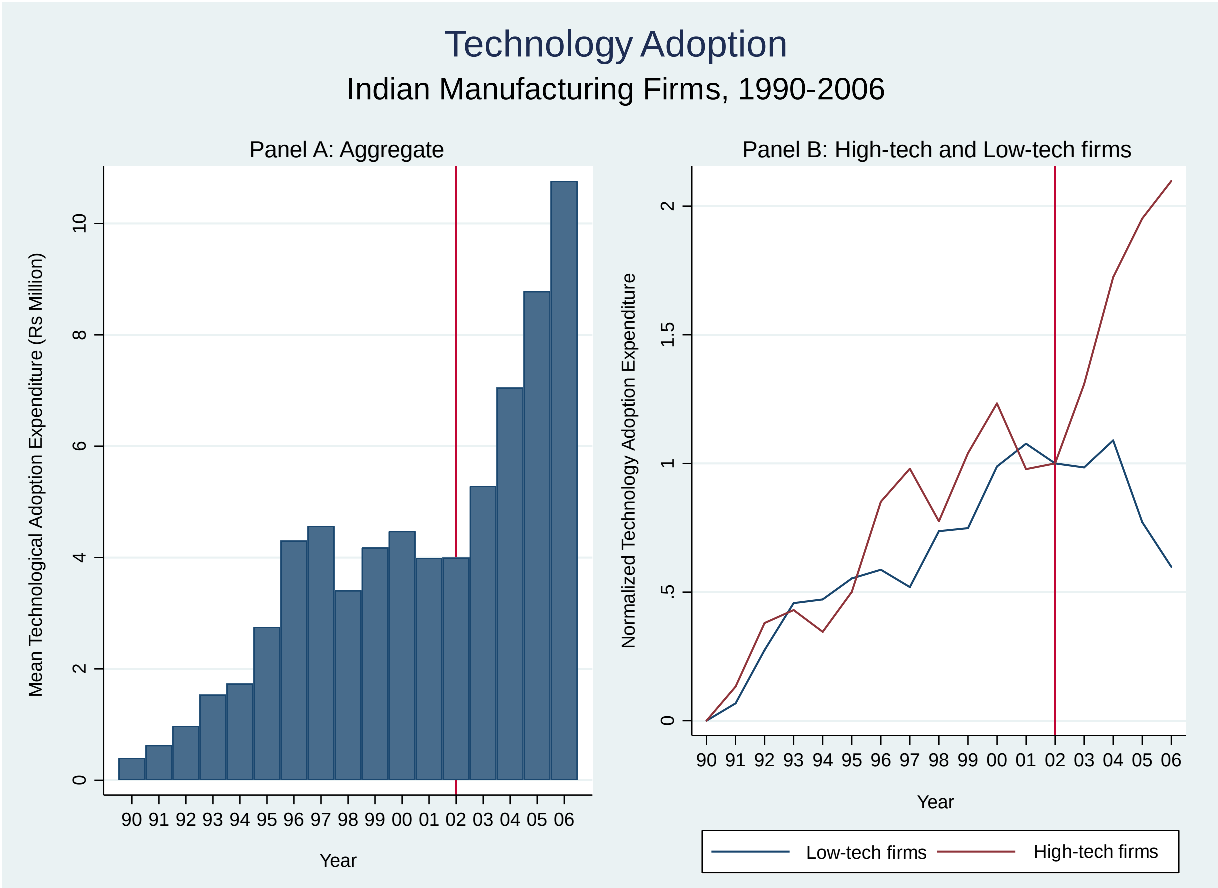

Figure 1: Technology Adoption: Indian Manufacturing Firms, 1990-2006

Notes: Figure presents the average technology adoption (sum of R&D expenditure and Technology Transfer) for manufacturing firms in India, 1990-2006

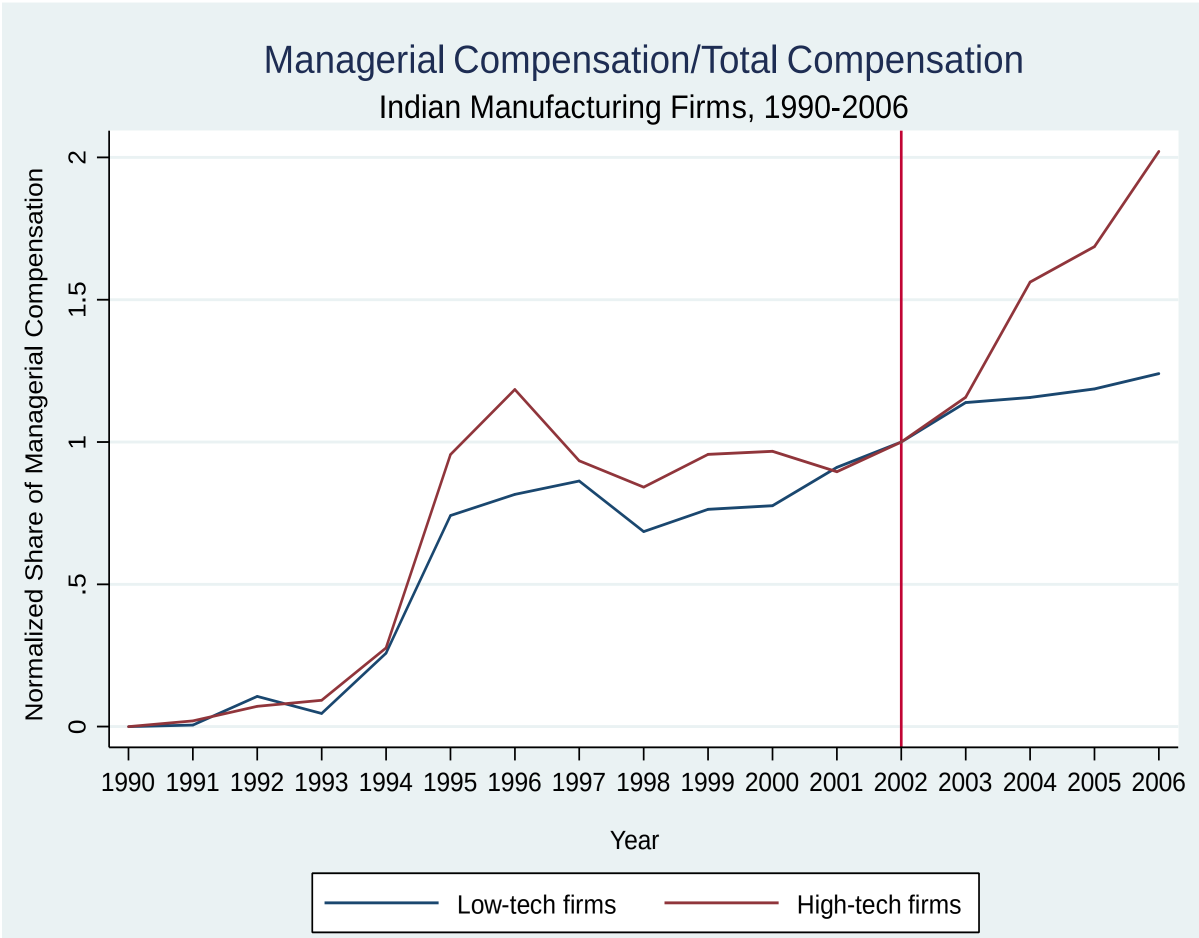

Figure 2: Managerial Compensation: High-Tech and Low-Tech Firms, 1990-2006

Notes: Figure presents the average share of managerial expenditure in total labour compensation for manufacturing firms in India, 1990-2006

