ISSN No. 2454 – 1427

CDE
October 2013

INNOVATION, PRODUCTIVITY AND IPRs

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Working Paper No. 230

http://www.cdedse.org/pdf/work230.pdf

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Abstract

We study the innovation, efficiency and productivity response to intellectual property (IP) reform vis-à-vis manufacturing industry in India. Studying the response of IP-sensitive industries relative to a control group of IP-insensitive industries, and using the fact that the IP reform was largely exogenously driven, we correct for confounding factors and endogeneity bias. We find a significant outward shift in the innovation frontier and consequent increase in productivity post-reform. This aggregate effect is driven by improvements in the non-electrical machinery industries, and to a lesser extent the drugs and pharmaceuticals sector. The comprehensive reforms notified 2003 provided the stimulus, rather than the token 1999 reform.

JEL codes: O34, O33, O31, O11
Keywords: Innovation, Efficiency, Productivity, IPRs

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1. Introduction

The BRICS[1] have attracted a lot of attention for an outstanding and sustained growth performance in the course of the last two decades.These economies have been amongst the fastest growing in the world barring Russia (performing commendably even during the recent ‘great recession’), they are the largest economies outside the Organisation for Economic Co-operation and Development with annual GDPs exceeding $1 trillion, they have become increasingly intertwined with the rest of the world with China in fact assuming the mantle of the world’s largest exporter, and they rank amongst the top ten holders of foreign exchange reserves which provides them the potential to become net creditor nations, with China actually outstripping Japan as the largest creditor nation (The Economist 2010). It is perhaps no coincidence, furthermore, that this period has also witnessed stronger protection of intellectual property rights in the wake of the Trade-Related Intellectual Property Rights (TRIPs) agreement of 1994, albeit only Brazil, India and South Africa were party to the original negotiations.

From an economist’s perspective a significant question that springs to mind is whether this spectacular performance has been accompanied by greater innovation, efficiency and productivity. Thus, a special report in the same issue of The Economist cited above, argues that firms in these emerging nations are now “hotbeds of business innovation”, welling with new commodities significantly cheaper than the competition, such as “$3,000 cars, $300 computers and $30 mobile phones”. These nations, the report suggests, are re-creating the production, distribution and business paradigms, thereby re-writing various aspects of modern business practice. This paper studies the innovation, production efficiency and productivity response to the stronger protection of intellectual property, with specific reference to manufacturing industry in the BRICS economy of India.

The received literature appears to strongly suggest that innovation, efficiency and productivity may have picked up in the post-TRIPs period, insofar as it is consistent with the prediction of a greater inflow of technology and superior inputs in response to stronger intellectual property rights. Of course, given the complexity of this phenomenon, the underlying factors at work can be quite diverse. Thus, stronger protection, by ensuring larger profits, may spur domestic innovation (Chen and Puttitanum 2005); stronger property rights, by reducing the risk of imitation by the licensee, may induce greater technology licensing (Yang and Maskus 2001, Smith 2001, Park and Lippoldt 2005, Branstetter et al. 2006); stronger protection, by reducing the risk of reverse engineering, may likely raise exports/high-tech exports from the North to the South (Ferrantino 1993, Maskus and Penubarti 1995, Smith 2001, Ivus 2010); stronger protection may encourage foreign direct investment and overseas R&D (Ferrantino 1993, Lee and Mansfield 1996, Javorcik 2004), as well as spillovers (Branstetter et al. 2006); and stronger property rights may result in an "overall enhancement" of Southern industrial development (Branstetter et al. 2011). At the same time, these positive effects of stronger protection cannot, unfortunately, be taken for granted. Thus, several studies find stronger property rights to have no significant bearing on domestic innovation (Sakakibara and Branstetter 2001, Lerner 2002, Qian 2007), or technology licensing (Ferrantino 1993, Fosfuri 2002), or indeed overseas R&D by multinationals (Kanwar 2012).

While it would no doubt be useful to study which of these channels underlie the effect of stronger property rights on innovation, efficiency and productivity in the Indian context, that objective is currently thwarted by the lack of appropriate data. Instead, as a first step in that direction, we focus on the direct overall relationship between the post-TRIPs intellectual property reform on the one hand, and innovation, efficiency and productivity changes on the other, something that none of the studies cited above do.

This paper is, to our knowledge, the first attempt at gauging whether stronger intellectual property rights post-TRIPs significantly raised the levels of technology, production efficiency, and productivity in the manufacturing sector of the BRICS economy of India. Did the strengthening of IPRs raise the technical frontier, and/or did it raise production efficiency, thereby raising overall productivity? Often relationships that hold 'on the average' for a specific sample of countries, as in the many empirical studies cited above, may not hold for individual countries to quite that extent. In fact, India is not even part of the samples used in some of the studies cited above. Therefore, focusing on the Indian case would help corroborate the 'average impression' that one carries about the relationships in question, or indeed provide fresh evidence to alter the existing average paradigm. Second, the availability of a data set pertaining to a large number of firms spread across a fairly large set of manufacturing industries allows us to study the response of IP-sensitive industries relative to a control group of IP-insensitive industries, thereby controlling for factors that may otherwise confound our study of the influence of IP reform. Third, using the fact that the post-TRIPs strengthening of intellectual property rights in developing countries was largely exogenous, we are able to correct for the possibility of endogeneity bias in studying the questions we raise. Comparing the post-intellectual property reform scenario with the pre-intellectual property reform scenario (for the IP-sensitive industries relative to the IP-insensitive industries) enables us to do that convincingly. Using a large underlying data set for Indian firms in the manufacturing sector spanning the period 1994-2011, we find that intellectual property reform is associated with a 'substantial' statistically significant increase in innovation, and a significant though small increase in total factor productivity. For firms in the group of IP-sensitive industries as a whole relative to firms in the IP-insensitive industries, the technical frontier shifted outward by about 2.8% per annum, and the level of total factor productivity rose by about 0.3% per annum, post-IP-reform. At the dis-aggregated level, these positive shifts appeared to be driven primarily by developments in the non-electrical machinery sector, and to a lesser extent drugs and pharmaceuticals. Furthermore, it seems to have been the IP reform of 2003 that evoked this positive response from manufacturing industry, rather than the earlier 'token' reform episode of 1999.

