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research paper series

Globalisation, Productivity and Technology

Research Paper 2019/06

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GEP

Technological Catch-up to the National and Regional Frontier: Firm-level Evidence for India

Shubin Yang[†] , Sandra Lancheros[‡] , Chris Milner[*]

Abstract

This paper studies productivity convergence to the regional and national frontiers among manufacturing firms in India, using panel data over the period 1999 to 2010. We find evidence of convergence by lagging firms to both their national and regional frontiers, with faster convergence to the national frontier than to their regional frontier. We examine the effects of export behaviour on this process of convergence, and the results demonstrate that exporting promotes productivity growth but slows down the convergence process since export firms tend to be nearer to frontiers. We also investigate the effect of outward FDI (OFDI) on firms' productivity growth and convergence. Likewise, the results show that OFDI facilitates firms' productivity growth but decelerates the speed of convergence.

Key words: Productivity convergence, technology frontiers, globalisation

JEL: O33; O24

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1. Introduction

Productivity convergence or catching up has been widely recognised to be one of the most important sources of productivity growth for countries and firms behind the technological frontier. This process has been extensively studied in the macroeconomic literature of economic growth for a long time. The intuition is that the relatively lower costs of imitation (compared to innovation) allows the less developed countries to grow relatively quickly and catch up to the technological leaders (Barro and Sala-I-Martin, 1997; Howitt, 2000).

In contrast with abundant empirical work at the country and industry levels[1], the process of productivity convergence at the firm level only started to receive attention in recent years. The bulk of this nascent firm-level literature has focused mainly on examining how the less productive firms catch up to the national technological frontier or leading firms nationally. For instance, Nishimura et al. (2005) find strong evidence of productivity convergence among firms in most industries in Japan. Girma and Kneller (2005) show firm-level productivity convergence in the UK service sector. Chevalier et al. (2012) find similar results amongst French firms, and Gemmell et al. (2018) confirm that productivity catch-up is important source of productivity growth for European firms using firm-level data for 11 countries.

One limitation of existing firm-level studies, however, is that typically they ignore the process of productivity convergence to the sub-national regional frontiers. Considering productivity catch-up to the national frontier only might be adequate in the context of developed or relatively small countries. Such economies often have relatively integrated economies, facilitated by high quality infrastructures, common institutions, and limited linguistic and cultural diversity, which tends to induce the adoption of relatively similar technologies within national boundaries. In the context of a large and less developed country such as India, however, the geographical location of firms is more likely to matter. There is a strong likelihood that institutional, linguistic, and cultural diversity gives rise to technological

[1] See for example, Bernard and Jones, 1996; Esteban, 2000; Aiello and Scoppa, 2008; Villaverde and Maza, 2008; and Lee, 2009.

heterogeneity between firms within industries across the country. In such circumstances, the process of technological catch-up to the frontier may not be appropriately represented by convergence only to the national frontier. In less than fully integrated national economies, one may need to allow for the possibility of convergence to both the national and sub-national, regional frontier. The first objective of this paper is therefore to extend existing studies on firms' productivity convergence by exploring the process of catching up of lagging (or non-frontier) firms in India to both the national and sub-national regional frontiers simultaneously.[2] To our knowledge only Griffith et al. (2009) and Zheng (2016) have explored the process of firms' productivity catching up to both frontiers in the context of advanced economies with relatively small and well-integrated territories, namely the UK and New Zealand respectively. The results from these studies indicate that the less productive firms converge faster towards the regional frontier than to the national frontier, suggesting that knowledge spillovers may be geographically concentrated, with firms benefiting more from leading firms that are located nearby.[3] In the context of India, a country with more homogeneity of conditions and deeper economic integration within than between regions, there may be greater opportunity or incentive for firms to converge faster to the regional than to the national frontier. However, it might be also plausible that in India (and in similar developing countries) there is greater concentration of national frontier firms in specific regions than is the case in more advanced economies. In which case, lagging firms will tend to be more distant from the national frontier than in smaller developed economies; this greater distance providing greater scope for catch-up. Which of these effects dominates in determining the relative extent of convergence to the regional and national frontier is therefore a question that needs to be explored empirically.

A second limitation of the existing research on firm-level productivity convergence is the lack of understanding of the role of firms' international engagement in fashioning the speed of

[2] In this paper, the sub-national regions are defined by the administrative divisions in India (i.e. states and territories).

[3] A related emerging literature has studied firms' productivity convergence to global and national frontiers (see for example, Bartelsman et al., 2008 for the UK, and Iacovone and Crespi, 2010 for Mexico). A key finding of from this literature is that the national frontier exerts a stronger pull on domestic firms than the global frontier, suggesting that technologically-lagging firms are less able to learn from the global frontier, perhaps because greater geographical distance and institutional and other barriers constrain the scope for learning effects.

technological convergence. Most of the existing literature has mainly focused on how globalisation facilitates firms' productivity growth, but its effects on the nature and speed of convergence to regional and national frontiers is not well understood.[4] Evaluating the effect of international activities on firms' productivity convergence is particularly relevant for firms from developing countries like India, where governments have been actively implementing outward-oriented reforms with the view of facilitating international technology transfer and helping indigenous firms to catch up with the technological frontier. In the case of India, one of the most important features of such outward-oriented economic reforms has been the promotion of exports and outward foreign direct investments (OFDI), which have resulted in India becoming a major player in world trade and an increasing source of FDI from the developing world. Despite the successful international expansion of Indian firms, the effectiveness of such activities in facilitating technology transfer and helping indigenous firms to catch up to the technological frontier remains open to question. Thus, the second objective of this paper is to improve our understanding of the role that exporting and OFDI play in facilitating productivity convergence to the national and regional frontier amongst Indian firms.

We perform our analysis using a firm level manufacturing panel dataset across 14 Indian regions (13 states and 1 territory) from 1999 to 2010. We find that Indian manufacturing firms converge to both their national and regional frontier, with somewhat more convergence to the national than to the regional frontier. While demonstrating the importance of convergence to the national frontier, the findings of the present paper show that by not allowing for regional frontier effects (as is the case of most of the related literature on productivity convergence at the firm or industry level) the role of the national frontier may well have been overstated. We also find that exporting and OFDI activities facilitate firms' productivity growth but slows

[4] Some of the few studies examining the role of trade on firms' speed of convergence include Iacovone and Crespi (2010) who find that exposure to trade allows Mexican firms to converge faster to the national frontier, whereas Chevalier et al. (2012), on the other hand, show that exporting slows down the rate of catching up of French firms to the national technological frontier. Similarly, Lancheros (2012) examines role of exporting and outward foreign direct investments on productivity convergence amongst Indian firms, but like most empirical studies only focuses on the process of catching up to the national frontier.

down the convergence speed. This is because export and OFDI are largely confined to the most productive firms at or near the frontier for whom there is limited scope for catch-up.

The remainder of the paper is organised as follows. Section 2 presents the empirical framework. This is followed by a discussion of the data used to measure and model productivity convergence (section 3). The empirical results are presented in section 4, and the overall conclusions are set out in section 5.

2. Empirical Framework

2.1. Baseline model

As discussed before, our main interest lies in investigating firm level productivity convergence towards both the national and regional frontier and in examining the role of exporting and OFDI in facilitating this process. To this end, we employ a formulation from the macroeconomic literature of productivity growth and convergence (see Bernard and Jones 1996 and Cameron et al. 2005) which has been extensively used in analysing cross-country productivity convergence, as well as firm level productivity catching up (e.g. Nishimura et al., 2005; Griffith et al., 2009). Equation (1) describes the standard baseline model used in empirical analysis of productivity convergence:

$$\ln A_{i,t} = \gamma_i + \lambda\left(\ln A_{F,t-1} - \ln A_{i,t-1}\right) + \ln A_{i,t-1} + \epsilon_{i,t} \qquad (1)$$

In the context of firm-level analysis, the dependent variable, $\ln A_{i,t}$, is the natural logarithm of firm *i*'s productivity level in year *t*. Productivity convergence is evaluated by introducing the term ($\ln A_{F,t-1}$- $\ln A_{i,t-1}$) defined as the distance or gap in productivity between the firm with the highest productivity level in the industry –or technological frontier (F)– and a laggard firm *i*'s productivity level in year *t-1*. The coefficient on this catching-up variable, λ, is an indicator of productivity convergence. Thus, a positive and significant value of λ indicates that firms further behind the technological frontier grow faster than firms near the frontier, providing evidence of productivity catching-up. Equation (1) also allows us to capture productivity persistence over time (by including firm *i*'s productivity level in the previous year, $\ln A_{i,t-1}$), as well as

heterogeneity in productivity levels across firms (γ_i). Finally, the term $\epsilon_{i,t}$ represents an idiosyncratic error term.