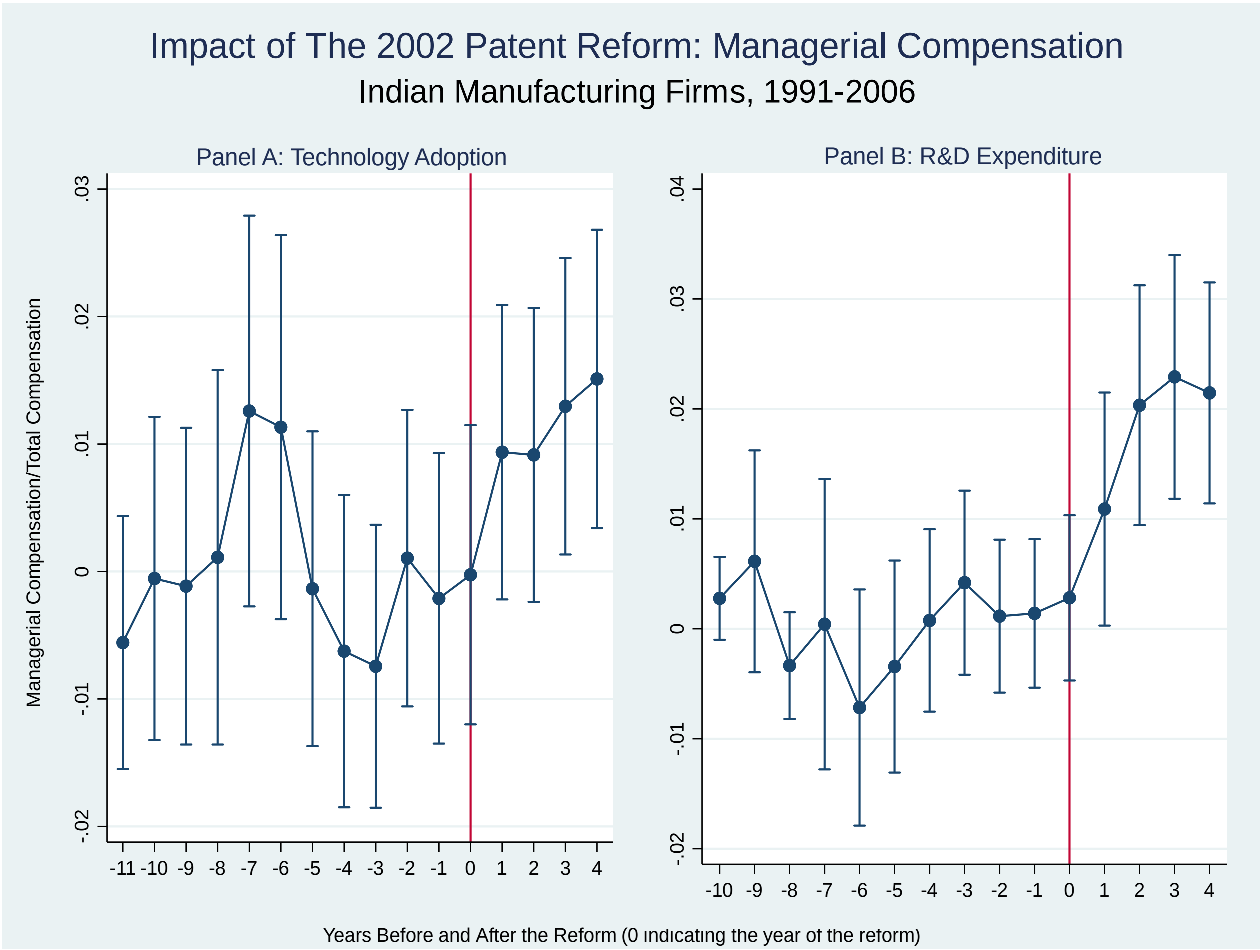

Figure 3: Impact of 2002 IPR reform: Managerial Compensation, 1991-2006

Notes: Figure presents the response of the difference in the share of managerial compensation in total compensation for high-tech and low-tech firms in our sample for the period 1991-2006. 95% confidence intervals are shown.

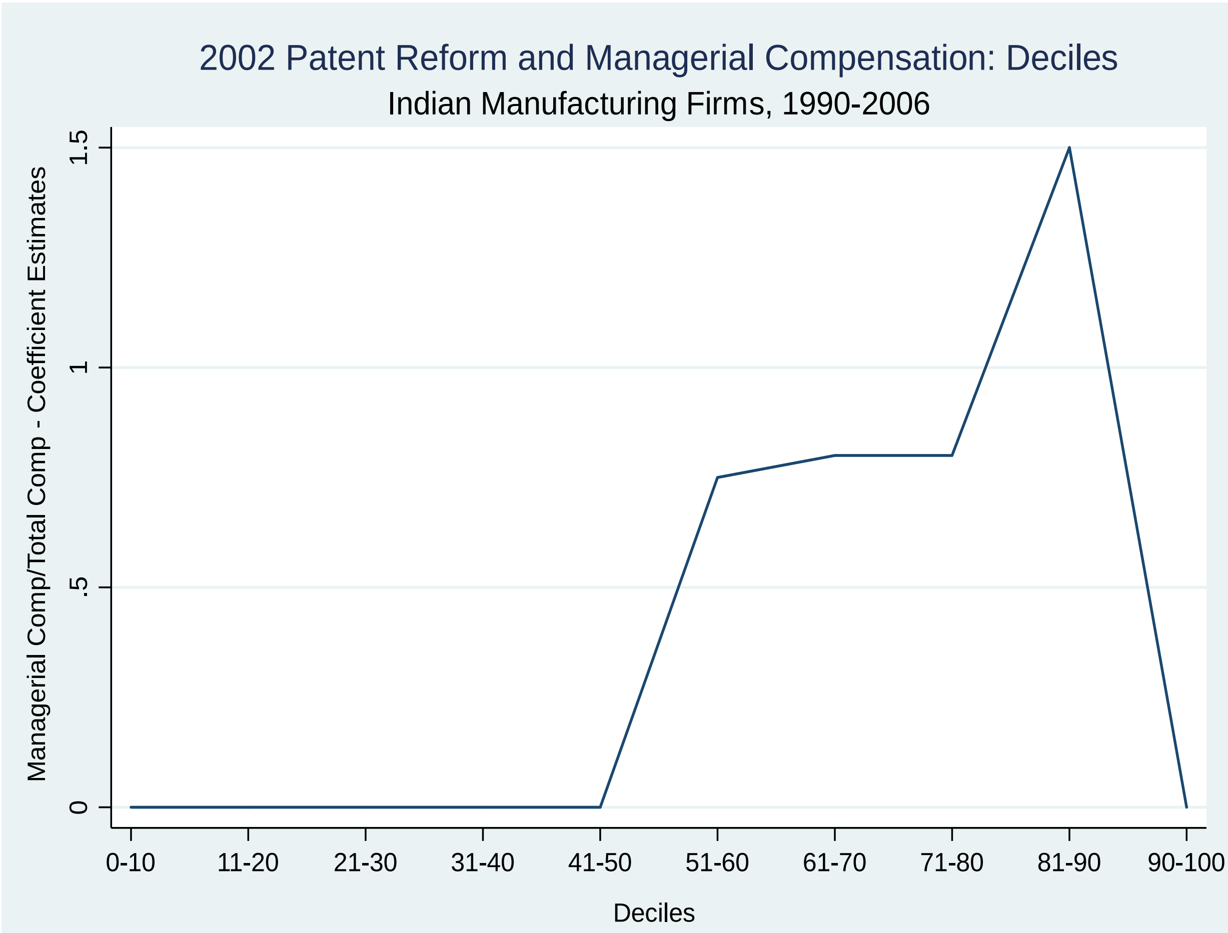

Figure 4: 2002 Patent Reform and Managerial Compensation: "Snail-Shaped" Effect
Notes: Figure presents the response of the difference in the share of managerial compensation in total labour compensation for firms within each decile in our sample for the period 1990-2006.

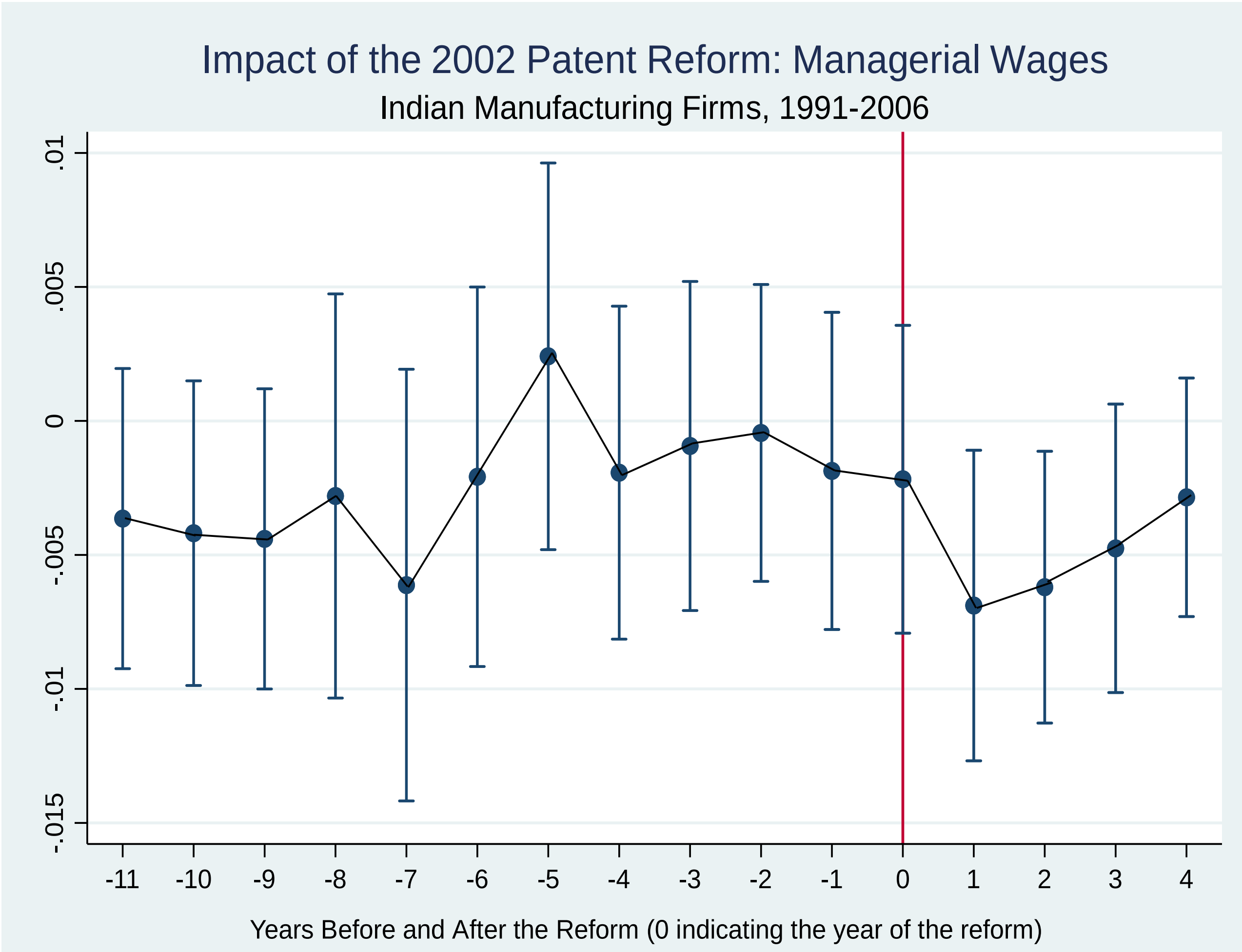

Figure 5: Impact of 2002 IPR reform: Managerial Wages, 1991-2006

Notes: Figure presents the response of the difference in the share of managerial wages in total wages for high-tech and low-tech firms in our sample for the period 1991-2006. 95% confidence intervals are shown.