Section 2 sketches out the identification strategy underlying our estimation. It also develops the estimation model, and to that end spells out the intellectual property reforms in the Indian context, and explains the concepts of the innovation or technical frontier, production efficiency and total factor productivity employed in this paper. Section 3 discusses the data sources, and details the computation of the innovation frontier, production efficiency, and total factor productivity indices for our sample of Indian manufacturing firms. It then uses these indices to compute the technical frontier, efficiency and productivity variables for firms in the IP-sensitive industries relative to firms in the IP-insensitive industries in our sample. Section 4 presents and analyses the aggregate estimation results, section 5 presents the dis-aggregated results for each of the IP-sensitive industries (relative to the IP-insensitive industries as a whole), section 6 traces out the effect of varying the threshold year for defining the IP reforms variable in the Indian context, and section 7 briefly concludes.

2. Identification Strategy

The identification strategy comprises two important elements. In the first place, we exploit the timing of the intellectual property reform to gauge its effect on firm innovation, efficiency and productivity in the Indian manufacturing sector. Evidence shows that the intellectual property reforms undertaken by the less developed countries post-TRIPs were largely externally driven, and not the consequence of the levels of innovation and production efficiency in these countries, or expectations thereof. The influence of IP reform, however, could be confounded by the presence of other macroeconomic shocks to the economy. The persistence of such shocks could, then, be mistaken for the effect of IP reform. To control for this possibility we study the innovation, efficiency and productivity response of firms that belong to industries that are strongly sensitive to intellectual property considerations relative to the response of firms that are supposedly not IP-sensitive. The latter group, in other words, would serve as the control group. We now discuss these and other related issues in developing the estimation model.

2.1 *The Exogeneity of Intellectual Property Reform*

Developing countries, it appears, were forced to strengthen their protection of intellectual property as per the TRIPs agreement of 1994, which they signed under pressure from developed nations. Thus, in his study of international standard-setting, Drahos (2002) points to the "continued use of webs of coercion by the US and EU, both of which … united on the need for strong global standards of intellectual property protection". The developing countries offered stiff resistance to the proposed changes, partially attested by the fact that these negotiations dragged on for almost eight years due to apprehensions about diminished access to patented products and technology. Certain developed countries used strong economic and diplomatic pressures to counter this intransigence of the developing countries (Deere 2009; Drahos 2002; Watal 2001). Thus, the United States used Section 301 of its Trade Act and the Generalized System of Preferences programme to deny trade benefits to non-complying countries, and 'Special 301' to place on the 'Watch List' or 'Priority Watch List' for punitive action those countries that resisted its intellectual property stance. The European Union also enacted similar laws – for example, Regulation 264/84 – but lacked the necessary consensus to use them equally effectively. One may justifiably argue, therefore, that the TRIPs agreement and the post-TRIPs intellectual property reforms in developing countries were externally driven.

Though it is commonly accepted that developing countries strongly opposed the TRIPs agreement, their implementation according to some appears to indicate otherwise.[2] Several less developed countries adopted stronger protection standards earlier than they needed to, and without fully availing of the flexibilities (Thorpe 2002; Deere 2008) which, ostensibly, contradicts their earlier adamant position and raises the possible agency of factors in addition to external pressure. However, Deere (2008) clarifies that this was often the result of delegating decision-making to regional groups or autonomous intellectual property offices, due to deficient expertise and capacity to handle such issues in individual countries, and a consequence of this 'outsourcing' was that local considerations were overlooked. Further, as Spennemann (2007) elucidates, it was the relatively advanced less developed countries such as India, Brazil, etc. that provided resistance during the TRIPs negotiations, and also the ones that subsequently delayed implementation and made substantial use of the flexibilities available; in other words, there really isn't a gap between what these countries professed and what they practiced. Therefore, although the strengthening of protection may have been motivated not just by external pressures but by domestic capacity as well, it is plausible that it was not a consequence of considerations of innovation and production efficiency, allowing us to treat the intellectual property reforms variable as exogenous from the perspective of this study.

2.1.1 *Intellectual Property Reforms in India*

The process of reforming the intellectual property laws in India witnessed three major milestones – the Patents (Amendment) Acts of 1999, 2002, and 2005. The Patents (Amendment) Act 1999, deemed effective retrospectively from January 1, 1995, introduced a 'mailbox facility' for product patent applications pertaining to drugs, pharmaceuticals and chemicals, which would be considered for the grant of product patents only after December 31, 2004. For the interim, it allowed the grant of exclusive marketing rights for (selling or distributing) drugs and pharmaceuticals and chemical products, for those 'mailbox' applications that satisfied certain conditions. The exclusive marketing rights would be valid for 5 years, or till the patent was granted or rejected, whichever was earlier. The Patents (Amendment) Act

2002, effective May 2003, proposed numerous changes to render the Indian patents law TRIPs compliant, while also harmonising patent granting procedures with international practice. Finally, the Patents (Amendment) Act 2005 introduced product patents in drugs, pharmaceuticals and chemicals, and also provided for post-grant opposition to patents.[3]

On this basis, one would be justified in treating 2004 (or even 2003) as a 'breakpoint' in intellectual property reform in India. The 1999 Act was rather limited in its ambit, and merely provided for exclusive marketing rights in the area of drugs, pharmaceuticals and chemicals, leaving other sectors of the economy unaddressed. Further, they were merely an interim provision, valid till the applications could be considered for grant of product patents from 2005 onwards. Therefore, the large number of applications filed in the 'mailbox' facility during this period (Maithani and Vyas 2009), amounted to just queuing up to be considered for product patents 2005 onwards. Stiffer competition for market share and profits given the exclusive marketing rights to foreign patentees could have arguably provided some impetus to innovation and production efficiency, had the number of products qualifying for this benefit been large, but that was not in fact the case.[4] It was the subsequent intellectual property reforms enshrined in the 2002 Act, notified in 2003 as outlined above, that served to substantively strengthen the property rights regime economy-wide, Accordingly, to begin with, we capture the watershed nature of these intellectual property reforms with dummy $IPD04$ that equals 1 for the period 2004 and after, and 0 for the period before 2004.