Re-arranging equation (1), we can also express our baseline mode as:

$$\Delta \ln A_{i,t} = \gamma_i + \lambda\left(\ln A_{F,t-1} - \ln A_{i,t-1}\right) + \epsilon_{i,t} \qquad (2)$$

2.2. Catching up to the national and regional frontiers

One of our main interests is to compare the speed of convergence to the national versus the regional frontiers. To this end, we extend equation (2) to include both the national and regional gaps as follows:

$$\Delta \ln A_{i,t} = \gamma_i + \lambda_1\left(\ln A_{NF,t-1} - \ln A_{i,t-1}\right) + \lambda_2\left(\ln A_{RF,t-1} - \ln A_{i,t-1}\right) + \epsilon_{i,t} \quad (3)$$

Where the terms $\ln A_{NF,t-1}$ and $\ln A_{RF,t-1}$ are the natural logarithm of the productivity level of the leading firms at the national and regional levels respectively. The terms $\left(\ln A_{NF,t-1} - \ln A_{i,t-1}\right)$ and $\left(\ln A_{RF,t-1} - \ln A_{i,t-1}\right)$ are therefore our national and regional gap variables, and the coefficients λ_1 and λ_2 capture the speed of technological convergence towards the national and regional frontiers, respectively.

2.3. The effects of exporting and investing abroad on productivity convergence

To evaluate the effects of exporting and investing abroad on the speed of productivity convergence we extend equation (3) as follows:

$$\Delta \ln A_{i,t} = \gamma_i + \delta Z_{i,t-1} + \lambda_1\left(\ln A_{NF,t-1} - \ln A_{i,t-1}\right) + \lambda_2\left(\ln A_{RF,t-1} - \ln A_{i,t-1}\right)$$

$$+\mu_1 Z_{i,t-1}\left(\ln A_{NF,t-1} - \ln A_{i,t-1}\right) + \mu_2 Z_{i,t-1}\left(\ln A_{RF,t-1} - \ln A_{i,t-1}\right) + \epsilon_{i,t} \quad (4)$$

where $Z_{i,t}$ is a vector comprising exporting and OFDI, both measured as dummy variables.[5]

[5] Since firms often sell their goods abroad at intervals, we also distinguish between continuous exporters, switchers and non-exporters as a robustness test.

The interaction terms $\mu_1 Z_{i,t-1}(\ln A_{NF,t-1} - \ln A_{i,t-1})$ and $\mu_2 Z_{i,t-1}(\ln A_{RF,t-1} - \ln A_{i,t-1})$ are included to capture the effects of our globalization variables on the speed of catching up to the national and regional frontiers respectively. Thus, a positive and significant coefficient μ_1 (μ_2) indicates that exporting and/or investing abroad accelerate the process of productivity convergence to the national (regional) frontier. In equation (4) we also include the term $\delta Z_{i,t-1}$ to measure the direct effect of exporting and investing abroad on the rate of productivity growth, with a positive and significant coefficient δ providing evidence of direct productivity-enhancing effects from these international activities.

Table 1 Summary statistics of the main variables used in the regression

Variable	Definition	obs	mean value	S.D	min	max
TFP	Logarithm of TFP	43,913	1.746	0.974	-3.716	5.995
TFP Growth	TFP growth rate	34,783	-0.008	0.595	-5.783	6.054
National Gap	Distance behind the national frontier	43,793	3.114	1.116	0.002	9.437
Regional Gap	Distance behind the regional frontier	42,280	2.107	1.171	0.000	9.078
Export	Dummy variable indicating whether a firm export.	43,913	0.522	0.500	0	1
OFDI	Dummy variable indicating whether a firm invests abroad.	43,913	0.059	0.236	0	1
Private without group affiliations	Dummy variable indicating whether a firm is private (without being affiliated to any group affiliations).	43,913	0.670	0.470	0	1
Foreign firms	Dummy variable indicating whether a firm has foreign capital.	43,913	0.033	0.179	0	1
Private with group affiliations	Dummy variable indicating whether a firm is private and is affiliated to a group.	43,913	0.266	0.442	0	1
State-owned firms	Dummy variable indicating whether a firm is completely or partially owned by the State.	43,913	0.031	0.172	0	1
lnAge	logarithm of firm age	43,913	2.941	0.712	0	4.883
lnSize	logarithm of total asset	43,913	5.264	1.669	-0.400	11.189

Note: The sample includes 43913 observations in manufacturing over the period 1999-2010. The national frontier is the firm with the highest TFP level in an industry in a year, and the regional frontier is the firm with the highest TFP level in an industry in a year in the state.
Source: Authors' calculations using the dataset.

2.4. Other control variables

In our empirical estimations also control for other firm's characteristics such as its age, ownership status, and size. Industry and year effects are also accounted for in our regressions.[6] The precise definition of the variables used in our analysis is provided in Table 1.

2.5. Empirical strategy

A well-known issue when estimating equations (2) - (4) is the potential sample selection problem, as the most productive firms are likely to be those that survive and, therefore, the ones that we observe in our dataset (Fariñas and Ruano, 2005; Nishimura et al., 2005). To account for any potential correlation between a firm's productivity level and its decision to exit the market we extend our equations (2) - (4) with an inverse Mills ratio term, obtained from estimating a firm's survival equation.[7]

Another issue that emerges when estimating equations (2) - (4) is that since $\ln A_{i,t-1}$ appears on both sides of the regression equations, shocks such as measurement errors to $\ln A_{i,t-1}$ could lead to biased estimation of the speed of convergence. Thus, on the one hand, the method of ordinary least squares (OLS) tends to underestimate the speed of convergence as it produces a negative correlation between the gaps and the error term, while on the other hand, the fixed effects model tends to overestimate the speed of convergence (Iacovone and Crespi, 2010). A solution to this problem is to find suitable instruments which unfortunately are not readily available in our dataset. Given this problem, and following Iacovone and Crespi (2010), we estimate our models using the OLS and fixed effects estimators, bearing in mind that OLS may generate downward bias, whereas the fixed effects estimator might result in upward biased estimates.

[6] All monetary variables included in our regression (including those used to calculate our productivity measure as described in section 3) where deflated using the wholesale price index based on financial year 1993-1994.

[7] This strategy has been adopted by Griffith et al. (2009) in a similar context. In our empirical approach we model a firm's survival as a function of its productivity, size, age, capital stock, technology investment, leverage level, inward and outward foreign investments, and exporting status. The results from this regression are available on request.

3. Data

Our main data source is the Prowess database, which is compiled by the Centre for Monitoring the Indian Economy (CMIE). The database includes annual financial statements for both listed and unlisted firms and is one of the most comprehensive firm-level databases in India. The firms covered by this database account for more than 70% of industrial output, 75% of corporate taxes and more than 95% of excise taxes collected by the government. It includes firms from a wide cross-section of industries in manufacturing, services and financial sectors. In this study, we concentrate on manufacturing firms from 1999 to 2010. The Prowess database also provides information on the regions in which firms are located. This information allows us to evaluate the speed of productivity convergence of Indian manufacturing firms towards their national and regional frontiers. In our empirical analysis, we focus on the 13 major states of India plus the capital, Delhi, which together contribute with about 70% of India's GDP and 87% of its population (Shingal, 2014).[8]

In our study, we use total factor productivity (TFP) to measure firms' productivity. Since firms almost always report positive use of intermediate inputs, we adopt the Levinsohn and Petrin (2003) approach to estimate TFP. To construct our TFP variable, we use net fixed assets to measure firms' capital stock. The intermediate inputs variable is calculated by aggregating the amount of raw materials and imported raw materials; and the value-added variable is calculated as the difference between sales and intermediate inputs.[9] To control for outliers, we deleted the upper and lower 0.1% of the observations for each of the variables employed in the estimation of TFP. Thus, our econometric analysis is based on an unbalanced panel dataset

[8] There are 14 major states in India, namely, Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. We exclude Bihar in our study, as it is a service-oriented state. With the exception Delhi, in our empirical approach we include the union territories in India (which are usually cities) as part of the states in which they are located in or close by. To be specific, we took "Chandigarh" as part of Punjab, "Dadra and Nagar Haveli" and "Daman and Diu" to Gujarat, "Pondicherry" to Tamil Nadu; "Andaman and Nicobar" and "Lakshadweep" are small islands with no data and were ignored in this study. We exclude the non-major states in India from our empirical analysis as very few firms in our dataset are located in these states and we would have very few observations to conduct any meaningful empirical analysis.

