India's Mysterious Manufacturing Miracle*

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Abstract

Using data on formal manufacturing plants in India, we report a large but imprecise acceleration in productivity growth starting around the mid-1990s (e.g., 1993-2004 compared to 1980-1992). We trace the acceleration to productivity growth within large plants (200 workers or more), as opposed to reallocation across such plants. As many economists believe Indian reforms during this era improved resource allocation, the absence of a growth pickup from reallocation is surprising. Moreover, when we look across industries we fail to robustly relate productivity growth to prominent reforms such as industrial de-licensing, tariff reductions, FDI liberalization, or lifting of small-scale industry reservations. Even under a generous reading of their effects, these reforms (at least as we measure them) seem to account for less than one-quarter of overall productivity growth.

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1 Introduction

Given their large populations and initial poverty, rapid economic growth in India and China in recent decades may have contributed more to world welfare than all of the growth experienced by the rest of the world's population combined (see related evidence in Pinkovskiy & Sala-i-Martin (2009)). This leaves no greater priority for growth economists than to reap policy lessons from the accelerated development of India and China.

There appears to be a growing consensus about a few aspects of China's growth speedup. It has been particularly rapid in manufacturing (Young (2003) and Bosworth & Collins (2008)), where it has been facilitated by the displacement of inefficient state-owned enterprises with new, more efficient private enterprises (Brandt, Biesebroeck & Zhang (2009) and Hsieh & Klenow (2009)).

Has growth similarly quickened in India's manufacturing sector? Did reallocation of capital, labor, and materials from less-efficient to more-efficient incumbents lift the growth rate? Did pre-existing plants experience rapid productivity growth? How important was input growth versus residual productivity growth? In turn, what quantitative role did did specific Indian policy reforms, such as trade liberalization and de-licensing, play in India's manufacturing growth?

The answers to these questions matter for welfare and policy. If reallocation of inputs from low to high marginal productivity plants fed growth, then reforms freeing up labor mobility or sharpening incentives for profitable lending may have been the key driver. Total Factor Productivity (TFP) growth in incumbent plants might point to investments in human capital and technology.[1]

If reforms were implemented with distinct timing and/or to a different degree across industries or regions, then we can try to use panel data to ask whether years, industries and/or regions in which reforms were concentrated exhibit unusual productivity growth. Rodrik & Subramanian (2004) carries out this strategy at the aggregate level, whereas Aghion, Burgess, Redding & Zilibotti (2005) and Aghion, Burgess, Redding & Zilibotti (2008) do so at the industry and regional levels.

Tracing any growth to policy is devilishly difficult, of course. First, empirical proxies for reforms are crude and incomplete. Enforcement may differ across industries and time. Second, reforms might not be implemented randomly with respect to an industry's productivity prospects. Struggling industries might be targeted for or shielded from

[1] In the context of India, Hulten & Srinivasan (1999) argue that TFP growth has been important in inducing capital accumulation as well.

reforms. Third, measurement of real industry output and inputs is far from perfect. Quality and variety are notoriously difficult to measure (but see Goldberg, Khandelwal, Pavcnik & Topalova (Forthcoming*b*) and Goldberg, Khandelwal, Pavcnik & Topalova (Forthcoming*a*) for efforts on both the output and input side for India). It is possible that there is less underreporting of input growth in industries after they are reformed, thereby understating the productivity boost from reforms freeing up input decisions. Fourth, general equilibrium forces can exaggerate or hide the gains when looking at the industry level. Skilled workers might move in or out of reformed industries, thereby affecting TFP in reformed industries more than aggregate TFP. Industries with rapid TFP growth may see declining relative prices, making it crucial to pick these up in industry deflators. Fifth, dynamic forward-looking behavior can mute or amplify gains around the years when an industry is reformed. Firms might undertake unobserved investments in intangible capital in anticipation of future reforms (or even at the height of reforms, with the TFP benefits not showing up until later). Taken together, it is clear that looking at the industry-year level could easily overstate or understate the productivity effects of reforms.

With these caveats in mind, we proceed to analyze micro data from the Indian Annual Survey of Industries (ASI) to decompose growth (inputs vs. productivity, different types of plants, etc.) and correlate it with a number of policy reforms. The ASI data consists of repeated cross-sections of formal manufacturing plants in India for most years from 1980 to the present.

The ASI has many shortcomings, which we will highlight shortly. Nevertheless, it has been increasingly used to analyze the effects of particular policies, such as liberalization of trade or de-licensing. Recent examples include Sharma (2006*b*), Chamarbagwalla & Sharma (2008), Sivadasan (2009), Topalova & Khandelwal (2010), and Chari (2010). Many such studies use several adjacent years of the ASI. We piece together a longer time series of growth rates, from 1980 to 2004, excluding a few years in between where no sample was conducted or when the sampling frame changed markedly.