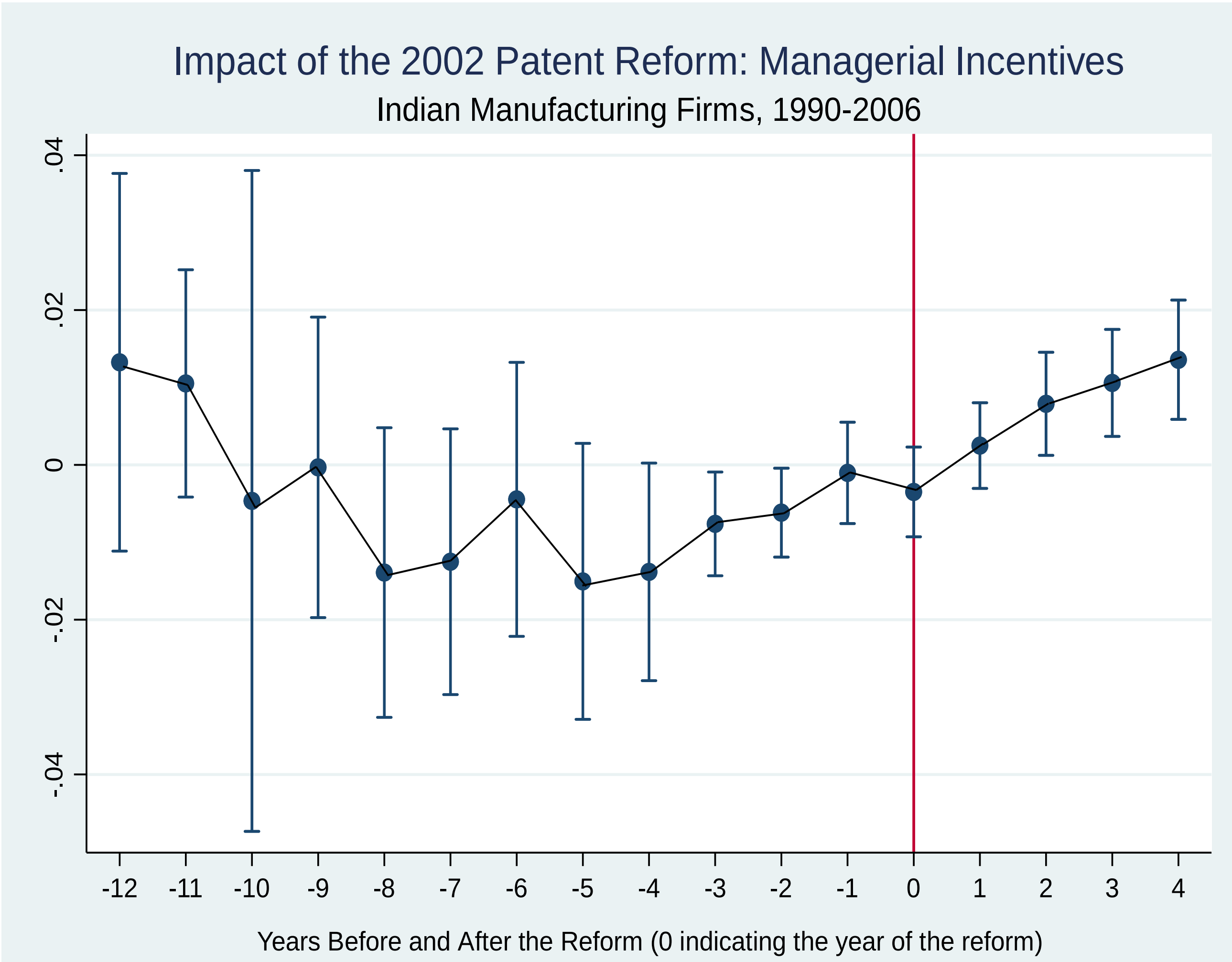

Figure 6: Impact of 2002 IPR reform: Managerial Incentives, 1990-2006

Notes: Figure presents the response of the difference in the share of managerial incentives in total incentives for high-tech and low-tech firms in our sample for the period 1990-2006. 95% confidence intervals are shown.

Table 1: Descriptive Statistics

	Mean	Median	Std. Dev.	Min	Max
Panel A: Dependent Variables					
Managerial Comp/Total Comp	0.09	0.05	0.13	$8.90e-06$	1
Managerial Compensation	6.51	1	343.94	0.1	66315.1
Number of Managers	1.82	2	0.85	1	9
Non-Managerial Compensation	99.67	14.8	675.13	0.1	52189.1
Managerial Wages	7.97	1.2	477.26	0.1	57590.5
Non-Managerial Wages	97.72	14.2	630.49	0.1	39720.6
Managerial Bonuses	3.49	0.3	19.43	0.1	8724.6
Non-Managerial Bonuses	21.95	3.5	147.55	0.1	9089.5
Panel B: Firm/Industry level Determinants - Explanatory Variables					
Capital Employed	1049.62	128.1	10599.64	2	891409
Technology Adoption/GVA	0.03	0	5.69	0	2163
Technology Adoption	36.68	3.7	214.74	0	8302.4
R&D Expenditure	29.46	3	163.10	0	6393.3
Technology Transfer	31.19	3.9	199.43	0	7551.5
Assets	1540.61	192.4	15736.8	1.4	1200000
Input Tariffs	69.95	46.95	49.17	17.34	202.02
Output Tariffs	72.71	49.29	56.72	14.5	298.07
$(ChineseM/TotalM)_{India}$	10.68	4.47	13.77	0.005	93.66
$(ChineseM/TotalM)_{US}$	14.22	12.03	11.68	0.007	100
Skill Intensity	0.26	0.25	0.07	0.04	0.71
Management Technology	2.41	2.48	0.60	0	3.17
Productivity	0.52	0.37	0.52	0.02	5.52
Factories	3920.77	3315	3037.77	15	14486
IT Expenditure	0.07	0	5.24	0	999.7
Consultancy Fees	8.13	0	217.53	0	46822.8
Product Varieties	4.49	3	4.44	1	86

Notes: Annual data at the firm level, covering the period of 1990-2006. Monetary values are in real INR Millions. Managerial Comp/Total Comp is the share of managerial compensation in total labour compensation. Managerial Compensation is the total managerial compensation. Number of Managers is the total number of managers (middle plus top) in a firm. Non-Managerial Compensation is the total non-managerial compensation. Managerial Wages, Non-Managerial Wages, Managerial Bonuses and Non-Managerial Bonuses is the total managerial wages, total non-managerial wages, managerial bonuses and non-managerial bonuses. Capital Employed is the amount of capital employed by a firm. Technology Adoption/GVA is defined as the share of the sum of Research and Development Expenditure and Royalty Payments for Technical Knowhow (Technology Transfer) in gross value-added of a firm. R&D Expenditure is the total amount of R&D expenditure undertaken by a firm. Technology Transfer is the royalty payment for technical knowhow of a firm. Assets is the total assets of a firm. Tariffs (input and output) are at the 4-digit NIC 2004. $(ChineseM/TotalM)_{India}$ is the share of Chinese imports in total imports of India. $(ChineseM/TotalM)_{US}$ is the share of Indian imports in total imports of the US. Skill Intensity is the ratio of non-production workers to total employees at the 3-digit NIC 2004. Management Technology is a measure of management quality score obtained from Bloom and Van Reenen (2010) at 2-digit NIC 2004. Factories is the number of factories at 3-digit NIC 2004. Productivity is a firm level measure, estimated following the Levinsohn and Petrin (2003) methodology. IT Fees is the amount of within-firm expenditure towards information technology services. Consultancy Fees is the amount of expenditure incurred by a firm towards information technology services, but from external sources. Product Varieties is the number of products manufactured by a firm in a year.

Table 2: Comparison of High-tech and Low-tech firms

	Pre-ReformPeriod (1990-2001)		Post-ReformPeriod (2002-2006)	
	Low-tech	High-tech	Low-tech	High-tech
Technology Adoption/GVA	0.003	0.046	0.004	0.167
Managerial Comp/Total Comp	0.012	0.019	0.022	0.054
Capital/GVA	2.747	2.887	2.948	3.956
Imports/GVA	0.285	0.395	0.304	1.387
Exports/GVA	0.279	0.283	0.393	0.512
Sales/GVA	2.745	2.853	3.299	4.513

Notes: Annual data at the firm level, covering the period of 1990-2006. Numbers represent average values over the period mentioned. Technology Adoption is defined as the sum of Research and Development Expenditure and Royalty Payments for Technical Knowhow (Technology Transfer). Managerial Compensation/Total Compensation is the share of managerial compensation in total labour compensation. Capital is the amount of capital employed by each firm. Imports is total imports of a firm. Total imports is the sum of import of raw materials, capital goods, finished goods and store and spares. Exports is total exports of a firm. Sales is total sales (exports plus domestic sales). GVA is the gross value-added of a firm. It is defined as total sales minus total expenditure on raw materials.