[9] A main limitation of Prowess is that it does not report information on the number of employees for all firms in the dataset. We, therefore, use wages as a proxy when constructing our measure of TFP. It is reassuring, however, that our proxy is adequate as judged by the high levels of correlation between the TFP estimates based on wages and employment for the group of firms with employment information (see Appendix 1).

that includes 7,140 manufacturing firms with 43,913 observations spanning a 12 years-period, from 1999 to 2010.[10]

For each year, we define the national and regional productivity frontier as the firm with the highest TFP in each industry in the country and the region respectively.[11] This approach allows for changes in the frontier over time, as one firm may catch up and overtake the initial frontier next year. A potential problem that arises from this approach is that the TFP measurement errors could lead to mis-measurement of the frontier. To address this potential problem, as a robustness test and following Griffith et al., (2009), we define the national productivity frontier as a weighted average of the top five firms with the highest productivity levels in each industry-year.

Our empirical strategy to test the hypothesis of productivity convergence relies on important variation in firms' productivity growth and their scope for catching up. Figure 1 shows that firms in our sample exhibit indeed substantial dispersion in their productivity growth rates and their scope for catching up.

Interestingly, the average productivity gap between lagging and frontier firms increased during the period of analysis (Figure 2). These trends, however, do not rule out the possibility of productivity convergence as our model allows for the possibility that the leading firms grow faster than their followers.

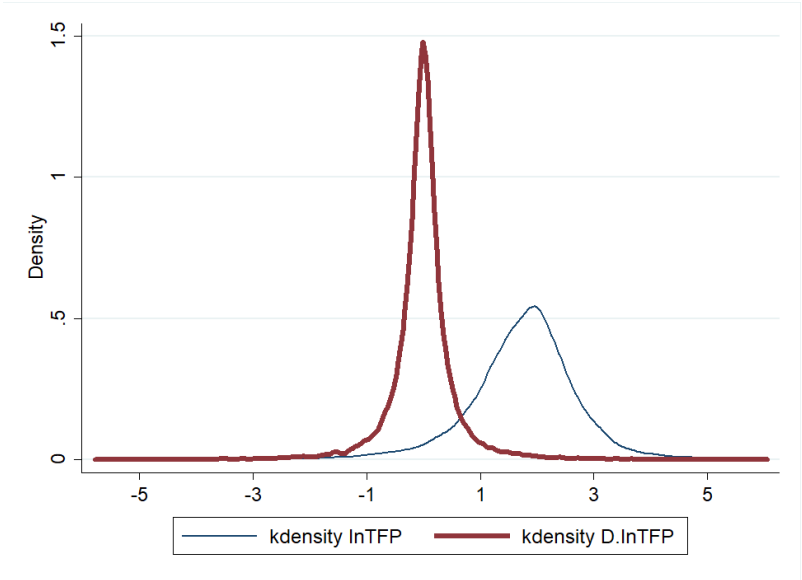
The distribution firms' productivity growth and their productivity gap across our two measures of global engagement is presented in Figure 3. We can see that compared with non-exporters, OFDI firms and exporters display smaller distribution of national and regional gaps and therefore have potentially less scope for catching up.

[10] To estimate equations (2) - (4) we dropped the national and regional frontier firms from the regressions. This explains why the number of observations reported in the results tables in section 4 is slightly below 43,913.

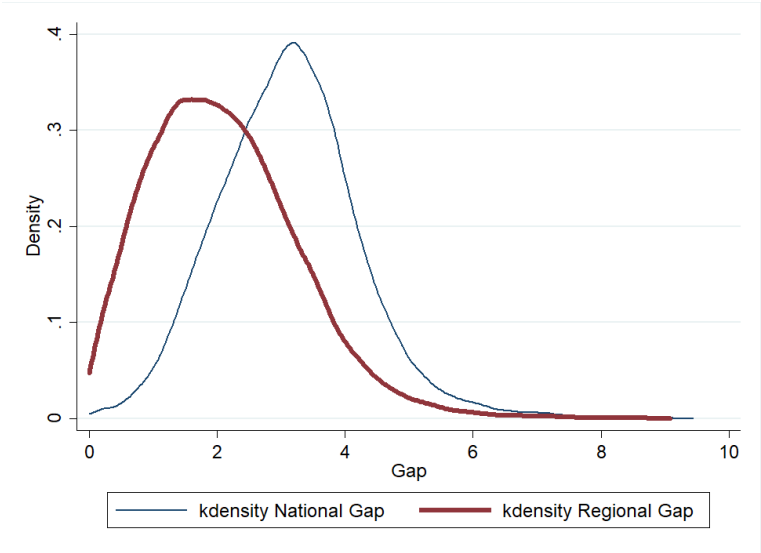
[11] We calculated the technological frontier for each of the 10 two-digit manufacturing industries included in the Prowess dataset for each year.

Figure 1 Distribution of TFP, TFP growth and the Gap

a) TFP and TFP growth

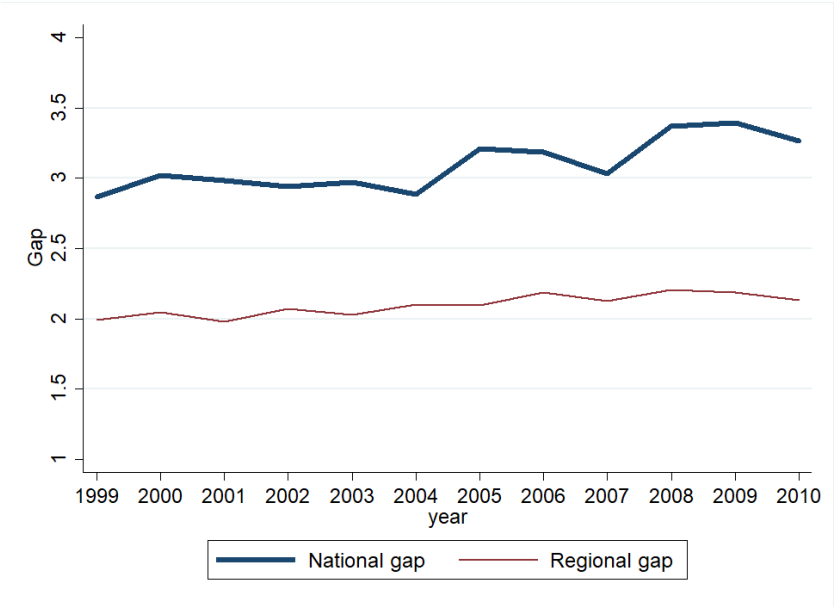


b) National gap and regional gap



Note: The figures show the distribution of logarithm TFP and TFP growth rate (1a) and the national gap and regional gap (1b) for of manufacturing firms over the period of 1999-2010 in India.
Source: Authors' calculations using the dataset.

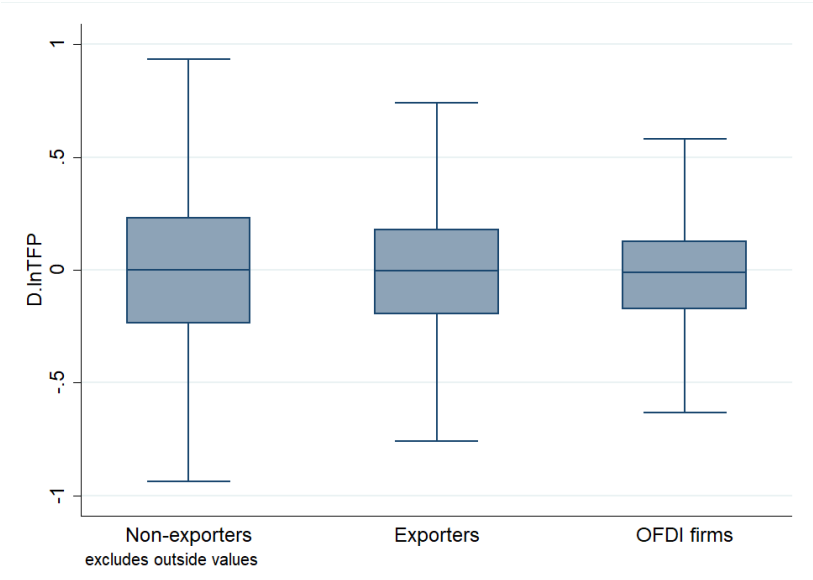
Figure 2 Average Productivity Gaps between Lagging Firms and the National and Regional Frontiers