We find evidence of a large acceleration in aggregate productivity growth in formal Indian manufacturing during the sample, for example in the early 1990s. The acceleration can be seen in large incumbents in particular.[2] And it arises from changes in such plants over time, not reallocation from low to high marginal product incumbents.

[2]This is in accord with the evidence in Alfaro & Chari (2009) on the still dominant share of old, large firms in the output and employment of most Indian sectors. Their results are about levels, not about growth rates. Sharma (2006*b*) and Chamarbagwalla & Sharma (2008) also present evidence on the importance of large plants in raising levels of labor productivity and the demand for skilled workers, respectively.

Across industry-years, however, we are unable to relate the level or growth rate of productivity to reforms such as de-licensing, trade and FDI liberalization, or lifting of size small-scale industry reservations. Even taking the high end of our estimates, which are similar to previous studies, these observable reforms account for less than a quarter of manufacturing productivity growth in India from 1980-2004, and essentially none of the acceleration. Other studies find important effects, to be sure, but do not account for most of the growth (or growth acceleration) we see.[3] It is as if a manufacturing miracle has occurred in India, but of some mysterious unknown origin(s). This echoes the qualitative conclusion of a recent book by Bardhan (2010).

Our findings (or lack thereof) must be taken with even more caution than usual. The time series is not long, and the annual growth rates are distressingly noisy. In addition to the caveats cited above, we must re-emphasize that our metrics for policy are imperfect, as is the methodology for measuring productivity growth. And the effects of policy might not show up in industry productivity growth immediately following the reforms or at all.

The rest of the paper is organized as follows. In Section 2 we describe the data used in our analysis, in Section 3 we define our measure of productivity growth and provide estimates using ASI data. In Section 4 we provide details about the reforms that took place in India in the 1980s and 1990s, as well as evidence about the effects of these reforms in India. Section 5 concludes.

2 ASI Data

The Annual Survey of Industries (ASI), which is conducted by the Indian Ministry of Statistics, is the only comprehensive annual survey of Indian manufacturing plants. We use the plant-level micro data from 1980-81 to 2004-05 (with the exception of the 1995-96 survey, which is not available). Despite its coverage, and growing use by economic researchers, there are substantial caveats. We outline these here—for further details, see the Data Appendix.

The ASI sampling frame consists of all registered factories employing 10 or more workers using power, or 20 or more workers without using power. The largest plants, which we call the "census sample", are surveyed every year. The size threshold for the census sample varied over this period between 50 and 200 workers (see Table A13), but all plants employing 200 or more workers are always surveyed. The remaining plants are

[3]The same statement applies if we incorporate the estimate of the impact of trade liberalization on *informal* Indian manufacturing establishments in Nataraj (2009).

sampled randomly, and we always weight by the inverse of the sampling probabilities.

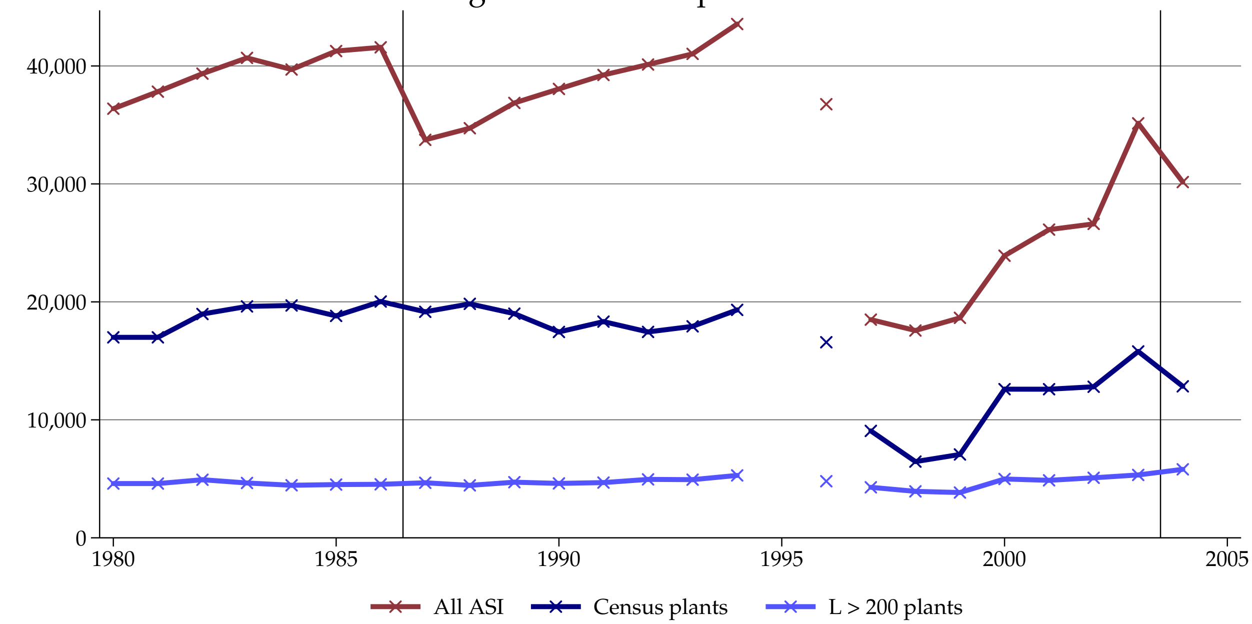
Plants report data on the value of output, materials and fuels, although from 1996-97 onwards up to one-third of these observations are missing. Capital is measured by the book value of fixed assets, and employment and wages are divided between workers and all other employees. We construct a common industry concordance of the NIC1970, NIC1987, NIC1998 and NIC2004 coding schemes, which gives just under 100 roughly 3-digit industries with a common definition over the entire period. We focus on plants in these manufacturing industries that were operating at the time of the survey and who report these variables. There are substantial numbers of extreme outliers, especially since 1996-97, and we attempt to reduce their influence by top-coding and bottom-coding the 1% tails ("Winsorizing") of all plant-level variables immediately prior to aggregation.