2.2 *Representing the Technical Frontier, Production Efficiency and Total Factor Productivity*

While exploring the evidence for any spurt in innovation, efficiency and productivity following the intellectual property reforms discussed above, we prefer to not define innovation narrowly in terms of patents or even research and development (R&D) expenditure, but rather attempt to capture it in terms of the technical change and efficiency change components of a firm's productivity growth over time. This is preferable not only because few Indian firms take out patents, and R&D data are patchy, but also because it allows for the possibility that these firms may nevertheless be conducting some innovations howsoever small. Even though the innovations in question (interpreted broadly to include business-processes as well) may not necessarily have been different enough from the state of the art to merit patents, they may nevertheless have contributed to raising firm productivity and production. For this purpose, we start off by considering the total, or more correctly, multi-factor productivity of a firm, and then decompose it into the components of interest.

We measure total factor productivity using the Färe-Primont productivity index (O'Donnell 2014, 2011), for it circumvents many of the difficulties with alternative measures such as the Solow residual and Divisia-Tornquist indices;[5] and, given its transitivity property, it is appropriate for inter-period and inter-firm comparisons. Following O'Donnell, for each industry j, total factor productivity of firm i in period t (TFP_{ijt}) is defined as the ratio of its 'aggregate output' (Y_{ijt}) to its 'aggregate input' (X_{ijt}), such that Y_{ijt} is a function of the output vector y_{ijt}, and X_{ijt} is a function of the input vector x_{ijt}. Using the shadow prices corresponding to the industry mean output vector ($\overline{y_j}$), the industry mean input vector ($\overline{x_j}$) and the final period (T) technology as weights, the firm output and input vectors are aggregated to derive the index of total factor productivity.as

$$TFP_{ijt} = D_O^T(\overline{x_j}, y_{ijt})/D_I^T(x_{ijt}, \overline{y_j}) \qquad (1)$$

where D_O^T is the Shepard (1953) output distance function for the last period technology, and D_I^T is the input distance function for the last period technology. Further, in any period t, the firm need not be producing on the industry production possibility frontier or industry technical frontier, so that its overall production efficiency may be defined as $PE_{ijt} = TFP_{ijt}/TF_{jt}$, where TF_{jt} is the industry j technical frontier in period t, or the maximum possible total factor productivity achievable with the best-practice technology available to firms in industry j in period t. This allows us to decompose the total factor productivity index as

$$TFP_{ijt} = (TF_{jt})(PE_{ijt}) \qquad (2)$$

The distance functions underlying these indices are computed using data envelopment analysis or linear programming, which constructs a piecewise linear surface or frontier over the industry input-output data; and production efficiency is measured relative to this industry frontier.[6] For the various linear programmes and the software used in estimating these indices, see O'Donnell (2011).[7] Being nonstochastic in nature this approach suffers from the drawback, however, that it clubs all random shocks with production inefficiency. On the flip side, it is superior to the alternatives available in a number of respects, as noted above. Accordingly, in the empirical analysis to follow, we use the Färe-Primont indices TF_{jt}, PE_{ijt} and TFP_{ijt} to construct the dependent variables of interest.

2.3 *The Estimation Relationship*

In examining whether the technical frontier, production efficiency, and total factor productivity underwent a significant shift in the post-IP reforms period although the exogeneity of the change in the IP variable (IPD) helps, the influence of the treatment variable $IPD04$ could nevertheless be confounded by other macroeconomic shocks. If the macroeconomic shocks impinging on the dependent variables in the pre-reform period persist in the post-reform period, and the potency of the latter is relatively stronger, that would make it seem *as if* the IP reform is behind the response of the dependent variables. To control for this possibility we separate the firms belonging to industries that are strongly sensitive to intellectual property considerations from those that are supposedly not sensitive, using the patent effectiveness rankings provided by Cohen et al. (2000). We then define all variables as differences of the IP-sensitive from the IP-insensitive, for each period t. For instance, our dependent variable representing the technical frontier TF_t^{s-n} is derived as $TF_t^s - TF_t^n$, where TF_t^s is the average TF_{jt} over all IP-sensitive industries $j = s$ for each period t, and TF_t^n is the average TF_{jt} over all IP-insensitive industries $j = n$ for each period t. The other variables of interest can be similarly derived. Evidently, the IP-insensitive group serves as the control group. Thus, any macroeconomic shocks from the pre- IP-reform period that may have persisted after the IP-reform would have affected both groups of industries, for there is no persuasive reason to believe otherwise. Therefore, the response of the dependent variables defined as above, to the treatment variable $IPD04$, may be presumed to be the response of the IP-sensitive firms per se.