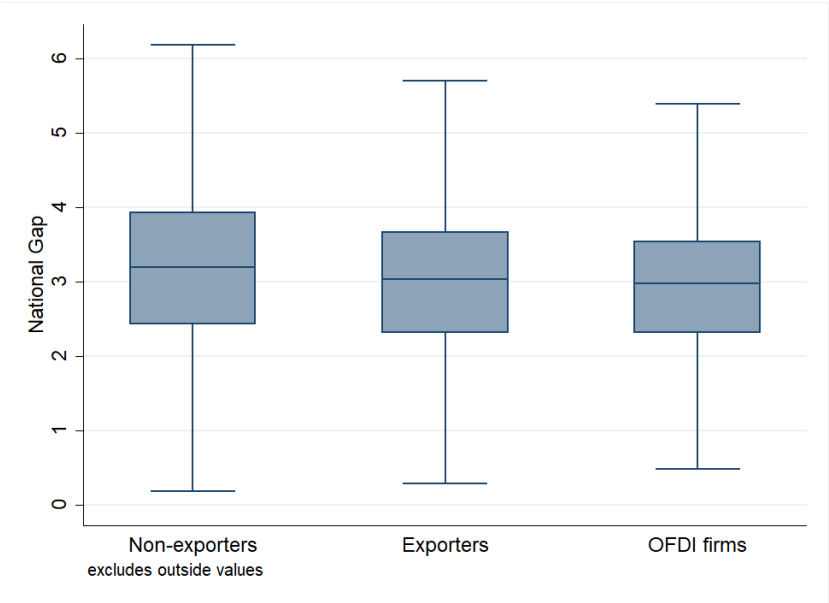
Note: The figures show the average productivity gaps between laggards and the national and regional frontiers of manufacturing firms over the period of 1999-2010 in India.
Source: Authors' calculations using the dataset.

Figure 3 Distribution of TFP growth and Gap across Global Engagement

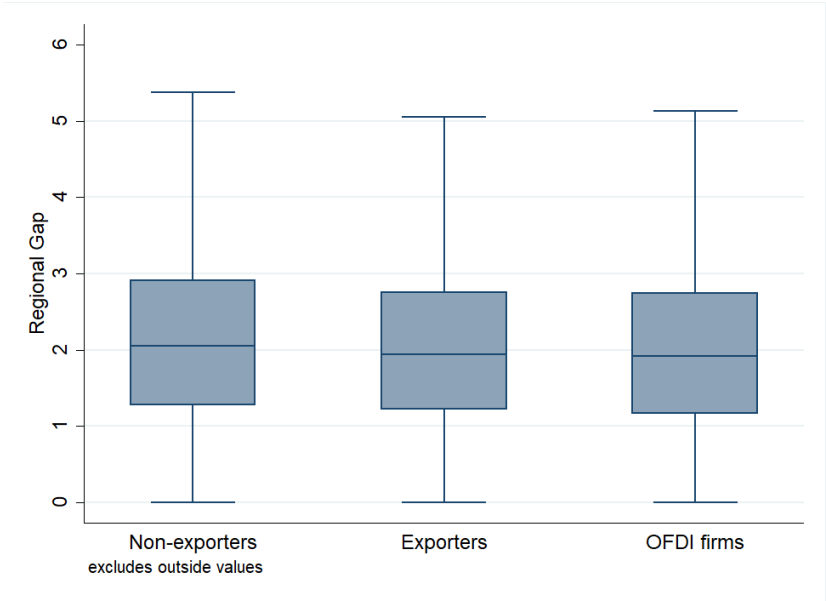
a) TFP growth



b) National gap



c) Regional gap



Note: The figures show the distribution of TFP growth rate (3a) and the national gap (3b) and regional gap (3c) according to firms' global activities for of manufacturing firms over the period of 1999-2010 in India. In this figure, non-exporters refer to firms that not engage in neither export nor OFDI, exporters refer to firms participate in exporting but not in OFDI, and OFDI refers to firms engage in both exporting and OFDI. Since around 95% OFDI firms are exporters, the features in this figure represent the sample trend.
Source: Authors' calculations using the dataset.

Table 2 reports the location of the national frontiers and the distribution of firms across regions. It is not a surprise that the most developed regions in India host a large fraction of firms and that the national leaders are highly concentrated in such advanced regions, a pattern that persist over time. In terms of our main variables of interest, figure 4 shows that there is a high variability in the scope for catching up across regions. In particular, firms located in low income region seems to have less scope to catch up to their regional frontier as judged by the smaller productivity gap to the regional leader.

Table 2 Summary Statistics by State

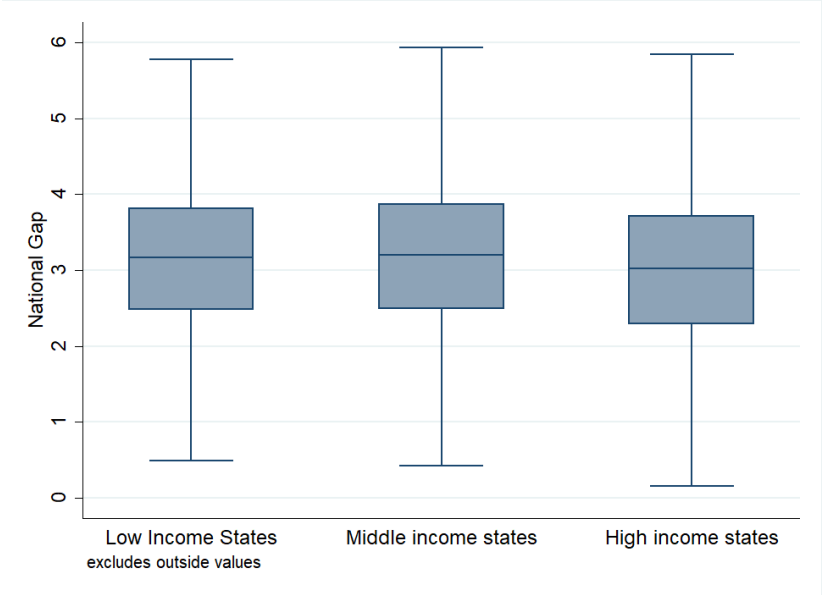
		Number of times national frontier is in state (% total)	Number of firms (% total)
Low Income States	Madhya Pradesh	3 (2.5%)	829 (1.9%)
	Orissa	5 (4.2%)	496 (1.1%)
	Rajasthan	1 (0.8%)	1,242 (2.8%)
	Uttar Pradesh	2 (1.7%)	1,515 (3.5%)
Middle income states	Andhra Pradesh	3 (2.5%)	3,261 (7.4%)
	Karnataka	0 (0%)	1,780 (4.1%)
	Kerala	0 (0%)	1,096 (2.5%)
	Tamil Nadu	18 (15%)	5,590 (12.7%)
	West Bengal	5 (4.2%)	3,772 (8.6%)
High income states	Gujarat	14 (11.7%)	4,703 (10.7%)
	Haryana	0 (0%)	1125 (2.6%)
	Maharashtra	44 (36.7%)	11,339 (25.8%)
	Punjab	0 (0%)	1,895 (4.3%)
	Delhi	25 (20.8%)	5,270 (12.0%)

Note: The sample includes 43913 observations in manufacturing over the period 1999-2010. The national frontier is the firm with the highest TFP level in an industry in a year, and the regional frontier is the firm with the highest TFP level in the state in an industry and year. We classify the states following Kumar and Managi (2012).

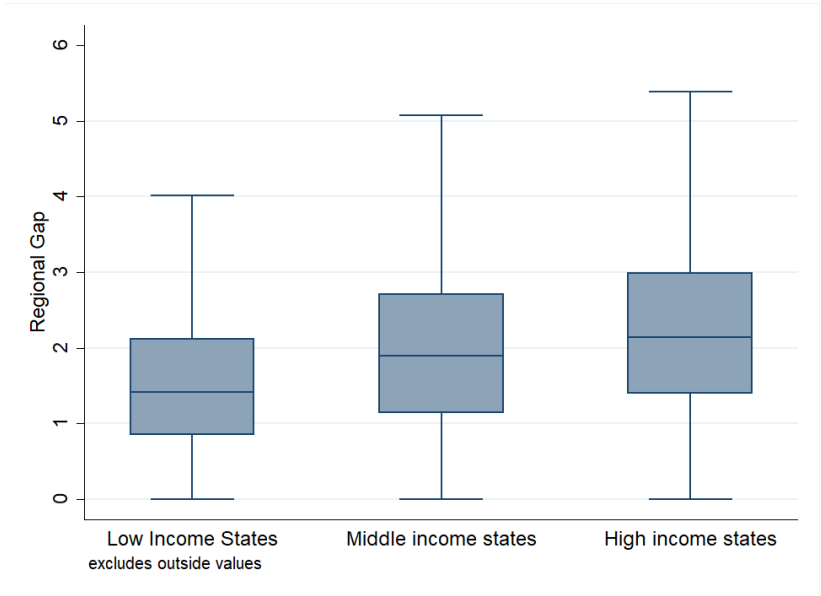
Source: Authors' calculations using the dataset.