Figure 1 plots the sizes of the full ASI sample, the census sample, and the sample of plants employing 200 or more workers over the period. Vertical lines reflect publicly announced changes in the sampling methodology. There are two gaps: the first reflects the missing 1995-96 survey year; the second reflects the fact that the 1996-97 survey substantially differs from the 1997-98 survey, both in the sampling methodology and the survey form. Most importantly, the total value added captured in the 1996-97 survey is more than a quarter less than that in the 1994-95 or 1996-97 surveys (see Figure A5). Because of this, we drop the 1996-97 survey year from the subsequent analysis (our main results are strengthened if we instead retain it).

As explained, we are interested in decomposing productivity growth into that occurring within plants versus across plants. The publicly available ASI micro data contains no plant identifiers, but by comparing plant records in adjacent years in the census sample, we are able to construct an imperfect panel. Our algorithm searches for unique matches between records on static variables such as location, and for "close" matches between year-end and year-start balance-sheet variables, such as opening and closing values of fixed assets.

Table 1 presents a few statistics about the samples for all plants, census plants and plants with 200 or more workers, respectively. The census sample contains the largest number of linked-up plants, but Figure 1 shows that its size jumps around disconcertingly over time. By contrast, the $L \geq 200$ sample reflects only the largest plants, which are always surveyed. The average ASI plant employs 89 people, whereas plants in the Census and $L \geq 200$ samples are much larger. The panel identification rate row shows that we are able to successfully match 86% of annual records in the census sample to adjacent records, and this match rate rises to 94% for the largest plants. The remaining records represent plants that either entered or exited the census sample, or

Figure 1: ASI sample sizes



All open manufacturing ASI plants with positive factors of production and output. Years refer to beginning year of survey. Vertical lines indicate changes in sampling methodology in 1987 and 2004. Gaps indicate missing data in 1995 and anomalous data in 1996.

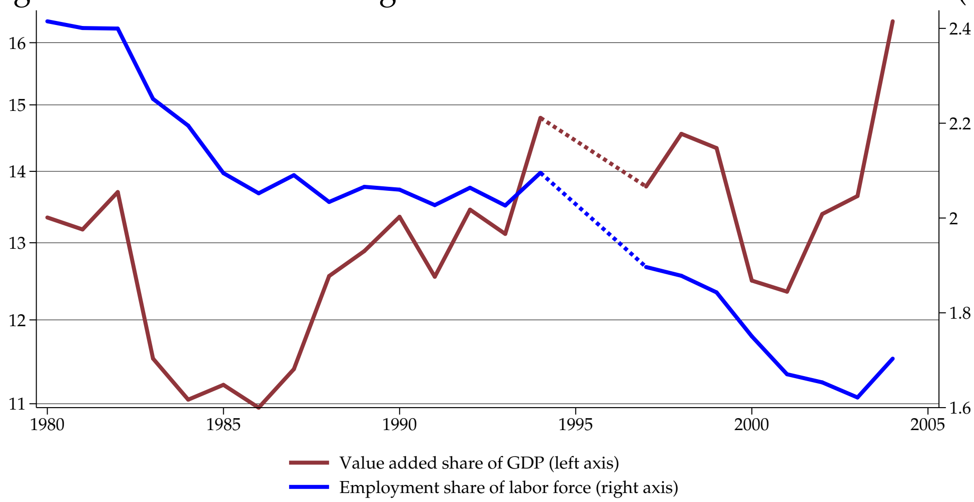
were not matched due to measurement error. The final row shows that, once the plant match rate and needing two years to calculate a growth rate are taken into account, we are left with about 10,500 annual plant growth rate observations in the census sample, and 3,400 annual plant growth rate observations in the $L \geq 200$ sample.