Table 3: Differences in Pre-Reform Time Trends in Managerial Compensation, 1990-2001: High-tech and Low-tech Firms

	Managerial Compensation/ Total Compensation		
	(1)	(2)	(3)
$HighTech_{i,90-01} \times Time\ Trend$	-0.0006 (0.034)		
$Time\ Trend$	-0.0002 (0.012)		
$HighTech_{i,90-01} \times Year1991$		-0.0004 (0.002)	
$HighTech_{i,90-01} \times Year1992$		-0.0002 (0.009)	
$HighTech_{i,90-01} \times Year1993$		0.004 (0.003)	
$HighTech_{i,90-01} \times Year1994$		-0.0005 (0.003)	
$HighTech_{i,90-01} \times Year1995$		-0.002 (0.005)	
$HighTech_{i,90-01} \times Year1996$		-0.002 (0.005)	
$HighTech_{i,90-01} \times Year1997$		0.001 (0.004)	
$HighTech_{i,90-01} \times Year1998$		-0.008 (0.007)	
$HighTech_{i,90-01} \times Year1999$		-0.008 (0.006)	
$HighTech_{i,90-01} \times Year2000$		-0.007 (0.006)	
$HighTech_{i,90-01} \times Year2001$		0.002 (0.004)	
$IPR_{02}(t-4) \times HighTech_{i,90-01}$			-0.003 (0.006)
$IPR_{02}(t-3) \times HighTech_{i,90-01}$			-0.001 (0.005)
$IPR_{02}(t-2) \times HighTech_{i,90-01}$			-0.001 (0.004)
$IPR_{02}(t-1) \times HighTech_{i,90-01}$			-0.003 (0.003)
$IPR_{02}(t+1) \times HighTech_{i,90-01}$			0.010^{***} (0.003)
$IPR_{02}(t+2) \times HighTech_{i,90-01}$			0.010^{**} (0.004)
$IPR_{02}(t+3) \times HighTech_{i,90-01}$			0.021^{***} (0.005)
$IPR_{02}(t+4) \times HighTech_{i,90-01}$			0.020^{***} (0.005)
Firm Controls_{t-1}	Yes	Yes	Yes
R-Square	0.51	0.52	0.49
N	33,407	33,407	57,461
Firm FE	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes

Notes: Columns (1) and (2) use share of of managerial compensation in total compensation as the dependent variable. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). $Time\ Trend$ is a linear time trend. $Year1991$, $Year1992$, $Year1993$, $Year1994$, $Year1995$, $Year1996$, $Year1997$, $Year1998$, $Year1999$, $Year2000$, $Year2001$are year dummies. These dummies equal to 1 for the respective years. IPR_{02} is a dummy variable, which takes a value 1 if year is greater than equal to 2002. $HighTech_{i,90-01}$is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). $IPR_{02}(t-4)$ is a dummy which is equal to 1 for all years that predate the reform by 4 or more years and is equal to 0 in all other years. $IPR_{02}(t+4)$ dummy is equal to 1 for all years at least four years after reform and 0 during other years. The other reform dummies are equal to 1 in specific years relative to reform and 0 during other years. There is no dummy for the year immediately prior to the reform (i.e., year $t-1$); the coefficients on the reform dummies provide estimates relative to that year. Firm controls include age, age squared of a firm, capital employed, and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported.

Table 4: Endogeneity of The Patents (Amendment), Act, 2002

	$IPR_{02} \times HighTech_{i,90-01}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$(\text{Mcomp/Tcomp})_i$	0.029 (0.028)					
Capital Intensity$_i$		0.002 (0.003)				
TechAdop$_i$			0.0002 (0.0003)			
Consultancy Fees$_i$				−0.0001 (0.0001)		
Skilled Workers$_j$					0.013 (0.059)	
Factory Size$_j$						0.001 (0.002)
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.27	0.28	0.26	0.26	0.27	0.27
N	57,457	47,998	57,457	57,457	57,457	57,457
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Columns (1) – (6) use $IPR_{02} \times HighTech_{i,90-01}$ as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year is greater than equal to 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Mcomp/Tcomp, Capital Intensity, Consultancy Fees, TechAdop are share of managerial compensation, capital employed, consultancy fees, and technological adoption expenditure of a firm. Skilled Workers and Factory Size are share of skilled workers (non-production workers/total employees) and number of factories at the industry level. All of these measures are an average of $(t-1)$ and $(t-2)$ period. Firm controls include age, age squared of a firm and size (assets) of a firm. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported.

Table 5: Intellectual Property Regimes and Wage Inequality: First Order Effects

	Factors of Production			Product Characteristics		Patent Claims
	R&D Expenditure	Technology Transfer	Capital Expenditure	Scope	Quality	Product Claims/ Total Claims
	(1)	(2)	(3)	(4)	(5)	(6)
$IPR_{02} \times HighTech_{i,90-01}$	0.644*** (0.028)	0.198*** (0.027)	0.249*** (0.013)	0.028*** (0.010)	0.237*** (0.091)	0.434*** (0.163)
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.74	0.68	0.95	0.85	0.42	n/a
N	56,981	56,980	51,462	39,597	253,001	15,754
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable in columns (1), (2) and (3) is the natural logarithm of R&D expenditure, expenditure on technology transfer, and capital expendiure, respectively. Columns (4) and (5) use product variety and product quality of a firm as the dependent variable. In column (6), I use share of product claims in total patent claims of a firm, as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Firm Controls include age of a firm, age squared, size (assets), and capital employed (except for column (3)) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are clustered standard errors at the firm level. Intercepts are not reported.*** denotes 1% level of significance.

Table 6: Intellectual Property Regimes and Wage Inequality: Benchmark Results

	Managerial Compensation/Total Compensation									
			Ind FE 2-digit	Ind FE 3-digit	Ind FE 4-digit	ATT	2SLS	$HighTech$ × Year FE	R&D Expenditure	Tech Transfer
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$IPR_{02} \times TechAdop/GVA_{i,t-1}$	0.001*** (0.0002)									
$IPR_{02} \times HighTech_{i,90-01}$		0.016*** (0.002)	0.017*** (0.002)	0.017*** (0.002)	0.017*** (0.002)	0.017*** (0.002)	0.007*** (0.002)	0.010*** (0.003)		
$IPR_{02} \times HighTech^{R\&D}_{i,90-01}$									0.012*** (0.004)	
$IPR_{02} \times HighTech^{TechTran}_{i,90-01}$										0.002 (0.005)
$(\text{CapEmployed})_{t-1}$	0.005*** (0.002)	0.004** (0.002)	0.005** (0.002)	0.005*** (0.002)	0.005*** (0.002)	Yes	0.005*** (0.001)	0.004** (0.002)	0.005*** (0.002)	0.005*** (0.002)
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.48	0.49	0.49	0.49	0.50	n/a	0.08	0.49	0.49	0.49
N	56,981	57,461	57,461	57,461	57,461	68,016	62,677	57,461	57,461	57,461
Firm FE	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE*Year Trend	Yes	Yes	No	No	No	Yes	No	Yes	No	No
Industry FE*Year FE	No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
	1st-Stage - $IPR_{02} \times HighTech_{i,90-01}$									
$TechAdop/GVA_{it}$							0.837*** (0.204)			

Notes: Columns (1) – (10) use share of managerial compensation in total compensation as the dependent variable. $TechAdop/GVA$ is the share of technology adoption in the gross value-added of a firm. IPR_{02} is a dummy variable, which takes a value 1 if year ≥ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. $^{**},^{***}$ denotes 5% and 1% level of significance.

Table 7: Intellectual Property Regimes and Wage Inequality: Robustness Checks

	Managerial Compensation/Total Compensation									
	Control for Total Comp	IPR × Firm FE	IPR × Firm Charac	1997–2006	1990–2005	Exclude Firms Close to Median	Balanced Panel	Agri, Pharma Chemical	PPML	1999 Patent Act
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$IPR_{02} \times HighTech_{i,90-01}$	0.017*** (0.002)	0.017*** (0.002)	0.017*** (0.002)	0.013*** (0.002)	0.015*** (0.002)	0.010*** (0.003)	0.007*** (0.002)	0.007** (0.003)	0.083*** (0.027)	0.017*** (0.002)
$IPR_{99} \times HighTech_{i,90-98}$										−0.0004 (0.002)
$(\text{CapEmployed})_{t-1}$	0.005*** (0.002)	0.005*** (0.002)	0.005*** (0.002)	0.005*** (0.002)	0.004** (0.002)	0.005*** (0.002)	0.002 (0.004)	0.004** (0.002)	0.563*** (0.035)	0.005*** (0.002)
Firm Controls$_{t-1}$	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.49	0.50	0.50	0.61	0.48	0.47	0.70	0.51	0.04	0.48
N	57,461	57,461	56,899	38,365	51,558	50,002	26,284	56,899	62,677	56,981
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	No	No	Yes	No
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Industry FE*Year Trend	No	No	No	No	No	No	No	Yes	Yes	No

Notes: Columns (1) – (10) use share of managerial compensation in total compensation as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. IPR_{99} is a dummy variable which takes value 1 for years 1999-2001. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). $HighTech_{i,90-98}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 1998, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. **,*** denotes 5% and 1% level of significance.

Table 8: Intellectual Property Regimes and Wage Inequality: Additional Results

	Total Managers		Man Comp		Avg Man Comp	
	(1)	(2)	(3)	(4)	(5)	(6)
$IPR_{02} \times HighTech_{i,90-01}$	0.047***	0.049***	0.714***	0.712***	0.460***	0.457***
	(0.017)	(0.017)	(0.023)	(0.023)	(0.051)	(0.051)
$(\text{CapEmployed})_{t-1}$	0.020	0.015	0.088***	0.073***	0.122**	0.096*
	(0.016)	(0.016)	(0.012)	(0.011)	(0.056)	(0.051)
$HighTech_{i,90-01}\times$ Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls_{t-1}	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.58	0.61	0.74	0.74	0.78	0.80
N	13,663	13,663	57,461	57,461	13,663	13,663
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE (5-digit)*Year Trend	Yes	No	Yes	No	Yes	No
Industry FE (2-digit)*Year FE	No	Yes	No	Yes	No	Yes

Notes: Columns (1) – (2), (3) – (4), and (5) - (6) use total number of managers, absolute managerial compensation, and average managerial compensation as the dependent variable, respectively. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm Controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. *,**,*** denotes 10%, 5% and 1% level of significance.