Figure 4 Distribution of Gap across Regions

a) National gap



b) Regional gap



Note: The figures show the distribution of the national gap (4a) and regional gap (4b) according to states income level for manufacturing firms over the period of 1999-2010 in India. The details of "Low income states", "Middle income states" and "High income states" are shown in Table 2.
Source: Authors' calculations using the dataset.

Table 3 reports a range of summary statistics of the key variables used in our empirical analysis. On average, national leaders are 1.51 times more productive than regional leaders, which in turn are 1.82 more productive than the laggard firms. As one might expect, there are also substantial productivity differences between domestic and globally engaged firms. As predicted by recent models in international economics, firms in our sample are sorted according to their productivity levels, with those firms engaged in foreign direct investments displaying the highest productivity, followed by exporters, and finally by non-exporters. These patterns result in internationally engaged firms having narrower productivity gaps and potentially less scope for catching up, as they are already closer to the frontiers.

Table 3 Summary Statistics by Firm Type

	TFP	TFP Growth	National Gap	Regional Gap
National Frontiers	4.666 (0.778)	0.353 (0.680)	-	-
Regional Frontiers	3.081 (1.013)	0.177 (0.548)	-	-
Lagging Firms	1.695 (0.934)	-0.015 (0.595)	-	-
OFDI Firms	1.971 (0.910)	-0.033 (0.487)	2.944 (1.019)	1.999 (1.123)
Exporters	1.824 (0.880)	-0.015 (0.521)	3.014 (1.035)	2.045 (1.112)
Non-exporters	1.662 (1.060)	0.001 (0.674)	3.224 (1.188)	2.175 (1.229)

Note: The sample includes 43913 observations in manufacturing over the period 1999-2010. Standard deviations are displayed in parentheses. The national frontier is the firm with the highest TFP level in an industry in a year, and the regional frontier is the firm with the highest TFP level in the state in an industry and year.

Source: Authors' calculations using the dataset.

4. Empirical Results

4.1. Productivity convergence

To examine the relationship between a firm's TFP growth rate and its distance to the national and the regional TFP frontier we start our analysis controlling for year and industry effects only. The results from using the OLS and fixed effects estimators are presented in Tables 4(a) and

4(b) respectively. The estimates in columns (1) and (2) in Tables 4(a) and 4(b) show a positive and significant correlation between firms' productivity growth rate and the distance to the national and regional frontiers when these frontiers are included separately, supporting the hypothesis of productivity convergence. Interestingly, the coefficient of the national gap is higher than that of the regional gap, indicating that firms converge faster to the national frontier than to the regional frontier. To further examine this result, in column (3) we regress firms' productivity growth rate on both the national and the regional gap simultaneously. Our results confirm that Indian manufacturing firms converge faster to the national frontier than to the regional frontier, suggesting that the greater distance and scope for catching up to the national frontier dominates any greater scope for learning from more geographically proximate regional leading firms. The regional frontier does, however, play a significant role in the productivity convergence process, and the role of the national frontier would be overstated if (as in many studies) the regional frontier was abstracted from. In column (4) and (5) (for separately included frontiers) and (6) (with both frontiers simultaneously included), we add firm size, and age, various characteristics of firm ownership, and the inverse Mills ratio resulting from estimating a firm's survival equation as mentioned in section 3 in order to correct for a possible bias due to sample selection. The results show that smaller and younger firms grow faster, consistent with the idea that small and young firms are more dynamic than large firms. Importantly for the present exercise, however, the magnitudes of the estimated coefficients on the gap measures and relative speeds of convergence to each frontier are very similar for each estimation method with and without these additional controls; compare columns (3) and (6) in tables 4(a) and 4(b).

Table 4(a) Productivity Convergence by Lagging Firms: Base Results (OLS estimates)

Dependent variable: TFP growth

	(1)	(2)	(3)	(4)	(5)	(6)
Distance from national frontier (t-1)	0.1937***		0.1499***	0.2071***		0.1624***
	(0.006)		(0.006)	(0.006)		(0.006)
Distance from regional frontier (t-1)		0.1434***	0.0568***		0.1481***	0.0578***
		(0.005)	(0.004)		(0.005)	(0.004)
lnSize				-0.0014	-0.0149***	-0.0016
				(0.003)	(0.003)	(0.003)
lnAge				-0.0858***	-0.0921***	-0.0878***
				(0.007)	(0.007)	(0.007)
Inverse Mills ratio				-0.7770***	-0.7782***	-0.7930***
				(0.061)	(0.062)	(0.061)
Private without group affiliations				0.0582***	-0.0317	0.0361*
				(0.019)	(0.020)	(0.019)
Foreign firms				0.0283	-0.0730***	0.0002
				(0.024)	(0.025)	(0.024)
Private with group affiliations				0.0533***	-0.0318	0.0296
				(0.019)	(0.020)	(0.019)
Constant	-0.5374***	-0.2898***	-0.5321***	-0.1245**	0.3299***	-0.0849
	(0.023)	(0.020)	(0.023)	(0.060)	(0.057)	(0.059)
year dummies	yes	yes	yes	yes	yes	yes
industry dummies	yes	yes	yes	yes	yes	yes
Observations	33477	33477	33477	33477	33477	33477

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India, using OLS and fixed effect respectively. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. The dependent variable is the annual TFP growth rate. The national productivity frontier is defined as the firm with the highest TFP in the industry in a year, and the regional frontier is the firm with the highest TFP in an industry-year-state basis. Size is measured by firms' total assets.

Table 4(b) Productivity Convergence by Lagging Firms: Base Results (Fixed Effects (FE) estimates)

Dependent variable: TFP growth

	(1)	(2)	(3)	(4)	(5)	(6)
Distance from national frontier (t-1)	0.4112***		0.2549***	0.4130***		0.2547***
	(0.010)		(0.008)	(0.010)		(0.008)
Distance from regional frontier (t-1)		0.3934***	0.2279***		0.3972***	0.2319***
		(0.010)	(0.008)		(0.010)	(0.008)
lnSize				-0.0363***	-0.0209*	-0.0236**
				(0.011)	(0.011)	(0.012)
lnAge				-0.1151***	-0.1288***	-0.1020**
				(0.042)	(0.042)	(0.042)
Inverse Mills ratio				-1.0182***	-1.1070***	-1.1064***
				(0.080)	(0.081)	(0.081)
Constant	-1.4007***	-0.8543***	-1.3621***	-0.7194***	-0.2068	-0.7865***
	(0.033)	(0.023)	(0.031)	(0.150)	(0.148)	(0.151)
year dummies	yes	yes	yes	yes	yes	yes
Observations	33477	33477	33477	33477	33477	33477

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India, using OLS and fixed effect respectively. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. The dependent variable is the annual TFP growth rate. The national productivity frontier is defined as the firm with the highest TFP in the industry in a year, and the regional frontier is the firm with the highest TFP in an industry-year-state basis. Size is measured by firms' total assets.

Overall, the results of the OLS and fixed effects models are highly consistent, except for the fact that the coefficients on the TFP gap terms are higher in the fixed effects model than in the case of the OLS estimates. This is consistent with the expected pattern of possible biases in the estimated convergence speeds from the two models, as discussed in section 2.