Table 1: ASI averages

	All ASI	Census plants	$L \geq 200$ plants
Annual observations	32,532	15,369	4531
Employees per plant	89	292	831
Panel identification rate		86%	94%
Annual growth rate observations		10,519	3367

All open manufacturing ASI plants with positive factors of production and output 1980-1994 and 1997-2004.

Figure 2: ASI Manufacturing shares of Indian GDP and Labor force (%)



Both series graphed in World Development Indicators. Manufacturing totals from ASI micro-data.

3 ASI Productivity Growth: Trends and Decomposition

3.1 Methodology for Estimating Growth and its Decomposition

Basu, Pascali, Schiantarelli & Serven (2010) show that, under certain conditions, a key contributor to welfare is the present and future behavior of aggregate total factor productivity (TFP), or TFP. With this motivation, we explore TFP growth rates in Indian manufacturing. We also decompose it into growth due to increased efficiency of economic units vs. growth due to reallocation of resources across economic units, following Basu & Fernald (2002), Petrin & Levinsohn (2008), and others.

Suppose value added at plant i, relative to an *ideal* aggregate price index, is produced by the function $Y_i = F(A_i, X_i)$. A_i denotes plant efficiency and X_i a vector of capital and labor inputs indexed by k. Denote growth in plant productivity, i.e., growth in A_i, as da_i.

Aggregate productivity growth is deflated aggregate value added growth less aggregate input growth:

$$
\begin{aligned}
da &= dy - dx \\
&= \sum_i \frac{P_i^Y Y_i}{P^Y Y} dy_i - \sum_k \frac{W^k X^k}{W^X X} dx^k,
\end{aligned}
\tag{1}
$$

where X^k is the economy-wide total of input k. Aggregate input shadow prices W^k are the quantity-weighted average of input shadow prices W_i^k for each plant:

$$W^k \equiv \frac{\sum_i W_i^k X_i^k}{\sum_i X_i^k}. \tag{2}$$

Total nominal value added is $P^Y Y \equiv \sum_i P_i^Y Y_i$ and total input costs are $W^X X \equiv \sum_k \sum_i W_i^k X_i^k$.

As Basu & Fernald (2002) show, aggregate productivity growth can be decomposed into growth from plant efficiency and growth from reallocation:

$$da = \sum_i \frac{P_i^Y Y_i}{P^Y Y} da_i + \sum_i \sum_k \frac{\left(W_i^k - W^k\right) X_i^k}{W^X X} dx_i^k, \tag{3}$$

The first term is a value-added-weighted average of plant efficiency growth rates. The second term reflects reallocation of inputs to plants that have a shadow value, W_i^k, of the input greater than the economy-wide average shadow value, W^k. We do not observe the plant-specific shadow values, W_i^k, but we can calculate the entire reallocation term as the residual difference between aggregate productivity growth in equation (1) and the weighted-average of plant efficiency growth rates.

In our constructed ASI panel, entry and exit are conflated with unmatched continuing plants. We therefore focus only on incumbent plants in each period. We calculate Divisia value added growth from plant gross output Q_i, materials M_i and fuels F_i as

$$dy_i = \frac{dq_i - \beta_{st}^M dm_i - \beta_{st}^F df_i}{1 - \beta_{st}^M - \beta_{st}^F}, \tag{4}$$

where β_{st}^M is the average share of materials expenditure in nominal output for the sector in that year.[4] Nominal value added is $P_i^Y Y_i = P_i^Q Q_i - P_i^M M_i - P_i^F F_i$. We calculate plant efficiency growth as

$$da_i = dy_i - \sum_k \alpha_{st}^k dx_i^k, \tag{5}$$

where α_{st}^k are sector-year input cost shares, assuming a 15% rental price of capital. There are three inputs: fixed assets, skilled labor and unskilled labor. We calculate all growth rates as 100 times the log difference, and all weights as Tornquist shares: $0.5 \times (w_t + w_{t-1})$. We have 2-digit gross output price deflators, which we use to construct a materials

[4] We exclude shares outside the unit interval when calculating the average. We also calculated Divisia value added using total input costs (materials, fuels, capital and labor) instead of nominal output in the denominator of β_{st}^M. This has the effect of dramatically increasing the observed productivity growth acceleration: see Appendix Table A15.

deflator, and economy-wide deflators for all other factors of production. See the Data Appendix for more details.

3.2 Estimated Growth and its Acceleration

Using manufacturing totals from ASI plant-level data and economy-wide totals from the World Development indicators, Figure 2 plots manufacturing share of total value added (GDP) and economy-wide employment. Though the data are noisy, there is evidence of acceleration in labor productivity in Indian manufacturing, particularly from the mid-1990s onwards. Note that economy-wide employment includes the informal sector while ASI data only includes the formal sector. Thus some of the decline in the employment share of manufacturing could be due to growth in informal sector employment as corroborated by the Survey of Unorganized Manufacture and the Economic Census. However the employment totals generated by these data are incompatible with each other and with those provided by ASI plant-level data. Thus it is hard to pin down the magnitude of growth of the informal sector.