It is possible, however, that this response may be biased due to the presence of trend increases in the variables in question, in particular in one or more of the dependent variables. For instance, studies have reported a significant increase in total factor productivity in India post-1991, when widespread economic reforms were initiated (see, for example, Topalova and Khandelwal 2011, and other studies cited therein). It might be these trends that are driving our results. We propose to allow for this possibility by including a trend term in our set of regressors. The estimating relationships may then be expressed as

$$TF_t^{s-n} = \beta_{11}\, IPD04_t + \beta_{12}\, T_t + \beta_{13} X_t^{s-n} + \varepsilon_{1t} \tag{3a}$$

$$PE_t^{s-n} = \beta_{21}\, IPD04_t + \beta_{22}\, T_t + \beta_{23}\, X_t^{s-n} + \varepsilon_{2t} \tag{3b}$$

$$TFP_t^{s-n} = \beta_{31}\, IPD04_t + \beta_{32}\, T_t + \beta_{33}\, X_t^{s-n} + \varepsilon_{3t} \tag{3c}$$

where TF_t^{s-n} is the technical frontier variable, PE_t^{s-n} is the production efficiency variable, TFP_t^{s-n} is the total factor productivity variable, $IPD04_t$ is the intellectual property reform dummy (which equals 1 for the years 2004 and after, and equals 0 for the earlier period), T_t is the trend variable, X_t^{s-n}represents control factors (such as firm size, concentration ratio, and ownership type), and ε_{*t} are the stochastic error terms. We estimate these relationships as a seemingly unrelated regression system.

3. Constructing the Sample Dataset

3.1 *The Sample*

To prepare the data set, we begin by extracting firm-level data from the 'Prowess' database, sold by the Centre for Monitoring Indian Economy (CMIE 2012). This database pertains to firms listed on the Bombay Stock Exchange and the National Stock Exchange, as well as 'major' unlisted firms. Using the patent effectiveness rankings provided by Cohen et al. (2000), we take the firms in the chemicals, drugs and pharmaceuticals, electronics and non-electrical machinery industries to be relatively IP-sensitive, and those in the cement, electrical machinery, plastic products and rubber products industries to be IP-insensitive. Data for firms in these eight industries were then selected. All firms for which data were missing for variables necessary for the estimation of the technical frontier, production efficiency and total factor productivity – namely, sales, raw materials, net fixed assets, and salaries – were dropped.[8] This left us with data on 349 firms spanning the period 1994-2011. We also ensured that data on the control variables used (see section 3.3 below) were also available for this set of firms and years.

The eight IP-sensitive and IP-insensitive industry groups, mostly at the 2-digit and a few at the 3-digit level of the National Industrial Classification (NIC), in turn comprised 69 industries at the finer 5-digit level of the NIC, too numerous to be named individually. On account of the small number of firms in industries defined at the 5-digit (or even 4-digit) levels of the NIC codes, however, the computations in the following section were conducted for firms clustered into the eight IP-sensitive and IP-insensitive industry groups at the 2-digit and 3-digit levels mentioned above.

3.2 *Estimating the Technical Frontier, Production Efficiency and Total Factor Productivity Indices*

The technical frontier, production efficiency and total factor productivity indices were computed using data on sales, raw materials, net fixed assets and salaries,[9] deflated by the appropriate industry-specific wholesale price indices (1993-94 = 100) brought out by the Ministry of Commerce and Industry. Specifically, while sales and salaries figures were deflated by the industry-specific wholesale price index (WPI),[10] the value of net fixed assets was deflated by the WPI for plant and machinery, and raw materials expenditure was deflated by a weighted WPI computed for the purpose as follows. For each industry group, we first identified the inputs and input proportions using input-output transactions tables, where the input-output table 1993-94 was used for the 1990s and the input-output table 2007-08 was used for the 2000s (CSO, various years). Applying these input proportions to the corresponding product's WPI, we computed the weighted WPI relevant for deflating the raw materials used by each industry, for each year of the sample.

Although firm-specific deflators might have been ideal (de Loecker 2009), these are not available. While this raises the possibility of contamination due to changes in the price-cost margin over time (Katayama, Lu and Tybout 2009), this fear may be unfounded in the Indian context where Krishna and Mitra (1998) provide evidence of productivity growth along with a decline in the price-cost margin owing to increasing competition. Moreover, as long as price-cost margins are associated with innate productivity, changes in the latter would be informative (Bernard et al. 2003, Topalova and Khandelwal 2011).

3.3 *The Control Variables*

The control variables considered are firm size, concentration ratio, and ownership type. Firm size is captured by (deflated) firm sales ($SALES$). The concentration ratio ($CRATIO$) is computed as the sales of the four largest firms divided by total industry sales for a specific year. Ownership type is captured by the dummy $PRIVATE$, which equals 1 for private (group) firms and equals 0 otherwise.[11]

Summary statistics for the variables in question are presented in Table 1, for 1994-2003, 2004-2011, and the full period 1994-2011. We find that the technical frontier index TF_t^s increased from an average of 0.122 in the pre-reform period to 0.154 in the post-reform period, implying an annual growth rate of 2.9%. Although all firms could not keep pace with this shift, resulting in their operating below the new frontier on average (as evidenced by the decline in the production efficiency index), nevertheless the total factor productivity index TFP_t^s rose from 0.038 to 0.043 between the two periods, implying an annual growth rate of about 1.5%. We now proceed to investigate whether and to what extent changes in the level of the technical frontier, production efficiency and productivity were related to the intellectual property reforms conducted during our sample period, while taking cognisance of various control factors and other relevant considerations.

4. The Effects of Intellectual Property Reforms: Empirical Results

The empirical results are reported in Table 2. Note that the regressions of columns (1a)–(1c) have been estimated together as a seemingly unrelated regression (SUR) system, as per our discussion in section 2.3 above, and similarly for (2a)–(2c), (3a)–(3c), (4a)–(4c), and (5a)–(5c). The Breusch-Pagan test of independence of the equation errors is strongly rejected in all cases, the associated p-value being 0 or close to 0, indicating efficiency gains in estimating the SUR system.

4.1 *Technical Frontier*

We begin by evaluating the empirical results pertaining to the response of the technical frontier variable TF^{s-n}. These results, reported in columns (1a), (2a), (3a), (4a) and (5a), indicate that in each of the regressions the regressors are jointly strongly significant, with p-values of the associated F-test equal to 0. The column (1a) results reveal a strong positive effect of the intellectual property reform dummy $IPD04$, with a jump of about 0.03 in the TF^{s-n} index in the post-reform period as compared to the pre-reform period. If this treatment variable is truly exogenous and independent of the controls, then its coefficient should not vary much with the introduction of the control variables. The addition of the trend in column (2a), the sales variable in column (3a), the concentration ratio in column (4a), and the private group firm dummy in column (5a) leaves the above result much the same, and the coefficient of $IPD04$ remains around 0.031. Thus, the results unambiguously indicate an outward shift in the technical frontier, or in other words indicate innovation in Indian manufacturing industry in the post-reform period.