Note that the present analysis relates to convergence of lagging firms behind both the regional and national frontier. We are abstracting therefore from the role that the national frontier plays in inducing convergence towards it by regional frontier firms. Note also that we have treated convergence to the two frontiers as being unaffected by whether the national frontier is or is not identified for lagging firms by a firm from within the same region. For about 18% of the sample in the base results (Table 4(a) and 4(b)) the national frontier is defined for a lagging firm by a firm from within the same region. This means that a common gap to the

regional and national frontier is applied in the econometric modelling, despite the possibility that only one of the frontiers may be inducing convergence by a specific lagging firm in that region. To check whether this significantly affects the estimated coefficients on our gap terms and the implied convergence rates, we re-estimated specification (3) in Table 4(a) where the common frontier cases were dropped. The estimated coefficients for this reduced sample of lagging firms are only marginally different to the base estimates, leaving the conclusions to be drawn from the base estimates unaltered.[12]

An important conclusion of the base estimates is that for the full sample of lagging firms convergence is on average faster to the national than regional frontier. Given that India is geographically large and culturally and linguistically diverse, this is perhaps a surprising finding. Indeed, this finding contrasts with the finding for two smaller, less culturally and linguistically diverse and more developed economies (the UK and New Zealand), where convergence is found to be faster to the regional than national frontier (see Griffith et al. 2009 for the UK and Zheng (2016) for New Zealand). A possible explanation for the difference in findings is the existence of greater technological heterogeneity across the states/regions of India than across the regions of the UK and New Zealand. If nationally efficient firms are relatively evenly distributed across regions in the UK and New Zealand, then the distance from the regional frontier is very similar to that from the national for lagging firms in most regions. As shown by Table 2, around 84% of the national frontier firms in India are found in just four states (Gujurat, Maharashtra, Tamil Nadu and Delhi). To explore whether our finding about the relative speeds to the national and regional frontier is being driven by this regional concentration of national frontier firms, we first split our sample in to lagging firms in the four above states and lagging firms in other states. The results of OLS re-estimation of the base specification (3) from Table 4(a) are presented in Table 5(a). In fact, we find that on average there is not a significant difference between the estimated models for the two sub-samples of firms in terms of the absolute and relative speeds of convergence to the regional and national frontiers. Further splitting of the four major frontier states does, however, reveal some

[12] The results from this regression are available on request.

important differences between the four states. Delhi and Tamil Nadu are in line with non-frontier states, with lagging firms in these states converging more rapidly to the national frontier (albeit with a convergence speed to the regional frontier only marginally slower than that to the national frontier in the case of Tamil Nadu). However, as shown in Table 5(b), we do find more rapid convergence by lagging firms to the regional than the national frontier in the cases of Gujurat and Maharashtra.[13] Interestingly, these two states account for nearly 50% of the national frontier firms in our full sample (Table 2). This does suggest that the relative importance of the regional and national frontier in driving convergence is fashioned by the distribution of frontier firms across the country.

Table 5(a) Productivity Convergence: Frontier Regions vs. Lagging Regions

Dependent variable: TFP growth

	the four major frontier states	the rest
	(1)	(2)
Distance from national frontier (t-1)	0.1441***	0.1441***
	(0.008)	(0.010)
Distance from regional frontier (t-1)	0.0631***	0.0644***
	(0.006)	(0.008)
Constant	-0.5486***	-0.5028***
	(0.029)	(0.038)
year dummies	yes	yes
industry dummies	yes	yes
Observations	20977	12500

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India using OLS. The four major frontier states are Gujarat, Maharashtra, Tamil Nadu and Delhi, which account for around 84% national frontier firms.

[13] This finding is not sensitive to whether common regional and national frontiers are included in the sample. The estimates reported in table 5(b) include the instances where there are common frontiers.

Table 5(b) Productivity Convergence: State Gujarat and Maharashtra

Dependent variable: TFP growth

	Gujarat	Maharashtra
	(1)	(2)
Distance from national frontier (t-1)	0.0581***	0.0582***
	(0.020)	(0.015)
Distance from regional frontier (t-1)	0.1694***	0.1493***
	(0.021)	(0.016)
Constant	-0.5614***	-0.5636***
	(0.067)	(0.048)
year dummies	yes	yes
industry dummies	yes	yes
Observations	3668	8945

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in state Gujarat and Maharashtra respectively using OLS. Around 12% of national frontiers are located in Gujarat, and 37% in Maharashtra.

The effect of globalisation

We extend our model by including a globalisation vector to capture the direct effects of exporting (exporting compared with non-exporting firms) and investing (versus non-investing) abroad on firms' productivity growth. We also add interaction terms between these two global indicators and the productivity gap terms in order to capture the impact of firms' international activities on their speed of convergence to the national and regional frontiers.

Table 6 Globalisation and Productivity Convergence by Lagging Firms: The Role of Exporting

Dependent variable: TFP growth

	OLS		
	(1)	(2)	(3)
Distance from national frontier (t-1)	0.2203***		0.1739***
	(0.008)		(0.008)
Distance from regional frontier (t-1)		0.1657***	0.0589***
		(0.007)	(0.007)
Export (t-1)	0.0507*	0.0339**	0.0420
	(0.028)	(0.017)	(0.027)
Export * Distance from national frontier (t-1)	-0.0280***		-0.0246**
	(0.010)		(0.010)
Export * Distance from regional frontier (t-1)		-0.0348***	-0.0019
		(0.009)	(0.008)
lnSize	0.0018	-0.0118***	0.0017
	(0.003)	(0.003)	(0.003)
lnAge	-0.0882***	-0.0947***	-0.0901***
	(0.007)	(0.007)	(0.007)
Inverse Mills ratio	-0.8220***	-0.8312***	-0.8406***
	(0.062)	(0.063)	(0.062)
Private without group affiliations	0.0709***	-0.0200	0.0492**
	(0.019)	(0.020)	(0.019)
Foreign firms	0.0410*	-0.0604**	0.0137
	(0.024)	(0.025)	(0.024)
Private with group affiliations	0.0654***	-0.0217	0.0421**
	(0.019)	(0.020)	(0.019)
Constant	-0.1621***	0.3023***	-0.1188*
	(0.062)	(0.057)	(0.061)
year dummies	yes	yes	yes
industry dummies	yes	yes	yes
Observations	33477	33477	33477

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India, including industry and time dummies. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. The dependent variable is the annual TFP growth rate. The national productivity frontier is defined as the firm with the highest TFP in the industry in a year, and the regional frontier is the firm with the highest TFP in an industry-year-state basis. "Export" is a dummy variable equals 1 if a firm export in that year. Size is measured by firms' total assets.

Table 6 presents the results of the effect of exporting on productivity growth and convergence, with the frontiers separately included in columns (1) and (2) and then

simultaneously in column (3).[14] In line with our base results, the coefficients of the national gap and regional gap variables remain positive and significant, thus showing convergence and a similar relative convergence speeds identified by the base estimates. The coefficients on (lagged) exporting are positive and significant, showing that exporting facilitates or at least is associated with firms' productivity growth. This is consistent with the literature that exporters gain new knowledge and expertise in export markets, and/or are subject to greater competition, which allows them to improve their productivity level (De Loecker 2007). The coefficients for the interaction terms between exporting and the national and regional gaps are negative and significant, indicating that exporting has a negative effect on the speed of convergence. A possible explanation for this is that exporters are generally the most productive firms (Chevalier et al. 2012), as shown in section 3, and this reduces the scope or need for convergence. The negative and significant coefficients on firm size and age demonstrate that smaller and younger firms grow faster than larger and older ones. Also, the private firms grow faster than state-owned firms.

In addition to exporting, Indian firms have recently taken globalization a step further by undertaking overseas investments. In our sample, around 5.9% of firms have expanded their operations abroad via OFDI, and 95.18% firms that conduct OFDI are exporters. It is important to test whether OFDI affects the growth and catch up of the firms. Table 7 shows, in similar fashion to Table 6, the results of the effect of OFDI on productivity growth and convergence. The coefficients of national gap and regional gap are consistent with our previous results, positive and significant. The coefficients of (lagged) OFDI are positive but not significant except in column (2), indicating the possibility that OFDI helps improve firms' productivity growth. The coefficients of the interaction terms of OFDI and gap (both national gap and regional gap) are negative throughout, but significant only in columns (2) and (3) in the case of the interaction with the regional gap. As in the case of exporting, OFDI tends to slow down technological convergence (in this case towards the regional frontier). In line with earlier

[14] For presentational convenience only the OLS estimates are reported in Tables 6 and 7, but the fixed effects (FE) estimates are available on request from the authors. The conclusions drawn from these tables is not sensitive to whether OLS or FE estimates are used.

arguments, this type of globalising firm with OFDI is generally among the most productive firms with limited need or opportunity for catch-up domestically.