Table 2 shows the results of a growth accounting exercise conducted on the Indian manufacturing sector. The table reports the rates of growth of annual aggregate output, value added and factor inputs for the period 1980-2004. Column 1 of the table presents estimated growth rates calculated using ASI published aggregates. The second column presents the rate of growth of TFP and its components (calculated as described in Section 3.1) which are calculated using a matched panel of plants belonging to the census sector of the ASI (see the Data Appendix for details about the plant matching algorithm). Then, in Column 3 of the table, we further restrict the sample of plants we use to calculate TFP and its components to those plants that employ more than 200 workers. As mentioned in Section 2 and illustrated in Figure 1, the $L \geq 200$ subsample is likely to be more reliable since these plants are always surveyed irrespective of changes in sampling methodology.

As shown in Table 2, TFP growth averaged about six percentage points from 1980-2004 in all three samples (all ASI plants, census plants in the ASI, and plants with 200 or more workers). In the census and $L \geq 200$ subsamples, about five percentage points a year comes from changes in productivity of plants over time, with the remaining one percentage point from reallocation of inputs across plants.

In Table 3 we account for growth in Indian manufacturing across two sub-periods: 1980-92 and 1993-2004.[5] The first thing to note from Table 3 is that there was a

[5]We choose the year 1992-93 as the break year for two reasons. Firstly, in the context of the industrial

sharp increase in the rate of growth of productivity across the two-sub periods. TFP calculated using published ASI aggregates (Column 1 and 4) shows that the growth rate of productivity rose from 3.5% to 8.4% from 1980-92 to 1993-2004. This sharp increase in the growth rate is also seen in TFP calculated using ASI micro-level data (3.6% to 9.1%), and is amplified further when the sample is restricted to large plants (those with employment greater than or equal to 200). No matter which data or sub-sample we use, our estimates of the growth rate of TFP are much larger in the 1990s as compared to the 1980s.[6] Figure 3 also illustrates this point. When we plot the growth rates of TFP and its components over time, we find that the slope of the graph is higher from the mid-1990s onwards, as compared to the 1980s. From Figure 3, we also get an idea of the high degree of variability in our estimates of TFP and its components from year to year. This will show up in estimated standard errors shortly.

Table 2: Average annual growth rates, 1980–2004 (%)

	ASI totals	Census panel	$L \geq 200$ panel
Output	7.3	5.1	5.0
Value added	8.6	6.2	6.4
Fixed assets	8.0	2.4	2.5
Unskilled labor	0.7	-1.2	-1.2
Skilled labor	0.9	-0.2	-0.3
Total factor inputs	3.0	0.2	0.3
Aggregate productivity	5.6	5.9	6.1
Plant efficiency		4.8	5.3
Reallocation		1.1	0.8

"ASI totals" are growth rates of annual aggregates, other columns are aggregated averages of plant-level growth rates. *Source:* ASI—see Data Appendix for sample construction details.

The second point that emerges from Table 3 is that all of the acceleration of TFP growth is attributable to growth in plant-level efficiency, rather than to reallocation

and trade policy reforms that took place in 1991 (following a balance of payments crisis), it is interesting to compare the growth of the manufacturing in the 1980s to that in the 1990s. Secondly, tests show that an era dummy variable which switches on in 1992-93 explains the largest fraction of the growth rate of TFP. In particular, we regress aggregate productivity growth in year t on $ERA_t^p = 1$ if$t >= p, p =$ 1980....2004 and we get the largest R^2 when $p = 1992 - 93$ (see Figure A6 and Tables A19 and A18). Thus, the data shows us that it locally prefers 1992-93 as the year in which the break in growth of TFP occurred. There is some evidence of another break in 2002-03 but we do not have data beyond 2004, and are unable to analyze this break.

[6]Table A15 reproduces Table 3 using Divisia value added growth calculated with total input cost shares instead of nominal output. This makes the difference in growth rates between the earlier and later periods even more stark.