Table 9: Intellectual Property Regimes and Wage Inequality: Dividing Firms into Quintiles and Deciles - Checking for the Control Group

	Managerial Compensation/Total Compensation								Total Managers	Avg. Man Comp
	Quintile			Decile					Decile	
							High-Tech	Low-Tech		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$IPR_{02} \times Qtile_1$	0.004 (0.006)	0.005 (0.006)	0.003 (0.007)							
$IPR_{02} \times Qtile_2$	0.002 (0.005)	0.003 (0.004)	0.001 (0.005)							
$IPR_{02} \times Qtile_3$	0.006 (0.004)	0.007* (0.004)	0.007* (0.004)							
$IPR_{02} \times Qtile_4$	0.006* (0.004)	0.007** (0.004)	0.007** (0.004)							
$IPR_{02} \times Qtile_5$	0.010** (0.005)	0.012** (0.005)	0.011** (0.005)							
$IPR_{02} \times Decile_0$				0.010 (0.007)	0.011 (0.008)	0.005 (0.010)	−0.006 (0.009)	0.008 (0.006)	0.045 (0.046)	0.056 (0.123)
$IPR_{02} \times Decile_1$				0.008 (0.006)	0.009 (0.006)	0.004 (0.007)	−0.001 (0.009)	0.007 (0.009)	0.038 (0.046)	0.170 (0.156)
$IPR_{02} \times Decile_2$				0.002 (0.008)	0.002 (0.007)	0.003 (0.008)	−0.017 (0.013)	0.013 (0.011)	0.037 (0.043)	0.272 (0.187)
$IPR_{02} \times Decile_3$				0.009 (0.008)	0.010 (0.008)	0.0002 (0.007)	0.007 (0.007)	0.007 (0.005)	0.018 (0.040)	0.262* (0.155)
$IPR_{02} \times Decile_4$				0.007 (0.006)	0.008 (0.006)	0.011 (0.008)	0.007 (0.006)	0.015 (0.011)	0.033 (0.037)	0.331** (0.156)
$IPR_{02} \times Decile_5$				0.007* (0.004)	0.008* (0.004)	0.007* (0.004)	0.007 (0.007)	0.012* (0.007)	0.040 (0.042)	0.435** (0.156)
$IPR_{02} \times Decile_6$				0.008* (0.005)	0.008* (0.005)	0.008* (0.005)	0.004 (0.006)	0.012* (0.006)	0.098** (0.047)	0.445** (0.196)
$IPR_{02} \times Decile_7$				0.008* (0.004)	0.009* (0.006)	0.007* (0.004)	0.010* (0.006)	0.018** (0.008)	0.070* (0.038)	0.319** (0.140)
$IPR_{02} \times Decile_8$				0.014** (0.007)	0.016** (0.008)	0.014** (0.007)	0.011* (0.007)	0.022** (0.008)	0.082** (0.040)	0.509*** (0.172)
$IPR_{02} \times Decile_9$				0.007 (0.007)	0.009 (0.007)	0.007 (0.007)	0.0003 (0.007)	0.003 (0.014)	0.058 (0.042)	0.181 (0.147)
$Qtile_i(Decile_i) \times$ Year FE	No	No	Yes	No	No	Yes	No	No	No	No
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.48	0.48	0.48	0.50	0.50	0.50	0.55	0.48	0.55	0.79
N	57,461	56,981	57,461	52,391	51,795	52,391	19,666	32,441	13,663	13,663
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	Yes	No	No	No	No
Industry FE (5-digit)*Year Trend	Yes	No	Yes	Yes	No	Yes	No	No	No	No
Industry FE (2-digit)*Year FE	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes

Notes: Columns (1) – (8) use share of managerial compensation in total labour compensation. Columns (9) and (10) use total number of managers and average managerial compensation as the dependent variable, respectively. IPR_{02} is a dummy variable, which takes a value 1 if year is greater than equal to 2002. *Qtile* (quintile) or *Decile* (decile) are dummy variables. For example, in case of $Qtile_1$, it takes a value 1 if a firm's average GVA share of technology adoption expenditure (R&D Expenditure + Technology Transfer) on or before the year 2001 falls wihtin the 0-20th percentile of the corresponding industry's technology adoption and so on. Similarly, in case of decile. If a firm's average GVA share of technology adoption expenditure on or before the year 2001 falls within 0-10th percentile of the corresponding industry's technology adoption expenditure, $Decile_0$ takes a value 1 and so on. Firm Controls include age, age squared of a firm, capital employed and size (assets) of a firm. Both Capital Employed and Assets are used at $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. *,** denotes 10% and 5% level of significance.

Table 10: Intellectual Property Regimes and Wage Inequality: Disaggregating the Compensation - Wages and Incentives

	Managerial Wages/ Total Wages	Managerial Incentives/ Total Incentives	Managerial Wages/ Total Compensation	Managerial Incentives/ Total Compensation
	(1)	(2)	(3)	(4)
$IPR_{02} \times HighTech_{i,90-01}$	-0.008^{**} (0.004)	0.044^{***} (0.012)	-0.010^{***} (0.003)	0.005^{***} (0.002)
$(\text{CapEmployed})_{t-1}$	0.004^{*} (0.002)	0.009^{***} (0.002)	0.004^{**} (0.002)	0.001^{**} (0.0002)
$HighTech_{i,90-01} \times$ Year FE	Yes	Yes	Yes	Yes
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes
R-Square	0.62	0.40	0.64	0.37
N	57,461	57,461	57,461	57,461
Firm FE	Yes	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes

Notes: Columns (1) and (2) use ratio of managerial wages to total wages, and ratio of managerial incentives to total incentives of a firm as the dependent variable, respectively. Columns (3) and (4) use ratio of managerial wages to total compensation and ratio of managerial incentives to total compensation of a firm as the dependent variable, respectively. IPR_{02} is a dummy variable, which takes a value 1 if year is greater than equal to 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. *,**,*** denotes 10%, 5% and 1% level of significance.

Table 11: Intellectual Property Regimes and Wage Inequality: Categorizing Industries into High- and Low-IP intensive Industries

	Managerial Compensation/Total Compensation									
	High-IP Group			High-IP Clusters			Patent Protection Index		Patent Intensity	
							Year < 2002	Year >= 2002		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$IPR_{02} \times HighPatentIntensity_j$									0.001 (0.004)	0.001 (0.005)
$IPR_{02} \times HighIP_j$	0.012** (0.005)	0.013* (0.007)	0.007** (0.003)	0.005* (0.003)	0.011** (0.005)	0.010* (0.006)				
$Patent_{Index} \times HighIP_j$							−0.016 (0.019)	0.004*** (0.001)		
$HighPatentIntensity_j \times$ Year FE	No	No	No	No	No	No	No	No	Yes	Yes
$HighIP_j \times$ Year FE	No	Yes	Yes	No	Yes	Yes	No	No	No	No
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.61	0.61	0.61	0.59	0.59	0.59	0.54	0.73	0.48	0.49
N	22,119	22,119	22,119	31,726	31,726	31,726	29,127	22,845	15,754	15,754
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
Industry FE (5-digit)*Year Trend	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
Industry FE (2-digit)*Year FE	No	No	No	No	No	No	Yes	Yes	No	Yes

Notes: Columns (1) – (10) use share of managerial compensation in total compensation as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002 in columns (1) - (2), (4) - (5), and (9) - (10). In columns (3) and (6), IPR_{02} takes 1 for year 2002, 2 for 2003, 3 for 2004 and so on. We use it in an increasing oder to measure the intensity of the 2002 IPR reform over the years. $HighIP_j$ is a dummy variable which takes a value 1 if an industry is classified into High-IP product or High-IP cluster in columns (1) - (3) and (4) - (6), respectively. We use this classification from Delgado et al. (2013). $Patent_{Index}$ is the patent protection index from Ginarte and Park (1997) and Park (2008). The index is based on the examination of the following five categories of the patent laws: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. $HighPatentIntensity_j$ is a dummy variable which takes a value 1 if the average patent filings for an industry before 2001 (1995-2001) is greater than the median patent filings of the manufacturing industry as a well. Firm Controls include age, age squared of a firm, size (assets) of a firm and capital employed by a firm. Both Capital Employed and Assets at used at $t-1$ period and are expressed in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. *,** denotes 10% and 5% level of significance.

Table 12: Intellectual Property Regimes and Wage Inequality: Firm Characteristics

	Managerial Compensation/Total Compensation					
	Export Orientation		Ownership		End Use	
	Exporters	Non Expoters	Domestic	Foreign	Intermediate Goods	Final Goods
	(1)	(2)	(3)	(4)	(5)	(6)
$IPR_{02} \times HighTech_{i,90-01}$	0.005*** (0.001)	0.015*** (0.005)	0.017*** (0.002)	0.022*** (0.005)	0.015*** (0.003)	0.017*** (0.002)
$(\text{CapEmployed})_{t-1}$	0.005*** (0.002)	0.006** (0.002)	0.004** (0.002)	0.004 (0.003)	0.003 (0.003)	0.005** (0.002)
Firm Controls_{t-1}	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.69	0.54	0.50	0.50	0.46	0.50
N	31,640	26,001	49,641	7,820	25,903	31,558
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Columns (1) – (6) use share of managerial compensation in total labour compensation as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year is greater than equal to 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. **,*** denotes 5% and 1% level of significance.

Table 13: Intellectual Property Regimes and Wage Inequality: Controlling for Different types of Trade Shocks

	Managerial Compensation/Total Compensation				
	India's Trade Liberalization Program			Domestic Market Competition - China	Export Market Competition - US
	(1)	(2)	(3)	(4)	(5)
$IPR_{02} \times HighTech_{i,90-01}$	0.010^{***} (0.002)	0.010^{***} (0.002)	0.011^{***} (0.002)	0.015^{***} (0.002)	0.022^{***} (0.003)
$HighTech_{i,90-01} \times InpTariff_{t-1}$	0.003^{***} (0.001)		-0.002 (0.008)		
$HighTech_{i,90-01} \times OutTariff_{t-1}$		0.003^{***} (0.001)	0.005 (0.008)		
$InpTariff_{t-1}$	-0.014^{**} (0.006)		-0.012^{*} (0.007)		
$OutTariff_{t-1}$		-0.006 (0.004)	-0.002 (0.005)		
$DComp_{IN}^{China} \times HighTech_{i,90-01}$				0.0002 (0.0002)	
$FComp_{IN}^{China} \times HighTech_{i,90-01}$					-0.0004 (0.003)
$(\text{CapEmployed})_{t-1}$	0.005^{**} (0.002)	0.005^{***} (0.002)	0.005^{***} (0.002)	0.004^{***} (0.002)	0.005^{**} (0.002)
Firm Controls_{t-1}	Yes	Yes	Yes	Yes	Yes
R-Square	0.50	0.50	0.50	0.49	0.49
N	52,391	52,391	52,391	52,014	56,971
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes

Notes: Columns (1) – (5) use share of managerial compensation in total compensation and average managerial compensation as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year is greater than equal to 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). $InpTariff_{t-1}$ and $OutTariff_{t-1}$ are input and output tariffs at 2004 NIC 4-digit level, respectively. $DComp_{IN}^{China}$ is the measure of Chinese import competition faced by Indian firms in the domestic market. $FComp_{IN}^{China}$ is the measure of export market competition faced by Indian firms in an export destination (US). Capital Employed is the total amount of capital used by a firm. Firm controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. All the regressions include the individual terms of the double interaction terms. Intercepts are not reported.*,**,*** denotes 10%, 5% and 1% level of significance.