4.2 *Production Efficiency*

Turning to the response of the production efficiency variable PE^{s-n} to the intellectual property reform, once again the results presented in columns (1b), (2b), (3b), (4b) and (5b) reveal that in each of the regressions the regressors are jointly strongly significant in explaining the dependent variable, the *p*-values of the associated F-test being 0. Column (1b) reports a significant negative effect of the intellectual property reform dummy $IPD04$ on the level of production efficiency, with a decline of about 0.009 in the PE^{s-n} index in the post-reform period as compared to the pre-reform period. Successive addition of the control variables trend, sales, concentration ratio and private group firm dummy, in columns (2b) through (5b) respectively, does not alter this result qualitatively, with the coefficient settling down around –0.008. This result needs to be interpreted with reticence, however, for it may not imply an actual decline in firm efficiency per se. An outward shift in the best-practice technology is usually a situation where initially only some firm(s) are to be found on the new frontier, and the others catch-up over a period of time. It is not as if the latter have become less efficient given the technology available till then; it is just that the best practice technology has improved, and compared to this they get seen as having been left behind. More importantly, we must realise that operating below the frontier may be a matter of choice, determined by the cost-benefit calculus behind the adoption of innovations. More subtly, such a position may well indicate an *inability* to adjust (due to one or more constraining factors such as access to credit) rather than an unwillingness to do so. Furthermore, the twin phenomena of shifts in the technical frontier and a firm's position vis-à-vis the frontier, may be interdependent inter-temporally, insofar as the availability of better technology (implied by the shifting frontier) may facilitate the process of subsequent catch-up by firms operating below the frontier..

4.3 *Total Factor Productivity*

We now consider the response of total factor productivity to the intellectual property reform. The results in columns (1c), (2c), (3c), (4c) and (5c) show that in each of these regressions the regressors are jointly strongly significant in explaining the regressand, the p-values of the associated F-test being 0. Column (1c) reveals a significant positive effect of the intellectual property reform dummy $IPD04$ on the level of total factor productivity, with TFP^{s-n} increasing by about 0.003 in the post-reform period in comparison with the pre-reform period. Successive addition of the control variables trend, sales, concentration ratio and private group firm dummy, in columns (2c) through (5c) respectively, causes no qualitative change in this result, with the coefficient settling down around 0.001. Thus, we find that total factor productivity exhibited a statistically significant increase in the post-reform period in comparison with the pre-reform period, though the increase in productivity appears to have been small.

We conclude that the intellectual property reform enacted in 2002 and notified in 2003 appears to have induced a statistically significant outward shift in the technical frontier in the post-reform period, with the level of index TF^{s-n} increasing by about 0.031. Given that this response is a proxy for the response of the IP-sensitive industries, comparing it to the pre-reform technical frontier index of the IP-sensitive industries (0.122) yields a shift in the technical frontier by about 2.8% per annum post-reform. Second, the production efficiency index PE^{s-n} declined by 0.008 or about 1.2% per annum compared to the pre-reform index for the IP-sensitive industries (0.086). In view of our discussion in section 4.2, however, this decline does not necessarily imply a decline in firm efficiency per se, and is merely a statement of the fact that some firms are operating within the new frontier. Third, there appears to have been a small but significant increase in total factor productivity, with TFP^{s-n} having increased by about 0.001 or about 0.3% per annum post-reform, compared to the pre-reform index of the IP-sensitive industries (0.038).

5. The Effects of Intellectual Property Reforms: Disaggregating Results by Industry

We now redo the estimations reported in section 4 for each of the IP-sensitive industries separately, that is, for the firms in the chemicals, drugs and pharmaceuticals, electronics and non-electrical machinery industries. The technical frontier, production efficiency and total factor productivity regressions for all four industries are estimated together as a seemingly unrelated regression system, and the estimation results are reported in Table 3. Note that the table reports only the 'full' regression results in each case. The Breusch-Pagan test of independence of the equation errors is strongly rejected, the associated p-value being 0, indicating efficiency gains in estimating the SUR system. The Berndt system F-test strongly rejects the hypothesis of the joint insignificance of the regressors, having a p-value of 0.

The results presented in columns (1), (4), (7) and (10) reveal that the technical frontier index TF^{s-n} increased post-reform in the case of all four IP-sensitive industries, although this shift was statistically significant for only the non-electrical machinery and the drugs and pharmaceuticals industries; albeit only weakly so using a one-tail test, for the latter. The relatively much larger coefficient on $IPD04$ in the regression of column (10) shows, that the aggregate result that we reported in section 4 appears to have been driven primarily by happenings in the non-electrical machinery sector. The results presented in columns (2), (5), (8) and (11) show that the production efficiency index PE^{s-n} declined significantly for all four industries, which is perfectly consistent with the aggregate result discussed in section 4. Once again we eschew interpreting this to necessarily mean that firms became relatively inefficient per se, and merely take it to mean that firms are not operating on the new frontier. The results in columns (3), (6), (9) and (12) indicate a decline in the total factor productivity index TFP^{s-n} for the chemicals, drugs and pharmaceuticals, and electronics industries, but indicate a positive though insignificant change for non-electrical machinery. While this result may appear a little out of sync with the overall result of a weak increase in productivity discussed in section 4, it may well be the consequence of reduced variation in the dependent variable in the individual industry regressions.[12] Other than this, the overall regression results of section 4 appear to square-up well with the industry-level regression results presented in this section.