Table 3: Average annual growth rates over two periods (%)

	1980 – 1992			1993 – 2004		
	ASI totals	Census panel	$L \geq 200$ panel	ASI totals	Census panel	$L \geq 200$ panel
Output	7.8	5.6	5.1	6.6	4.5	4.7
Value added	7.0	4.2	4.0	10.8	8.8	9.5
Fixed assets	10.1	3.1	3.3	5.2	1.5	1.4
Unskilled labor	0.5	-0.8	-0.8	1.0	-1.8	-1.8
Skilled labor	1.7	0.6	0.4	-0.2	-1.3	-1.3
Total factor inputs	3.5	0.6	0.7	2.4	-0.3	-0.3
Aggregate productivity	3.5	3.6	3.3	8.4	9.1	9.8
Plant efficiency		2.5	2.6		8.0	8.9
Reallocation		1.1	0.7		1.1	0.9

"ASI totals" are growth rates of annual aggregates, other columns are aggregated averages of plant-level growth rates. *Source:* ASI—see Data Appendix for sample construction details.

of resources (between or within sectors). This result is particularly interesting in the context of various industrial and trade policy reforms that occurred during the mid-1980s and early-1990s. One might have expected that moves toward a more market-oriented and deregulated economic environment would lead factors to move from less to more productive plants and sectors. Our result that the role of reallocation was, and remained, small across the two sub-periods is surprising in this context. It is consistent with Hsieh & Klenow (2009), however, who find that resource misallocation in India did not improve from 1987-1994.

It is useful to compare our estimates of TFP growth to other studies. Productivity growth estimates from selected studies are reported in Table A14. For the earlier period, our estimates of roughly 3.5% average annual TFP growth are modestly higher than those of Hulten & Srinivasan (1999) (2.2%) or Bosworth & Collins (2003) (2.5%) for similar periods. Hulten & Srinivasan (1999) also use ASI published aggregates, but they use double deflation method whereas we calculate real value added using a Divisia index. Our estimate is closer to that of Unel (2003) (3.2%). For the later period, however, our TFP growth of approximately 9% is significantly higher than that reported by Bosworth & Collins (2003) (1.9%) or even Unel (2003) (4.7%). Bosworth & Collins (2003) use data on agriculture, industry and services rather than just manufacturing. Industry includes construction and utilities in addition to manufacturing. According to GDP by sector data, manufacturing averaged 69.5% of nominal industry value added from 1980-

2000, and *formal* manufacturing averaged just 44% of nominal industry value added. Finally, the Bosworth-Collins deflators differ from ours as well. Our later sample of 1993-2004 does not overlap much with the 1991-1997 sample in Unel (2003), which could be particularly important given some high growth rates in the 2000s. The divergence of our estimates from Bosworth-Collins stem from some combination of sector coverage, deflators, and time period.[7]

To get an idea of the statistical significance of the acceleration of TFP growth, we regress the growth rate of TFP on a dummy variable that takes on a value of 1 if year is greater than 1993. The first column of Table 4 reports the results for the L$\geq$200 subsample of plants, and Table 5 for all matched census plants. We find that the growth rate of TFP rose by about 6.5 percentage points from 1980-1992 to 1993-2004. Further, panel B shows that all of the higher growth in TFP is attributable to plant efficiency growth. Panel C confirms that between- and within-sector reallocation has little role to play in the growth acceleration that took place in the early 1990s.

Note that we can aggregate TFP growth to the annual level before running these regressions, or instead run regressions at the sectoral or plant level. The coefficients are identical, but the standard errors differ a little, with significance mostly at the 5% level. In each case we cluster by year, in the sectoral case by sector as well, and in the plant case also by plant.

Because of the sizable standard errors, our estimates are far from precise. The most generous interpretation of Column 1 of Tables 4 and 5 is that the data show a large but imprecise acceleration in productivity growth starting around the mid-1990s. Finally, we note from Table 5, Column 1 that the growth acceleration is a little smaller once we include smaller plants (those that were of the census sector of the ASI but smaller than 200 workers).