Table 14: Intellectual Property Regimes and Wage Inequality: Controlling for Other Possible Channels

	Managerial Compensation/Total Compensation										
	Industry Characteristics			Firm Characteristics					State Characteristics		
	Skill Intensity	Manage Technology	Factories	TFP	IT & Consul Fees	Family Firm	Insider Board	Product Claims	Labour Reg	Judicial Quality	Fin Develop
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
$IPR_{02} \times HighTech_{i,90-01}$	0.007*** (0.002)	0.007*** (0.002)	0.007*** (0.002)	0.010*** (0.002)	0.011*** (0.002)	0.016*** (0.002)	0.003 (0.006)	0.008+ (0.005)	0.016*** (0.002)	0.007*** (0.002)	0.008*** (0.002)
$HighTech_{i,90-01} \times SkIntens_{t-1}$	0.010*** (0.002)										
$HighTech_{i,90-01} \times ManTech$		0.015*** (0.002)									
$HighTech_{i,90-01} \times Factories_{t-1}$			0.002*** (0.0001)								
$HighTech_{i,90-01} \times TFP_{t-1}$				0.009** (0.0004)							
$HighTech_{i,90-01} \times ITFees_{t-1}$					0.003 (0.006)						
$HighTech_{i,90-01} \times ConsFees_{t-1}$					0.005*** (0.001)						
$HighTech_{i,90-01} \times Famfirm_i$						0.012*** (0.003)					
$HighTech_{i,90-01} \times IndDir_{it}$							−0.006 (0.007)				
$IPR_{02} \times (PClaims/TClaims)_{t-1}$								0.005+ (0.003)			
$HighTech_{i,90-01} \times LabLaws_s$									0.015*** (0.004)		
$HighTech_{i,90-01} \times JudicialQ_{st}$										−0.0002*** (0.0000)	
$HighTech_{i,90-01} \times FinDev_s$											0.014*** (0.002)
Firm Controls$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.49	0.49	0.49	0.70	0.49	0.51	0.87	0.85	0.51	0.50	0.49
N	57,456	56,210	57,456	26,264	56,084	52,391	4,834	15,754	52,391	30,484	48,460
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE*Year FE	No	No	No	No	No	No	No	No	Yes	Yes	Yes

Notes: Columns (1) – (8) use share of managerial compensation in total compensation and average managerial compensation as the dependent variable. *SkIntens* is a proxy for skill intensity at the industry level. It is defined as the share of non-production workers to total employees at the NIC 3-digit level. *ManTech* is an index of Management Quality at 2004 NIC 2-digit level and has been sourced from Bloom and Van Reenen (2010). *Factories* is the number of factories at 3-digit level NIC 2004. *TFP* is total factor productivity at firm level estimated using Levinshon and Petrin (2003). *ITFees* is the expenditure by a firm towards its information technology enabled services. *ConsFees* is the expenditure by a firm towards its consultancy for technological upgradation or transfer. *Famfirm* is an indicator for family firm constructed based on the percentage of shares held by the Hindu undivided-family as promoters in 2007. *IndDir* is the number of independent directors within the Board of Directors of a firm. It is an indicator for poor governance settings. *PClaims/TClaims* is the shaer of product claims in total patent claims of a firm. *LabLaws* takes a value 1 if a state has pro-employer labour regulation. *JudicialQ* indicates the institutional quality of a state. We use pendency ratio of high courts as the indicator for instutional quality of a state. *FinDev* denotes the level of financial development of a state. It is measured as credit per capita in 1992, with states above the median classified as having high financial development and *FinDev* will take a value 1 for those states. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Firm Controls include age, age squared of a firm, capital employed and size (assets) of a firm. Both Capital Employed and Assets are used at $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. All the regressions include the individual terms of the double interaction terms. Intercepts are not reported. $^{+,*,**,***}$ denotes 12%, 10%, 5% and 1% level of significance.

Appendix

A Data

We use a yearly panel of Indian firms that covers up to 8,000+ firms, across 108 industries within the manufacturing sector, over the period of 1990-2006 (with the exception of specific cases, where specified so). Unless otherwise specified, variables are based on data from the PROWESS database of the Centre for Monitoring Indian Economy (CMIE). All monetary-based variables measured in millions of Rupees, deflated to 2005 using the industry-specific Wholesale Price Index). All industry level variables are based on the 2004 National Industrial Classification (NIC).

Variable definitions

1. **Managerial Compensation/Total Compensation**: Share of managerial compensation in total labour compensation; compensation defined as the sum of wages and bonuses.

2. **Total Managers**: Total number of managers in a firm. This is a sum of total number of managers at the top and middle management level.

3. **Average Managerial Compensation**: Total managerial compensation divided by total number of managers.

4. **Managerial Wage/Total Wage**: Share of managerial wage in total wage of a firm.

5. **Managerial Incentives/Total Incentives**: Share of incentives or bonuses in total incentives of a firm. Incentives is a sum of bonuses or perquisites, commission, contribution to pension, contribution to provident fund.

6. $HighTech$: It takes a value 1 if the average of R&D expenditure and royalty payments for technical knowhow (technology transfer) is greater than the median of the industry average of the corresponding industry of the firm and zero otherwise.

7. IPR_{02}: It takes a value 1 if year is greater than equal to 2002.

8. **Input/Output tariffs**: Input/output tariffs at the 4-digit industry level, obtained from Ahsan and Mitra (2014) for the period of 1990-2003, with the balance collected from Chakraborty and Raveh (2018).

9. $DComp_{IN}^{China}$: Share of Chinese imports in total imports of India. It is a measure of import competition that Indian firms face at the domestic market.

10. $FComp_{IN}^{China}$: Share of Chinese imports in total imports of the US. It is a measure of export market competition that Indian firms face.

11. **Skill Intensity (**$SkIntens$**)**: The 3-digit industry level ratio of non-production workers to all employees, obtained from the Indian Annual Survey of Industries (2001-2006) and from Ghosh (2014) (1990-2000).

12. **Management Technology (**$ManTech$**)**: The 4-digit industry level management quality score in 2004, obtained from Bloom and Van Reenen (2010); the score is between 1 and 5, with 5 denoting the highest quality.

13. **Factories (**$Factories$**)**: The 3-digit industry level number of factories/plants.

14. **Productivity (**TFP**)**: Total Factor Productivity (TFP) at the firm level is computed using the Levinsohn and Petrin (2003) methodology.

15. **IT Fees** ($ITFees$): All expenses paid by a firm towards information technology.

16. **Consultancy Fees** ($ConsFees$): All expenses paid by a firm towards technology upgradation.

17. **Family Firm** ($Familyfirm$): It is a dummy variable. It takes a value 1 if a firm has positive ownership share by undivided families (Hindu) and 0 otherwise.

18. **Number of Independent Directors** ($IndDir$): Number of independent directors at the Board of Directors of a firm.

19. $HighIP$: It takes a value 1 if an industry falls into the category of High-IP group or clusters as defined by Delgado et al. (2013).

20. **Exporter/Non-Exporter**: It takes a value 1 if a firm's export earning is greater than zero and 0 otherwise.

21. **Intermediate/Final goods**: These goods are classified according to the I-O table by end-use. The intermediate goods category includes intermediates, capital and basic goods, whereas the final goods category includes consumer durable and consumer non-durables.

22. **Capital employed**: Total amount of capital employed by a firm.

23. **Assets**: Total assets of a firm. It is an indicator of size.

24. **Age**: Age of a firm in years.

25. **Ownership**: It indicates whether a firm is domestic-owned or foreign-owned.

B Tables

Table B1: Intellectual Property Regimes and Wage Inequality: Dividing into Middle and Top Managers

	Managerial Compensation/ Total Compensation	
	Top Managers	Middle Managers
	(1)	(2)
IPR_{02}	0.008* (0.005)	0.009*** (0.002)
$IPR_{02} \times HighTech_{i,90-01}$	0.012*** (0.002)	0.005*** (0.000)
$(\text{CapEmployed})_{t-1}$	0.003* (0.001)	0.002*** (0.000)
Firm Controls_{t-1}	Yes	Yes
R-Square	0.47	0.35
N	57,461	56,981
Firm FE	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes

Notes: Columns (1) – (2) use share of managerial compensation for managers belonging to the top and middle management in total compensation as the dependent variable, respectively. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. **,*** denotes 5% and 1% level of significance.

Table B2: Intellectual Property Rights and Wage Inequality: Non-Managers

	Total Non-Managers	Non-Man Comp/ Total Comp	Avg Non-Man Comp	Avg Non-Man Wages	Avg Non-Man Incentives
	(1)	(2)	(3)	(4)	(5)
$IPR_{02} \times HighTech_{i,90-01}$	1.048***	−0.019***	0.031	0.027	−0.003
	(0.097)	(0.003)	(0.022)	(0.019)	(0.004)
$(\text{CapEmployed})_{t-1}$	0.020	−0.011**	−0.007	0.003	0.003
	(0.028)	(0.005)	(0.017)	(0.017)	(0.006)
Firm Controls_{t-1}	Yes	Yes	Yes	Yes	Yes
R-Square	0.54	0.62	0.82	0.85	0.85
N	2,082	57,461	2,082	2,082	2,082
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE (2-digit)*Year FE	Yes	Yes	Yes	Yes	Yes

Notes: Columns (1) - (5) use total number of non-managers, share of non-managerial compensation in total compensation, average non-managerial compensation, average non-managerial wages and average non-managerial incentives, respectively as the dependent variable. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). Capital Employed is the total amount of capital used by a firm. Firm Controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported. **,*** denotes 5% and 1% level of significance.