Table 7 Globalisation and Productivity Convergence by Lagging Firms: The Role of Outward Foreign Direct Investment (OFDI)

Dependent variable: TFP growth

	OLS		
	(1)	(2)	(3)
Distance from national frontier (t-1)	0.2088***		0.1628***
	(0.006)		(0.006)
Distance from regional frontier (t-1)		0.1510***	0.0595***
		(0.005)	(0.004)
OFDI (t-1)	0.0404	0.0526*	0.0364
	(0.052)	(0.027)	(0.052)
OFDI *Distance from national frontier (t-1)	-0.0288		-0.0125
	(0.019)		(0.019)
OFDI * Distance from regional frontier (t-1)		-0.0478***	-0.0237*
		(0.015)	(0.013)
lnSize	0.0006	-0.0130***	0.0006
	(0.003)	(0.003)	(0.003)
lnAge	-0.0854***	-0.0914***	-0.0871***
	(0.007)	(0.007)	(0.007)
Inverse Mills ratio	-0.7813***	-0.7815***	-0.7972***
	(0.061)	(0.061)	(0.061)
Private without group affiliations	0.0634***	-0.0276	0.0410**
	(0.019)	(0.020)	(0.019)
Foreign firms	0.0324	-0.0704***	0.0038
	(0.024)	(0.025)	(0.024)
Private with group affiliations	0.0590***	-0.0275	0.0349*
	(0.019)	(0.020)	(0.019)
Constant	-0.1469**	0.3070***	-0.1081*
	(0.060)	(0.057)	(0.060)
year dummies	yes	yes	yes
industry dummies	yes	yes	yes
Observations	33477	33477	33477

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on all non-frontier firms of manufacturing over the period of 1999-2010 in India, including industry and time dummies. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. The dependent variable is the annual TFP growth rate. The national productivity frontier is defined as the firm with the highest TFP in the industry in a year, and the regional frontier is the firm with the highest TFP in an industry-year-state basis. "OFDI" is a dummy variable equals 1 if a firm invests outside India in that year. Size is measured by firms' total assets.

Robustness checks

To address the potential measurement error in the identification of the national productivity frontier, we use an alternative measure, namely the weighted average logarithm TFP in the top five firms with the highest TFP levels as the national frontier.[15] The empirical results are shown in the Appendix 2 in Table A.1. Columns (1) – (2) depict the base results for productivity convergence to the national and regional frontier using OLS and fixed effect respectively. The results confirm that firms converge to both their national and regional frontiers, with a faster speed of catching up to the national frontier than to the regional frontier. Columns (3) and (4) report the effect of exporting on productivity growth and convergence, and columns (5) and (6) examine the effect of OFDI on growth and convergence. All the results are in line with our previous findings.

As mentioned in section 3, a limitation of Prowess is that it does not report information on the number of employees for all firms in the dataset. Following Girma and Vencappa (2014), we estimated the employment data by running a regression in logs of the total number of employees (for those that are available) on the firm's total assets, controlling for year and industry, and use the predicted values for all other firms to impute the missing employment data. Then we use this imputed employment data to calculate TFP, and re-estimate our models to examine productivity convergence. The results are reported in the Appendix 2 in Table A.2. Columns (1) - (2) show the base results of productivity convergence to the national frontier and regional frontier for the alternative estimation methods. Columns (3) and (4) similarly report the effect of exporting on productivity convergence, and columns (5) and (6) the effect of OFDI on convergence. Again, we can confirm that the conclusions drawn from the base results are not sensitive to the method used to proxy wages.

So far, we have treated exporters as those firms that export in year *t*, while during our study period, some firms export continuously while other firms export at intervals. As a

[15] That is, we take the weighted average logarithm TFP of top five highest productive firms in each year and industry as the national frontier.

robustness check, following Greenaway et al. (2007), we define “continuous exporters” as those firms that exported in all the years in which they are present in the sample, “non-continuous exporters” (switchers) as those firms that export at intervals, and the rest as “non-exporters”, and examine and compare productivity convergence among firms in these different categories. The results are shown in the Appendix 2 in Table A.3. The coefficients of national gap and regional gap are positive and significant for all the three types of firms, and consistent with the base results finding faster convergence to the national frontier than to the regional frontier. The coefficients of the gap terms of non-exporters are higher than those for non-continuous exporters, which in turn are higher than for continuous exporters, suggesting that non-exporters are converging faster than non-continuous exporters, and continuous exporters converge more slowly than other types of firms. This confirms our previous results that exporting slows down the convergence speed.

5. Conclusions

In this paper we study the process of productivity convergence to both national and regional frontiers at the firm level, using a comprehensive micro manufacturing panel dataset for the regions (13 states and 1 territory) of India from 1999 to 2010. Our results confirm the process of convergence of productivity levels of lagging firms to frontier firms. Unlike many other studies we allow for convergence to both the regional and national frontier. The results show that firms converge to both their national and regional frontiers, and that abstraction from the regional frontier (as is the case in many studies) would tend to overstate the role of the national frontier in fashioning productivity catchup at the firm level. We compare the convergence speed to the national frontier with that to the regional frontier and find that firms on average converge more rapidly to their national frontier than to the regional frontier, indicating that the influence of greater distance of lagging firms in general from the national frontier tended in this particular country context to dominate the greater scope to learn from more proximate, regional frontier firms. This is apparently surprising and in contrast to findings for smaller and more integrated

economies (UK and New Zealand), where more rapid convergence to regional than national frontiers has been identified. We find, however, that there is considerable concentration of frontier firms India, with virtually half of the frontier firms being located in just two states. In these two states we do find more rapid convergence to the regional frontier than to the national frontier. We infer that greater technological heterogeneity across regions in the case of India than the above developed economies may account for the different patterns of convergence. Unlike in the case of the developed countries above, nationally-efficient firms are often located an Indian region in which the lagging firms are not located; the resulting greater distance of lagging firms to the national than the regional frontier inducing faster convergence to the national than the regional frontier (despite the greater homogeneity and integration within than between regions).

Since the trade liberalization in 1991, Indian firms have been quite active in globalisation activities. Exploring the role of globalisation on productivity growth and convergence is of great importance. We first examine the role of export on firms' catching up and growth, where we find that exporting facilitates productivity growth but slows down the convergence process. This is because exporters are more productive than non-exporters and they are closer to or at the frontier and have less scope to converge. We also examine whether OFDI facilitates firms' productivity growth and the results confirm this conjecture, showing that OFDI induces the productivity growth but slows down the convergence process for these near or at frontier firms.

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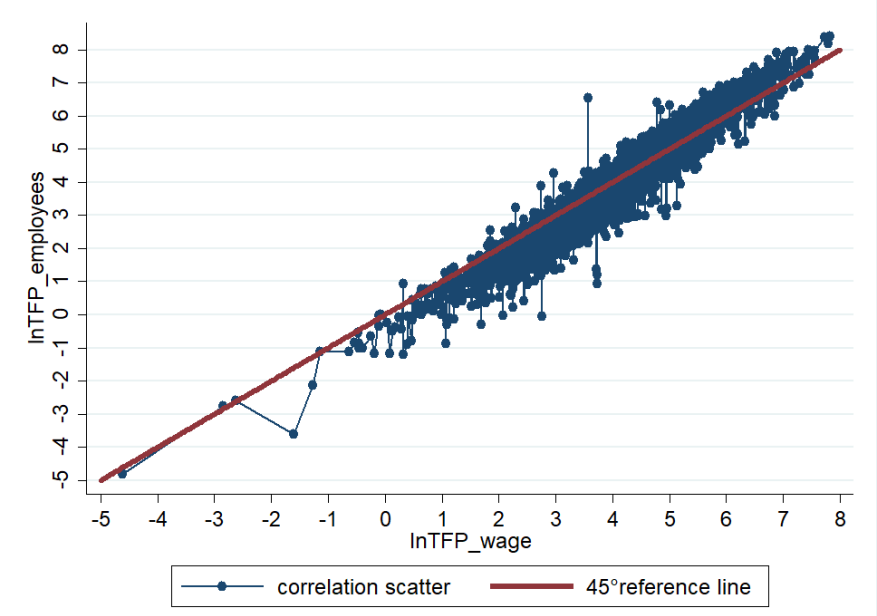
Appendix 1: Testing the Validity of Using Wage to Calculate TFP

A problem of our dataset is that most firms' employment information is missing, with only a small fraction of firms reporting employee numbers. Fortunately, most firms have the wage information. Therefore, we use wage as a proxy for the employee numbers in calculating TFP. To test whether it is valid to use wage to proxy to employee numbers, we calculate TFP for those observations that have both the employment data and wages, using employee numbers and wages as free input respectively, and then compare the results.