6. The Effects of Intellectual Property Reforms: Shifting the IP-Reform Threshold Year

As we noted in section 2.1, the first IP-related amendment Act was passed in 1999, but its ambit was very restricted. It was the intellectual property reforms amendment Act of 2002 that brought India's intellectual property laws in line with those required under the TRIPs agreement, which would suggest that we take the IP-reform threshold year as 2003. However, we preferred to use 2004 as the threshold year because the amendment Act of 2002 was notified by the government in 2003. Further, we also pointed out that product patents in the IP-sensitive area of drugs, pharmaceuticals and chemicals were allowed only from 2005 onwards. To gauge how the response of the technical frontier, production efficiency and productivity vis-à-vis the IP dummy changed with the threshold year, we redo the exercise of section 4 using alternative IP dummies, varying the threshold years from 1999 through 2007.

The results are reported in Table 4, where we present the coefficient of the relevant IP dummy from the respective 'full' regressions. The coefficients of $IPD04$ from the corresponding regressions are the same as those in section 4 above, and have been reproduced here for convenience. It appears, indeed, that the IP reforms of 1999 were not deep enough to evoke any significant response of the technical frontier, production efficiency or productivity variables. Things starting moving in 2003 with a small outward shift in the technical frontier, although it was only from 2004 onwards that the technical frontier showed a strong outward shift, which in turn led to a small but significant increase in total factor productivity, as we have already discussed above. This tendency continued in 2005, although the magnitude of the outward shift of the technical frontier declined, and the productivity increase became insignificant. From 2006 onwards the technical frontier did not display any further significant shift, allowing firms to catch-up with the earlier improvements in the best-practice technology, as evidenced by the fact that the production efficiency index is no longer negative significant. Overall, by then the growth impetus stemming from the IP reforms seemed to have petered out.

7. Conclusions

The notable growth performance of the BRICS economies has attracted much attention in the recent past. The interest, it appears, is not only in the performance per se, but also in the promise that it holds for the reforming economies. Innovation, efficiency and productivity growth are important even in situations where the less developed countries can increase output by using larger magnitudes of various factor inputs. Quite unsurprisingly, there could be several factors at work behind this growth impetus. One such may be the strength of intellectual property protection. This paper studies the possible contribution of the Indian intellectual property reforms to technical change, production efficiency, and consequent total factor productivity growth in Indian manufacturing industry, over the period 1994-2011. We find evidence of a significant positive influence of intellectual property reform on the technical frontier and productivity in the Indian manufacturing sector even though the latter appears to have been small. We also found that this effect of the IP reforms was driven by the non-electrical machinery industries, and to a lesser extent the drugs and pharmaceuticals sector. This may be viewed as the innovation-inducing and productivity-augmenting influence of reforms that serve to facilitate imports of better-quality inputs, technology and investment, and encourage domestic research and development. Of course, which of these factors contribute in a specific case could vary across countries and time, and is consistent with the Indian performance.

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Table 1
Sample Statistics of the Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
		Pre-Reform: 1994-2003		
TF^{s-n}	0.035	0.001	0.034	0.038
TF^{s}	0.122	0.002	0.117	0.123
TF^{n}	0.087	0.003	0.079	0.089
PE^{s-n}	0.037	0.005	0.033	0.045
PE^{s}	0.086	0.008	0.078	0.098
PE^{n}	0.049	0.004	0.045	0.055
TFP^{s-n}	0.009	0.001	0.006	0.011
TFP^{s}	0.038	0.003	0.035	0.043
TFP^{n}	0.030	0.002	0.027	0.033
$SALES^{s-n} * 10^{-3}$	0.003	0.000	0.002	0.003
$CRATIO^{s-n}$	0.043	0.003	0.038	0.047
$PRIVATE^{s-n}$	0.083	0.010	0.072	0.092
		Post-Reform: 2004-2011		
TF^{s-n}	0.065	0.000	0.065	0.065
TF^{s}	0.154	0.000	0.154	0.154
TF^{n}	0.089	0.000	0.089	0.089
PE^{s-n}	0.029	0.002	0.027	0.031
PE^{s}	0.080	0.002	0.077	0.083
PE^{n}	0.051	0.001	0.050	0.053
TFP^{s-n}	0.011	0.001	0.010	0.013
TFP^{s}	0.043	0.001	0.041	0.044
TFP^{n}	0.031	0.001	0.029	0.033
$SALES^{s-n} * 10^{-3}$	0.004	0.001	0.003	0.006
$CRATIO^{s-n}$	0.039	0.005	0.036	0.050
$PRIVATE^{s-n}$	0.072	0.000	0.072	0.072
		Full Period: 1994-2011		
TF^{s-n}	0.048	0.015	0.034	0.065
TF^{s}	0.136	0.016	0.117	0.154
TF^{n}	0.088	0.003	0.079	0.089
PE^{s-n}	0.034	0.006	0.027	0.045
PE^{s}	0.084	0.007	0.077	0.098
PE^{n}	0.050	0.003	0.045	0.055
TFP^{s-n}	0.010	0.002	0.006	0.013
TFP^{s}	0.040	0.003	0.035	0.044
TFP^{n}	0.030	0.002	0.027	0.033
$SALES^{s-n} * 10^{-3}$	0.003	0.001	0.002	0.006
$CRATIO^{s-n}$	0.042	0.004	0.036	0.050
$PRIVATE^{s-n}$	0.078	0.009	0.072	0.092

Table 2
TF^{s-n}, PE^{s-n}, TFP^{s-n} and Intellectual Property Reform: Seemingly Unrelated Regression Estimates