Table B3: Intellectual Property Regimes and Wage Inequality: Trend Break Analysis

	Man Comp/ Total Comp		Total Managers	Avg Managerial Compensation
	(1)	(2)	(3)	(4)
$HighTech_{i,90-01} \times (t-2001)Trend$	0.001***	0.001***	0.005	0.038**
	(0.000)	(0.000)	(0.004)	(0.015)
$HighTech_{i,90-01} \times (2002-2006)Trend$	0.005***	0.005***	0.022***	0.050***
	(0.000)	(0.000)	(0.005)	(0.013)
$IPR_{02} \times (t-2001)Trend$	0.003	−0.001	−0.017	−0.014
	(0.002)	(0.004)	(0.026)	(0.082)
$IPR_{02} \times (2002-2006)Trend$	0.006***	0.008**	0.079***	0.010
	(0.001)	(0.004)	(0.023)	(0.047)
$(\text{CapEmployed})_{t-1}$	0.004**	0.004***	0.075***	0.168
	(0.002)	(0.002)	(0.031)	(0.164)
Firm Controls_{t-1}	Yes	Yes	Yes	Yes
R-Square	0.49	0.49	0.52	0.81
N	57,461	57,461	10,252	4,371
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE (5-digit)*Year Trend	Yes	No	Yes	Yes
Industry FE (2-digit)*Year FE	No	Yes	No	No

Notes: Columns (1) – (2), (3), and (4) use managerial share of total compensaiton, total number of managers, and average managerial compensation as the dependent variable, respectively. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighTech_{i,90-01}$ is a dummy variable which takes a value 1 if a firm's GVA share of technology adoption expenditure (R&D + Technology Transfer) on or before the year 2001, is greater than the median of the corresponding industry (to which the firm belongs). $(t-2001)Trend$ captures the differntial pre-trend and post-trends of the 2002 Patent reform, whereas $(2002-2006)Trend$ only captures a fixed time trend after the patent reform of 2002. Capital Employed is the total amount of capital used by a firm. Firm Controls include age, age squared of a firm and size (assets) of a firm. Both Capital Employed and Assets are used in $t-1$ period and in their natural logarithmic form. All the regressions include the individual terms of the double interaction terms. Numbers in the parenthesis are robust clustered standard errors at the firm level. Intercepts are not reported.**,*** denotes 5% and 1% level of significance.

Table B4: IPR reform and Wage Inequality: Benchmark Results

	Managerial Compensation/ Total Compensation		
	(1)	(2)	(3)
$IPR_{02} \times HighIP_j$	0.007*** (0.002)	0.029*** (0.002)	0.023*** (0.001)
Plant Controls$_{t-1}$	Yes	Yes	Yes
R-square	0.12	0.08	0.08
N	289,723	289,723	289,723
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE(2-digit)*IPR_{02}	No	Yes	No
Year FE*$HighIP_j$	No	No	Yes
Industry FE(4-digit)*Year Trend	Yes	Yes	Yes

Notes: Columns (1) – (3) use share of managerial workers compensation in total labour compensation of a plant as the dependent variable from the Annual Survey of Industries (ASI) data for the years 1999-2006. IPR_{02} is a dummy variable, which takes a value 1 if year $\geq$ 2002. $HighIP_j$ is a dummy variable which takes a value 1 if an industry is classified into 'High-IP' group. We use this classification from Delgado et al. (2013). Plant Controls include size (assets) and capital employed. Both Capital Employed and Assets at used at $t-1$ period and are expressed in their natural logarithmic form. Numbers in the parenthesis are robust clustered standard errors at the plant level. Intercepts are not reported. *,**,*** denotes 10%, 5%, and 1% level of significance.

C Proofs from the Theoretical Model

In this section, we shall present the proofs to the propositions 1 and 2 presented in the main text.

C.1 Proof of Proposition 1

We shall denote the set of all firms by N and a generic subset of firms by $S \subset N$.

The profit function of firm j is

$$\pi_j(m_1, m_2, ...m_n) = \frac{m_j k_j^\alpha}{\sum_{i=1}^n m_i k_i^\alpha} v - m_j w - f(L^*(k_j))$$

In Nash equilibrium, each firm j chooses $m_j \geq 0$ to maximize π_j given the other firms' choices.

We have

$$\frac{\partial \pi_j}{\partial m_j} = \frac{k_j^\alpha}{\left(\sum_{i=1}^n m_i k_i^\alpha\right)^2} \left[\sum_{i=1}^n m_i k_i^\alpha - m_j k_j^\alpha\right] v - w \tag{5}$$

Notice that m_j appears only in the denominator of the expression for $\frac{\partial \pi_j}{\partial m_j}$, and thus $\frac{\partial \pi_j}{\partial m_j}$ is weakly decreasing in m_j. This implies that the Nash equilibrium is given by the first order conditions

$$\frac{\partial \pi_j}{\partial m_j} \leq 0 \text{ and } m_j \frac{\partial \pi_j}{\partial m_j} = 0 \text{ for all } j.$$

Let the set of *active firms* in equilibrium be $A \subset N$. Clearly, for $j \in A$, $m_j^* > 0$ and $\frac{\partial \pi_j}{\partial m_j} = 0$.

Therefore, for the subset $A \subset N$, we can write(5) as

$$\frac{\partial \pi_j}{\partial m_j} = \frac{k_j^\alpha \left[\sum_{i \in A, i \neq j} m_i k_i^\alpha\right]}{\left(\sum_{i \in A} m_i k_i^\alpha\right)^2} v - w = 0 \tag{6}$$

Denoting $\sum_{i \in A}^n m_i k_i^\alpha = x$, we can write

$$x - m_j k_j^\alpha = \left(\frac{w}{v}\right) \frac{x^2}{k_j^\alpha} \tag{7}$$

Adding over all $j \in A$ in (7) we get

$$nx - x = \left(\frac{w}{v}\right) x^2 \left[\sum_{i \in A} \frac{1}{k_i^\alpha}\right] \Rightarrow x = \frac{n-1}{\sum_{i \in A} \frac{1}{k_i^\alpha}} \left(\frac{v}{w}\right) \tag{8}$$

With a little algebra, we can solve for this unconstrained game. In equilibrium, for $j \in A$

$$m_j^A = \left(\frac{v}{w}\right) \left(\frac{n-1}{k_j^\alpha \left(\sum_{i \in A} \frac{1}{k_i^\alpha}\right)}\right) \left(1 - \frac{n-1}{k_j^\alpha \left(\sum_{i \in A} \frac{1}{k_i^\alpha}\right)}\right)$$

Denoting $c_j = \frac{1}{k_j^\alpha}$ as an inverse measure of a firm's capital stock, we have the unique Nash equilibrium of the unconstrained game in terms a normalized value of c_j :

$$m_j^A = \left(\frac{v}{w}\right)\left(\frac{c_j}{\frac{1}{n-1}\sum_{i\in A} c_i}\right)\left(1 - \frac{c_j}{\frac{1}{n-1}\sum_{i\in A} c_i}\right) \tag{9}$$

Expression (9) denotes the equilibrium choice of active firms. However, this expression treats the set of active firms as arbitrary. We now identify the set of active firms in the original game. The following result says that firms with large enough capital stock are the active ones.

Lemma 1 *For $j \geq 2$, if firm j is active in equilibrium, then firm $j-1$ must be active too.*

Proof. Assume that for some $j \geq 2$, $j \in A$, but $j-1 \notin A$. According to (6), we must have for firm j

$$\frac{\partial \pi_j}{\partial m_j} = \frac{k_j^\alpha \left[\sum_{i\in A, i\neq j} m_i k_i^\alpha\right]}{\left(\sum_{i\in A} m_i k_i^\alpha\right)^2} v - w = 0$$

and for firm $j-1$, $\frac{\partial \pi_{j-1}}{\partial m_{j-1}} \leq 0$. For firm $j-1$, $\frac{\partial \pi_{j-1}}{\partial m_{j-1}}$ is given by (5), but since $m_i = 0$ for $i \notin A$, it boils down to

$$\begin{aligned}\frac{\partial \pi_{j-1}}{\partial m_{j-1}} &= \frac{k_{j-1}^\alpha \left[\sum_{i\in A} m_i k_i^\alpha\right]}{\left(\sum_{i\in A} m_i k_i^\alpha\right)^2} v - w > \frac{k_j^\alpha \left[\sum_{i\in A} m_i k_i^\alpha\right]}{\left(\sum_{i\in A} m_i k_i^\alpha\right)^2} v - w \\ &> \frac{k_j^\alpha \left[\sum_{i\in A, i\neq j} m_i k_i^\alpha\right]}{\left(\sum_{i\in A} m_i k_i^\alpha\right)^2} v - w = \frac{\partial \pi_j}{\partial m_j} = 0,\end{aligned}$$

which is a contradiction. ■

By the above Lemma, there must be some cut-off T such $A = \{\ j : j \leq T\}$. All that remains to be done is to identify T. In order to do so, denote the index d_j^t as

$$d_j^t \equiv \frac{c_j}{\frac{1}{t-1}\sum_{i=1}^t c_i},\ j = 1, 2, ...t$$

for $t = 2, 3, ...n$. Then, if the set of active firms in equilibrium is $\{1, 2, ...t\}$, the firm $j \leq t$ has a managerial demand $m_j^* = \frac{v}{w} d_j^t (1 - d_j^t)$. Clearly, this requires t to be such that $d_j^t < 1$ for all $j \leq t$. Since c_j is increasing in j, we must have $d_{j-1}^t < d_j^t$ for all $j \leq t$. Thus, in order to check that $d_j^t < 1$ for all $j \leq t$, we need to only check if $d_t^t < 1$. The following Lemma shows that there is a threshold T such that $d_t^t < 1$ for all $t < T$ and $d_t^t > 1$ for $t \geq T$.