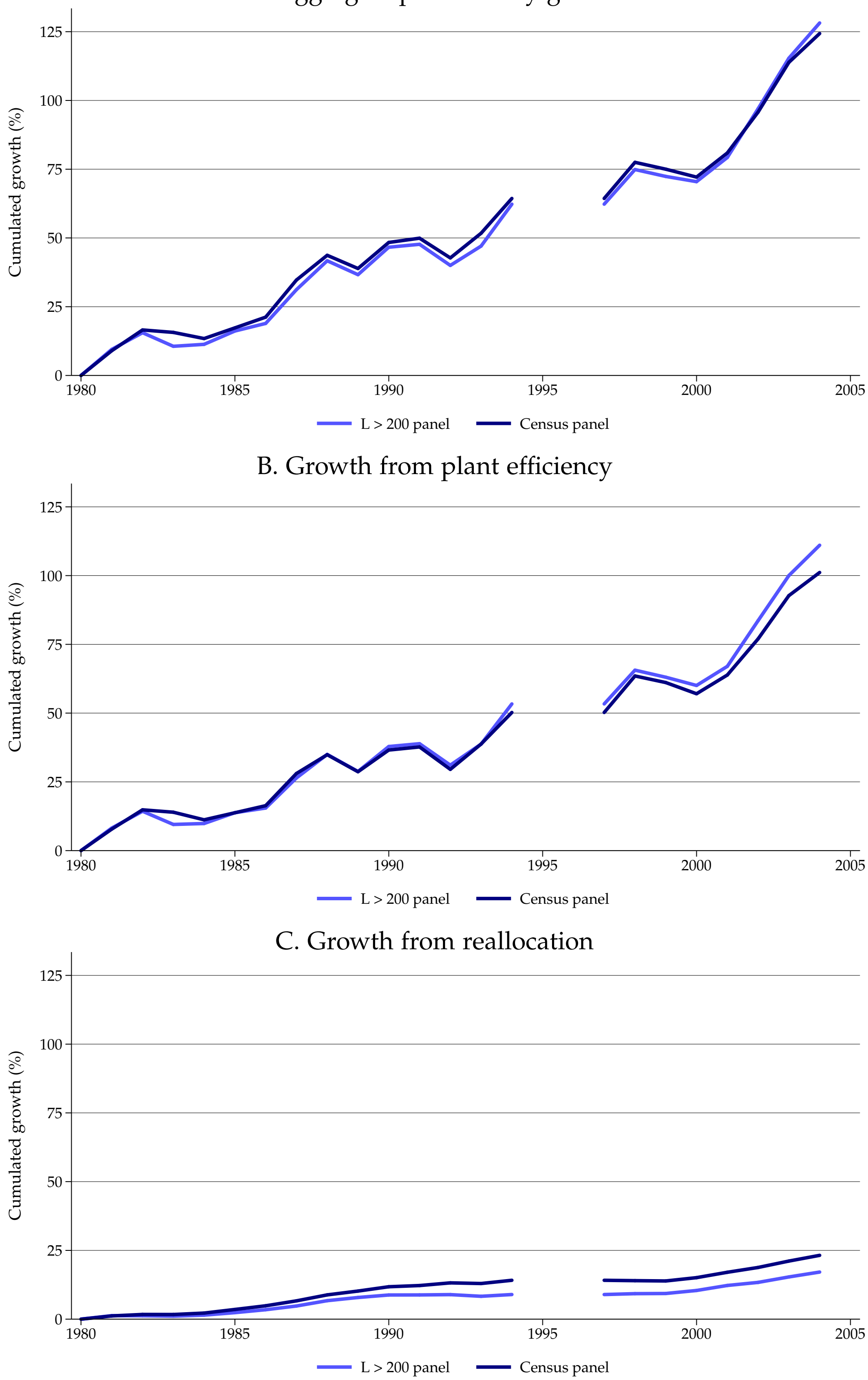
In Columns 2-4 of Tables 4 and 5 we test for the presence of a growth acceleration in the mid-1990s after making corrections for heteroskedasticity. Our motivation is to get more precise estimates of any acceleration, but these will also serve as robustness checks. We implement three alternative weighing schemes. First, we are worried that plant-level data is particularly noisy in some years. In Column 2, we weigh each year by the inverse of the cross-sectional variance of plant growth rates in that year.[8]. Second,

[7]Rodrik & Subramanian (2004) use the Unel (2003) estimates for manufacturing from 1980-1997. Our sample extends seven more years, in which growth appears notably faster. Also, Rodrik and Subramanian mostly use data for the whole economy from Bosworth and Collins when arguing that TFP growth picked up in the 1980s and stayed high in the 1990s.

[8]That is, the weight is $\frac{1}{E[Var_t(g_{it}-\hat{g}_t)]/N_t}$, where g_{it} is the growth rate of TFP of plant i and $\hat{g}_t$ is the average growth rate of TFP in year t.

Figure 3: Cumulative productivity growth and its components

A. Aggregate productivity growth



Series re-initiated in 1997 at 1994 levels due to missing 1995 and 1996 data.

we are concerned about sector-specific noise. So in Column 3 of Tables 4 and 5, we use FGLS techniques to estimate the time series variance of sectoral TFP growth around its sectoral mean for the whole time series, and use the inverse of that to weight each sector-year growth rate observation.[9] In Column 4, we weigh each observation by the inverse of both plant and sectoral noise.

Columns 2-4 reveal that noise correction gives more precise estimates only for the census panel sample of plants. This reinforces our intuition that the L≥200 sub-sample of plants is the more reliable one. We also find that, while the magnitude of our estimate of the productivity speedup bounces around a little, our basic result continues to hold. That is, there was a large acceleration in productivity growth in Indian manufacturing starting in the mid-1990s of around six percentage points. This was typically significant at the 5% level, but occasionally at the 1% level.