	Dependent Variable								
	TF^{s-n}	PE^{s-n}	TFP^{s-n}	TF^{s-n}	PE^{s-n}	TFP^{s-n}	TF^{s-n}	PE^{s-n}	TFP^{s-n}
Regressor	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
$IPD04$	0.030***	–0.009***	0.003***	0.031***	–0.003	0.003***	0.031***	–0.004*	0.003***
	(0.0004)	(0.002)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)
T				–0.0002**	–0.001**	–0.00001	–0.0003***	–0.001***	–0.0002
				(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0003)	(0.0001)
$SALES^{s-n} * 10^{-3}$							0.709**	2.885**	0.892*
							(0.330)	(1.167)	(0.447)
$CRATIO^{s-n}$									
$PRIVATE^{s-n}$									
$Intercept$	0.035***	0.037***	0.009***	0.369**	1.283**	0.036	0.626***	2.328***	0.359
	(0.0003)	(0.001)	(0.0003)	(0.144)	(0.524)	(0.192)	(0.175)	(0.620)	(0.237)
N	18	18	18	18	18	18	18	18	18
$P-value\ (all\ slopes\ 0)$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$Robust\ standard\ errors$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$Root\ Mean\ Squared\ Error$	0.001	0.004	0.001	0.001	0.003	0.001	0.001	0.003	0.001
R^2	0.996	0.631	0.619	0.997	0.719	0.619	0.998	0.790	0.688
$Berndt\ System\ \overline{R^2}$	0.945			0.954			0.963		
$B-P\ test, p-value$	0.000			0.000			0.000		

Note: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively, for a two-tail test. Standard errors in parentheses (robust estimation).

Table 2 contd.
TF^{s-n}, PE^{s-n}, TFP^{s-n} and Intellectual Property Reform: Seemingly Unrelated Regression Estimates

	Dependent Variable					
	TF^{s-n}	PE^{s-n}	TFP^{s-n}	TF^{s-n}	PE^{s-n}	TFP^{s-n}
Regressor	(4a)	(4b)	(4c)	(5a)	(5b)	(5c)
$IPD04$	0.031***	–0.008***	0.001	0.031***	–0.008***	0.001*
	(0.001)	(0.002)	(0.0007)	(0.001)	(0.002)	(0.0006)
T	–0.0003***	–0.002***	–0.0004***	–0.0003**	–0.002***	–0.001***
	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0003)	(0.0001)
$SALES^{s-n} * 10^{-3}$	0.828*	6.010***	2.034***	0.889*	7.060***	2.534***
	(0.425)	(0.961)	(0.391)	(0.494)	(1.012)	(0.395)
$CRATIO^{s-n}$	–0.027	–0.698***	–0.255	–0.029	–0.744***	–0.277***
	(0.060)	(0.136)	(0.055)	(0.061)	(0.125)	(0.049)
$PRIVATE^{s-n}$				–0.009	–0.161*	–0.076**
				(0.039)	(0.080)	(0.031)
$Intercept$	0.665***	3.347***	0.732***	0.722**	4.322***	1.197***
	(0.195)	(0.442)	(0.180)	(0.306)	(0.627)	(0.245)
N	18	18	18	18	18	18
$P - value\ (all\ slopes\ 0)$	0.031	0.000	0.000	0.000	0.000	0.000
$Robust\ standard\ errors$	Yes	Yes	Yes	Yes	Yes	Yes
$Root\ Mean\ Squared\ Error$	0.001	0.002	0.001	0.001	0.002	0.001
R^2	0.998	0.915	0.857	0.998	0.931	893
$Berndt\ System\ \overline{R^2}$	0.982			0.984		
$B - P\ test, p - value$	0.002			0.003		

Note: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively, for a two-tail test. Standard errors in parentheses (robust estimation).

Table 3
TF^{s-n}, PE^{s-n}, TFP^{s-n} and Intellectual Property Reform: Seemingly Unrelated Regression Estimates for Individual Industries

	Chemicals			Drugs and Pharmaceuticals			Electronics			Non-Electrical Machinery		
	Dependent Variable											
	TF^{s-n}	PE^{s-n}	TFP^{s-n}	TF^{s-n}	PE^{s-n}	TFP^{s-n}	TF^{s-n}	PE^{s-n}	TFP^{s-n}	TF^{s-n}	PE^{s-n}	TFP^{s-n}
Regressor	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$IPD04$	0.001	–0.006***	–0.005***	0.002†	–0.007***	–0.005***	0.001	–0.006***	–0.005***	0.032***	–0.012***	0.0002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.0007)
T	–0.0003	0.0004***	0.0004***	–0.001***	0.001***	0.001***	–0.001***	0.001***	0.001***	–0.001***	–0.0001	0.00004
	(0.0002)	(0.0002)	(0.0001)	(0.0003)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0003)	(0.0002)
$SALES^{s-n} * 10^{-3}$	0.096	–0.916	–0.040	–1.732***	2.471***	1.129***	–1.721***	2.944***	1.407***	–2.588***	0.506	0.134
	(0.481)	(0.558)	(0.252)	(0.615)	(0.454)	(0.249)	(0.208)	(0.342)	(0.168)	(0.594)	(0.904)	(0.494)
$CRATIO^{s-n}$	–0.045	0.106	0.016	–0.095	0.288***	0.206***	–0.380***	0.242***	0.181***	–0.251***	–0.290***	–0.094**
	(0.055)	(0.067)	(0.030)	(0.078)	(0.072)	(0.045)	(0.040)	(0.069)	(0.033)	(0.042)	(0.084)	(0.045)
$PRIVATE^{s-n}$	0.037	0.013	–0.079	–0.053	0.015	0.002	–0.088**	0.013	0.008	0.349	0.190	0.163
	(0.160)	(0.142)	(0.101)	(0.042)	(0.027)	(0.018)	(0.034)	(0.042)	(0.031)	(0.221)	(0.214)	(0.132)
$Intercept$	0.489	–0.840***	–0.864***	2.065***	–2.290	–1.302***	2.024***	–2.720***	–1.789***	2.807***	0.149	–0.103
	(0.329)	(0.302)	(0.205)	(0.527)	(0.363)	(0.228)	(0.209)	(0.274)	(0.187)	(0.485)	(0.608)	(0.349)
N	18	18	18	18	18	18	18	18	18	18	18	18
$P-value\ (all\ slopes\ 0)$	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$Robust\ standard\ errors$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$Root\ Mean\ Squared\ Error$	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
R^2	0.393	0.648	0.743	0.617	0.904	0.870	0.851	0.915	0.874	0.990	0.954	0.714
$Berndt\ System\ \overline{R^2}$	0.935											
$B-P\ test, p-value$	0.000											

Note: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively, for a two-tail test; † denotes significance at the 10% level, for a one-tail test. Standard errors in parentheses (robust estimation).