There are 4858 observations that have both the information of employee numbers and wage. We calculate TFP for this subsample. The correlation between these two measures of TFP is 0.9633, implying that our method of using wages to compute TFP is adequate. We also depict the relationship between these two TFP estimates, which is shown in Figure A.1 below. The y-axis indicates the TFP using employee numbers and the x-axis refers to the TFP using wages. The red thick line is the 45-degree reference line. From this graph we can see that the two TFP measures are highly correlated. Therefore, we feel it is appropriate to use wages as a proxy for employee numbers to calculate TFP in our sample.

Figure A. 1 Correlation between the Alternative TFP Estimates



Note: The figure shows the correlation between TFP calculated using employees and wage for the sub-sample (4,858 observations) that has both employees and wage information. The y-axis indicates the TFP using employee numbers and the x-axis refers to the TFP using wage. The thick line is a 45-degree reference line.

Appendix 2: Robustness Tests

Table A.1 Productivity Convergence (Using Alternative Frontier Measures)

Dependent variable: TFP growth

	OLS	FE	OLS	FE	OLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)
Distance from national frontier (t-1)	0.2121***	0.4728***	0.2220***	0.4779***	0.2132***	0.4717***
	(0.007)	(0.012)	(0.010)	(0.015)	(0.007)	(0.012)
Distance from regional frontier (t-1)	0.0332***	0.1044***	0.0332***	0.1131***	0.0343***	0.1059***
	(0.004)	(0.008)	(0.007)	(0.011)	(0.004)	(0.008)
Export (t-1)			0.0180	0.0696*		
			(0.025)	(0.039)		
Export * Distance from national frontier (t-1)			-0.0218**	-0.0135		
			(0.011)	(0.016)		
Export * Distance from regional frontier (t-1)			0.0005	-0.0164		
			(0.008)	(0.013)		
OFDI (t-1)					0.0411	0.0054
					(0.043)	(0.061)
OFDI *Distance from national frontier (t-1)					-0.0262	0.0118
					(0.021)	(0.027)
OFDI * Distance from regional frontier (t-1)					-0.0128	-0.0215
					(0.014)	(0.020)
lnSize	0.0030	-0.0127	0.0062*	-0.0120	0.0051	-0.0122
	(0.003)	(0.012)	(0.003)	(0.012)	(0.003)	(0.012)
lnAge	-0.0860***	-0.0717*	-0.0883***	-0.0740*	-0.0855***	-0.0726*
	(0.007)	(0.043)	(0.007)	(0.043)	(0.007)	(0.043)
Inverse Mills ratio	-0.8001***	-1.1514***	-0.8478***	-1.1456***	-0.8046***	-1.1487***
	(0.061)	(0.080)	(0.062)	(0.080)	(0.061)	(0.080)
Private without group affiliations	0.0560***		0.0687***		0.0612***	
	(0.019)		(0.020)		(0.019)	
Foreign firms	0.0221		0.0355		0.0260	
	(0.024)		(0.024)		(0.024)	
Private with group affiliations	0.0486**		0.0609***		0.0542***	
	(0.019)		(0.019)		(0.019)	
Constant	-0.2330***	-1.1310***	-0.2573***	-1.1608***	-0.2558***	-1.1309***
	(0.057)	(0.157)	(0.058)	(0.158)	(0.057)	(0.157)
year dummies	yes	yes	yes	yes	yes	yes
industry dummies	yes		yes		yes	
Observations	33325	33325	33325	33325	33325	33325

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. The national productivity frontier is defined as the weighted average logarithm TFP of the top five firms with highest levels of TFP in each industry and year, and the regional frontier is the firm with highest TFP firms in the state in each industry and year. "Export" and "OFDI" are dummies. Size is defined as the logarithm of firms' total assets.

Table A.2 Productivity Convergence (Using Alternative Employment Estimates)

Dependent variable: TFP growth

	OLS	FE	OLS	FE	OLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)
Distance from national frontier (t-1)	0.1624***	0.2979***	0.1766***	0.3118***	0.1633***	0.2949***
	(0.008)	(0.010)	(0.012)	(0.015)	(0.008)	(0.011)
Distance from regional frontier (t-1)	0.0633***	0.2696***	0.0640***	0.2817***	0.0658***	0.2743***
	(0.007)	(0.011)	(0.011)	(0.016)	(0.007)	(0.011)
Export (t-1)			0.0824***	0.1368***		
			(0.024)	(0.036)		
Export * Distance from national frontier (t-1)			-0.0302**	-0.0292*		
			(0.014)	(0.017)		
Export * Distance from regional frontier (t-1)			-0.0043	-0.0280		
			(0.013)	(0.019)		
OFDI (t-1)					0.0850**	0.0432
					(0.041)	(0.053)
OFDI *Distance from national frontier (t-1)					-0.0170	0.0375
					(0.023)	(0.028)
OFDI * Distance from regional frontier (t-1)					-0.0543**	-0.0744**
					(0.025)	(0.032)
lnSize	-0.0279***	-0.1081***	-0.0284***	-0.1080***	-0.0262***	-0.1083***
	(0.003)	(0.014)	(0.003)	(0.014)	(0.003)	(0.014)
lnAge	-0.0940***	0.0101	-0.0956***	0.0061	-0.0932***	0.0102
	(0.008)	(0.046)	(0.008)	(0.046)	(0.008)	(0.046)
Inverse Mills ratio	-1.1718***	-1.2418***	-1.1725***	-1.2235***	-1.1737***	-1.2396***
	(0.065)	(0.084)	(0.065)	(0.084)	(0.065)	(0.084)
Private without group affiliations	-0.0180		-0.0193		-0.0147	
	(0.020)		(0.020)		(0.020)	
Foreign firms	-0.0171		-0.0212		-0.0150	
	(0.025)		(0.025)		(0.025)	
Private with group affiliations	0.0096		0.0069		0.0125	
	(0.020)		(0.020)		(0.020)	
Constant	0.3955***	-0.5319***	0.3653***	-0.5902***	0.3740***	-0.5333***
	(0.058)	(0.162)	(0.059)	(0.165)	(0.059)	(0.162)
year dummies	yes	yes	yes	yes	yes	yes
industry dummies	yes		yes		yes	
Observations	33441	33441	33441	33441	33441	33441

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. The TFP is calculated using imputed employees to test the robustness of the empirical results. The national productivity frontier is defined as the firm with the highest TFP in the industry in a year, and the regional frontier is the firm with the highest TFP in an industry-year-state basis. "Export" and "OFDI" are dummies. Size is defined as the logarithm of firms' total assets.

Table A.3 Productivity Convergence (According to Exporter Type)

Dependent variable: TFP growth

	continuous exporters		non-continuous exporters		non-exporters	
	OLS	FE	OLS	FE	OLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)
Distance from national frontier (t-1)	0.1380***	0.2262***	0.1579***	0.2464***	0.1872***	0.2823***
	(0.010)	(0.013)	(0.011)	(0.014)	(0.011)	(0.015)
Distance from regional frontier (t-1)	0.0506***	0.1893***	0.0679***	0.2283***	0.0573***	0.2787***
	(0.006)	(0.013)	(0.007)	(0.013)	(0.008)	(0.017)
lnSize	0.0091*	-0.0533***	-0.0019	-0.0199	-0.0248***	-0.0211
	(0.005)	(0.018)	(0.006)	(0.018)	(0.007)	(0.025)
lnAge	-0.0245**	0.0675	-0.0900***	-0.2578***	-0.1982***	0.0125
	(0.010)	(0.055)	(0.013)	(0.075)	(0.017)	(0.087)
Inverse Mills ratio	-0.2161**	-0.5303***	-0.8651***	-1.3926***	-1.8879***	-2.0221***
	(0.088)	(0.112)	(0.116)	(0.155)	(0.155)	(0.207)
Private without group affiliations	-0.0231		0.0820**		0.0536*	
	(0.026)		(0.037)		(0.032)	
Foreign firms	-0.0145		0.0288		0.0335	
	(0.030)		(0.049)		(0.071)	
Private with group affiliations	0.0032		0.0640*		0.0115	
	(0.025)		(0.037)		(0.035)	
Constant	-0.3866***	-1.0166***	-0.1914*	-0.2247	0.5457***	-1.2503***
	(0.087)	(0.230)	(0.107)	(0.249)	(0.129)	(0.296)
year dummies	yes	yes	yes	yes	yes	yes
industry dummies	yes		yes		yes	
Observations	10967	10967	12355	12355	10155	10155

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors are displayed in parentheses. The regressions are estimated on non-frontier firms of manufacturing over the period of 1999-2010 in India. Non-frontier firms lag behind both the regional (RF) and national (NF) frontier. Size is defined as the logarithm of firms' total assets.