Lemma 2 *If $d_t^t \geq 1$ for some $t < n$, then $d_{t+1}^{t+1} > 1$.*

Proof. Define, for $t = 2, 3...n$,

$$K_t = \frac{1}{t-1}\sum_{i=1}^t c_i - c_t$$

We can write

$$\begin{aligned}K_{t+1} &= \frac{1}{t}\sum_{i=1}^{t+1} c_i - c_{t+1} = \frac{t-1}{t}\left[\frac{1}{t-1}\sum_{i=1}^t c_i - c_{t+1}\right] \\ &= \frac{t-1}{t}\left[K_t + (c_t - c_{t+1})\right]\end{aligned}$$

Since $c_t < c_{t+1}$, $K_{t+1} < 0$ if $K_t \leq 0$. ■

We know that $K_2 = c_1 > 0$, guaranteeing existence of t for which $K_t > 0$. Define $T = \max\{t : K_t > 0\}$. The next Lemma describes the unique equilibrium of the game.

Lemma 3 *Define $T = \max\{t : K_t > 0\}$. In the unique Nash equilibrium of the game, the set of active firms is $A = \{1, 2, ...T\}$. The equilibrium demand for managers $m_j^* = m_j^A = \frac{v}{w} d_j^T (1 - d_j^T)$ for $j \in A$ and $m_j^* = 0$ for $j \notin A$.*

Proof. First, note that $c_j \leq c_T < \frac{1}{T-1} \sum_{i=1}^{T} c_i$ since $K_T > 0$. Therefore, $m_j^* = m_j^A > 0$ for all $j \leq T$. Now consider the action profile $m_j^* = \frac{v}{w} d_j^T (1 - d_j^T) > 0$ for all $j \leq T$ and $m_j^* = 0$ for $j > T$. We first show that this is a Nash equilibrium and then establish uniqueness.

By Since $m_j^* = m_j^A$ for $j \in A$, , the active firms are best responding in the original game. Next, we verify that at the candidate action profile, $m_j^* = 0$ is the best response for $j > T$. We show that at the candidate profile, $\frac{\partial \pi_j}{\partial m_j} \leq 0$ for $j > T$.

$$\frac{\partial \pi_j}{\partial m_j} = \frac{k_j^\alpha}{\left(\sum_{i=1}^{T} m_i k_i^\alpha\right)^2} \left[\sum_{i=1}^{T} m_i k_i^\alpha\right] v - w = \frac{k_j^\alpha}{\sum_{i=1}^{T} m_i k_i^\alpha} v - w$$

From (8) we can plug in $x = \frac{T-1}{\sum_{i=1}^{T} \frac{1}{k_i^\alpha}} \left(\frac{v}{w}\right)$, which gives us after some algebra

$$\frac{\partial \pi_j}{\partial m_j} \leq 0 \text{ iff } \frac{1}{T-1} \sum_{i=1}^{T} c_i \leq c_j$$

For $j > T$,

$$\frac{1}{T-1} \sum_{i=1}^{T} c_i - c_j \leq \frac{1}{T-1} \sum_{i=1}^{T} c_i - c_{T+1} = \frac{T}{T-1} K_{T+1} \leq 0,$$

which implies that $\frac{\partial \pi_j}{\partial m_j} \leq 0$ for $j = T+1$ and $\frac{\partial \pi_j}{\partial m_j} < 0$ for $j > T+1$. This establishes that the action profile in the proposition is indeed an equilibrium.

It remains to verify uniqueness. By Lemma 1, it is enough to show that there is no $T' \neq T$ such that the set of active firms in equilibrium is $S = \{1, 2, ...T'\}$. Suppose first that $T' < T$. If $T' = 1$, firm 1 has no optimal action. Assume $T' > 1$ and consider the firm $T' + 1$. At the candidate profile, we have

$$\frac{\partial \pi_{T'+1}}{\partial m_{T'+1}} = \frac{k_{T'+1}^\alpha}{\sum_{i=1}^{T'} m_i k_i^\alpha} v - w$$

Assume first that $T' > 1$. Now, From (8), plugging in $\sum_{i=1}^{T'} m_i k_i^\alpha$, we have $\frac{\partial \pi_{T'+1}}{\partial m_{T'+1}}$ has the same sign as $\frac{1}{T'-1} \sum_{i=1}^{T'} c_i - c_{T'+1} = \frac{T'}{T'-1} K_{T'+1} > 0$ since $T' < T$. Therefore, $\frac{\partial \pi_{T'+1}}{\partial m_{T'+1}} > 0$, which implies that firm $T' + 1$ has a profitable deviation to a positive action. Next, suppose that $T' > T$. Now,

$$m_{T'}^* = \left(\frac{v}{w}\right) \left(\frac{c_j}{\frac{1}{T'-1} \sum_{i=1}^{T'} c_i}\right) \left(1 - \frac{c_j}{\frac{1}{T'-1} \sum_{i=1}^{T'} c_i}\right) \leq 0$$

since $K_{T'} \leq 0$, which is a direct contradiction. ■

C.2 Proof of Proposition 2

Let

$$C(k_j) = \frac{wm_j^*}{wm_j^* + zAk_j^\beta} \text{ and and } S(k_j) = \frac{wm_j^*}{zAk_j^\beta}$$

We have

$$S(k_j) = \frac{wm_j^*}{zAk_j^\beta} = \begin{cases} 0 & \text{for } j > T \\ v\frac{d_j^T(1-d_j^T)}{zAk_j^\beta} & \text{for } j \leq T \end{cases}$$

Therefore

$$\frac{dS(k_j)}{dv} = \begin{cases} 0 & \text{for } j > T \\ \frac{d_j^T(1-d_j^T)}{zAk_j^\beta} > 0 & \text{for } j \leq T \end{cases}$$

Lemma 4 $\frac{dS(k_j)}{dv}$ *is single-peaked in* j *for* $j \leq T$.

Proof. Denote $d = \frac{1}{T-1}\sum_i^T \frac{1}{k_i^\alpha}$.Notice that d can be taken to be constant as the identities of the firms are fixed. Then $d_j^T = \frac{1}{dk_j^\alpha}$. For $j \leq T$, $\frac{dS(k_j)}{dv}$ can be written as

$$\frac{1}{zAk_j^\beta}\left[\frac{1}{dk_j^\alpha}\left(1 - \frac{1}{dk_j^\alpha}\right)\right], \text{ where } d = \frac{1}{T-1}\sum_i^T \frac{1}{k_i^\alpha}$$

Therefore, $\frac{dS(k_j)}{dv} = f(k_j)$, where

$$f(k) = \frac{1}{zAd}\left[\frac{1}{k^{\alpha+\beta}} - \frac{1}{dk^{2\alpha+\beta}}\right]$$

Now, if we show that $f(k)$ is hump-shaped in k, we are done. Ignoring the constant term $\frac{1}{zAd}$,

$$\begin{aligned} f'(k) &= -(\alpha+\beta)k^{-(\alpha+\beta+1)} + (2\alpha+\beta)dk^{-(2\alpha+\beta+1)} \\ &= -k^{-(\alpha+\beta+1)}\left[(\alpha+\beta) - (2\alpha+\beta)\frac{1}{dk^\alpha}\right], \end{aligned}$$

which has a unique solution

$$\frac{1}{dk^\alpha} = \frac{\alpha+\beta}{2\alpha+\beta}$$

Finally, we note that at the optimum

$$\begin{aligned} f''(k) &= (\alpha+\beta)(\alpha+\beta+1)k^{-(\alpha+\beta+2)} - (2\alpha+\beta)(2\alpha+\beta+1)dk^{-(2\alpha+\beta+2)} \\ &= k^{-(\alpha+\beta+2)}(\alpha+\beta)(-\alpha) < 0 \end{aligned}$$

Therefore, $S(k_j)$ is single-peaked in j, with the maximum value occurring for the firm with j closest to $k^* = \frac{\alpha+\beta}{2\alpha+\beta}$. ■

Now we show that $C(k_j)$ has the same properties as long as $S(k_j) < 1$ for all j. Notice that

$$\begin{aligned} C(k_j) &= \frac{wm_j^*}{wm_j^* + zAk_j^\beta} = \frac{S(k_j)}{1+S(k_j)} \\ \Rightarrow \frac{dC(k_j)}{dv} &= \frac{1}{(1+S(k_j))^2}\frac{dS(k_j)}{dv} \end{aligned} \tag{10}$$

By (10), we have $\frac{dC(k_j)}{dv} = 0$ for $j > T$.
For $j \leq T$, $S(k_j) = vf(k_j)$. Therefore,

$$\frac{dC(k_j)}{dv} = \frac{f(k_j)}{(1 + vf(k_j))^2} \text{ for } j \leq T$$

Denoting $\frac{f(k)}{(1+vf(k))^2}$ by $g(k)$, we have

$$\begin{aligned} g'(k) &= \frac{1}{(1 + vf(k))^4} \left[(1 + vf(k))^2 f'(k) - 2f(k)(1 + vf(k)) vf'(k) \right] \\ &= \frac{f'(k)}{(1 + vf(k))^3} [1 - vf(k)] = \frac{f'(k)}{(1 + vf(k))^3} [1 - S(k)] \end{aligned}$$

Therefore, if $S(k) < 1$ for all k, $g'(k)$ has the same sign as $f'(k)$ for all k. By Lemma 4, $\frac{dC(k_j)}{dv}$ is also hump-shaped in j, and the maximum value occurs for the firm with j closest to $k^* = \frac{\alpha+\beta}{2\alpha+\beta}$.