Table 4
TF^{s-n}, PE^{s-n}, TFP^{s-n} and Intellectual Property Reform: Changing the IP-Reform Threshold Year

	Dependent Variable		
	TF^{s-n}	PE^{s-n}	TFP^{s-n}
Regressor	(1)	(2)	(3)
$IPD99$	–0.004	–0.0005	0.0003
	(0.009)	(0.003)	(0.001)
$IPD00$	–0.065	–0.008	0.006
	(0.150)	(0.051)	(0.014)
$IPD01$	–0.003	–0.0003	–0.001
	(0.009)	(0.003)	(0.001)
$IPD02$	0.002	–0.001	–0.0002
	(0.008)	(0.003)	(0.001)
$IPD03$	0.016^{**}	–0.003	0.001
	(0.007)	(0.003)	(0.001)
$IPD04$	0.031^{***}	-0.008^{***}	0.001^{*}
	(0.007)	(0.003)	(0.001)
$IPD05$	0.016^{**}	–0.002	0.001^{*}
	(0.006)	(0.002)	(0.0006)
$IPD06$	0.005	0.002	0.001
	(0.007)	(0.002)	(0.001)
$IPD07$	0.001	0.005^{**}	0.001
	(0.008)	(0.002)	(0.001)

Note: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively, for a two-tail test. Standard errors in parentheses (robust estimation).

Endnotes

[1] The acronym BRICS stands for Brazil, Russia, India, China and South Africa. When it was first coined, only the first four countries were included in the group, and the acronym used was BRICs

[2] The TRIPs agreement required developing countries to make their intellectual property laws TRIPs-compliant within ten years, starting January 1, 1995. The least developed nations could implement this by end-June 2013 in general, and by end-2015 for drugs and pharmaceuticals. In contrast, developed countries had an implementation period of just one year, till end-1995. In addition to staggered implementation, nations could also avail of several flexibilities pertaining to, inter alia, compulsory licensing, parallel imports, and research exceptions.

[3] In addition to the patent law amendments, changes were also made in other aspects of intellectual property laws. Relevant in our context of the manufacturing sector, though less important than the patent reforms, are the Copyright (Amendment) Act 1999, the Trademarks Act 1999, the Industrial Designs Act 2000, and the Semiconductor Integrated Circuits Layout Design Act 2000.

[4] Thus, while the grant of exclusive marketing rights to Eli Lilly and Company for Cialis, Novartis for Glivec, United Phosphorous for Saaf, and Wockhardt for Nadifloxacin stymied several Indian generic manufacturers of those formulations (Mathew 2004), there are few other cases of note.

[5] The Solow method involves the oxymoronic exercise of measuring the residual of a regression of output on inputs, a component that is supposed to be randomly determined (Griliches 1998). It also requires assumptions about the production technology, and the presumption that firms are always technically efficient. Alternative measures such as the Divisia-Tornquist index require data on input prices, which are typically patchy, and may not reflect true scarcity value in the case of administered prices.

[6] For an excellent exposition of some of these ideas in simple non-set theory terms see Ray (2004).

[7] It is a moot point whether one should use measures that allow for technical regress. It is true that all the extant measures capture technical change as what is left after allowing for input growth, and by definition, this reflects technical change both on account of technological innovations as well as non-technological innovations, where the latter pertain to improvements in business methods, management practices etc. Therefore, even if the first component is always positive, for one could argue that technology cannot decline, the second component may be negative, because firms may be unable to

function at the same level of managerial efficiency in all periods insofar as new workers and teams may not be as efficient as the ones they replace. However, there is no reason to expect this factor to be any different post-TRIPs than pre-TRIPs, and therefore we do not allow for technical regress.

[8] We must add a caveat for the variable 'salaries', for which there were gaps for some years before 2000, for some firms. For each of these firms, the gaps were filled on the basis of a non-linear trend estimated for that firm, using the data for the available years.

[9] Salary data are superior to data on number of employees or even hours worked (Branstetter et al. 2011). Employee data would need to be supplemented with data on full-time and part-time employees, information that is seldom available. Data on hours worked would be better, but do not capture the 'efficiency wages' and morbidity/health aspects. Salaries implicitly correct for all these factors – they reflect variations in the proportions and wages of the skilled and unskilled, they reflect variations in the proportions of the full-time and part-time workers, and they reflect (though not completely) the variations in morbidity of workers across firms and over time, insofar as wages are not paid to (daily wage) workers who fail to turn up.

[10] Deflating salaries by the WPI makes sense from the producer's (or production) standpoint. An alternative would be to deflate salaries by the Consumer Price Index which, however, would be more relevant from the worker's (or consumption) standpoint. In the present context, the former appears preferable.

[11] Another relevant ownership variable might be the dummy $FOREIGN$, which equals 1 for foreign firms and equals 0 otherwise. However, this was found to be very highly collinear with the $PRIVATE$ dummy, and could not be considered separately.

[12] The coefficient of $IPD04$ in the TFP^{s-n} regression for the non-electrical machinery sector was found to be not just positive but strongly significant as well, when this SUR system was re-estimated under the constraint that the sum of the coefficients of $IPD04$ in the productivity regressions for each of the four IP-sensitive industries equals the coefficient of $IPD04$ in the aggregate productivity regression of section 4, and similarly for the technical frontier and efficiency regressions (detailed regression results not presented).