Table 4: Estimates of the pick-up in productivity growth since 1993, $L \geq 200$ panel

Noise weighting:	(1) None	(2) Plant Noise	(3) Sector Noise	(4) Both
	A. Aggregate productivity			
Annual data	6.46	6.49		
	(3.22)*	(3.25)*		
	B. Plant efficiency			
Annual data	6.29	6.00		
	(3.07)*	(3.10)*		
Sectoral data	6.29	6.00	5.77	6.03
	(2.50)**	(2.72)**	(2.30)**	(2.75)**
Plant data	6.29	6.00	7.44	7.45
	(2.50)**	(2.72)**	(2.81)**	(3.21)**
	C. Reallocation			
Annual data	0.17	0.50		
	(0.35)	(0.31)		

* $p < 10\%$, ** $p < 5\%$. The dependent variable is $100 * (logTFP_{jt} - logTFP_{jt-1})$. Heteroskedasticity-robust standard errors, clustered by year and sector in sectoral data, and by year, sector and plant in plant data. (In the annual data, conventional standard errors are substantially smaller.) All p-values evaluated from t-distribution with 19 degrees of freedom. Sectoral and plant data regressions weighted by Basu-Fernald aggregation weights.

[9]To apply the GLS technique, we regress the growth rate of TFP on the era dummy variable in an ancillary regression and obtain the corresponding residuals. Then we project the log of square of those residuals on sector fixed effects as variance predictors. The predicted values from this regression are the variance estimates used to obtain the FGLS estimator. Finally, we re-estimate the pick-up equation, but now weighting by the inverse of the variance estimate. Note that we can implement this technique using either plant-level or sectoral data, not annual data.

Table 5: Estimates of the pick-up in productivity growth since 1993, Census panel

	(1)	(2)	(3)	(4)
Noise weighting:	None	Plant Noise	Sector Noise	Both
		A. Aggregate productivity		
Annual data	5.50	6.18		
	(3.04)*	(2.76)**		
		B. Plant efficiency		
Annual data	5.49	5.77		
	(2.90)*	(2.58)**		
Sectoral data	5.49	5.77	5.28	6.66
	(2.34)**	(2.02)**	(2.09)**	(2.21)**
Plant data	5.49	5.77	6.48	7.10
	(2.34)**	(2.02)**	(2.68)**	(2.73)**
		C. Reallocation		
Annual data	0.01	0.41		
	(0.39)	(0.35)		

* $p < 10\%$, ** $p < 5\%$. The dependent variable is $100 * (logTFP_{jt} - logTFP_{jt-1})$. Heteroskedasticity-robust standard errors, clustered by year and sector in sectoral data, and by year, sector and plant in plant data. (In the annual data, conventional standard errors are substantially smaller.) All p-values evaluated from t-distribution with 19 degrees of freedom. Sectoral and plant data regressions weighted by Basu-Fernald aggregation weights.

4 Reforms and Productivity Growth

Given the results of the previous section, we turn to the following question: what may have caused the large, statistically significant pick-up in TFP growth in Indian manufacturing? Recent research (such as Sharma (2006*b*), Sivadasan (2009), and Topalova & Khandelwal (2010)) has stressed the importance of a series of industrial and trade policy reforms which began in the mid-1980s. In Section 4.1 we provide details about these reforms and the mechanisms by which they might affect TFP growth and its components (reallocation and within-plant growth). In Section 4.2 we attempt to explain the productivity pick-up with these reforms, exploiting their pace and timing across industries.

4.1 Industrial Policy In India

After independence India adopted or continued industrial licensing, tariff and non-tariff barriers on imports, and restrictions on foreign direct investment. Later, a number of industries were "reserved" for small firms. Topalova & Khandelwal (2010), Sivadasan

(2009), and Sharma (2006*b*) provide details about the trade policy regime, the controls on FDI, and the license "raj" respectively. Panagariya (2008) provides a thorough review of the Indian growth experience and government policies. Below we provide a brief overview of some of the key policies and reforms affecting manufacturers.

The license "raj" refers to a system of controls on the entry of firms into the manufacturing sector commencing in 1956. Each and every plant that wanted to produce a manufactured good needed to receive permission (i.e., a license) from the central government. The issue of a license was conditional on certain conditions that the plant needed to fulfill. These conditions included limits on output that could be produced, raw materials that could be imported, intermediates that could be purchased, the technology that could be used to produce, and the location of the plant.[10] The license regime arguably affected both the incentive and the ability of Indian plants to be productive. Complaints about the resulting high costs and low productivity in Indian manufacturing began building from the first decade of the license regime (Sharma (2006*a*)). But the first serious attempt to deregulate the system only came about in the 1980s. This was a piecemeal approach, in which a handful of industries were de-licensed in 1984, another handful in 1985 and so on. In 1991, the Indian economy faced a balance of payments crisis and received loans from the IMF and other international organizations. Under pressure from these organizations, the biggest de-licensing episode occurred. Almost all industrial licensing was removed – by 1994 all but 16% of manufacturing output had been de-licensed. Studies have linked de-licensing reforms to increases in the productivity of some plants (Sharma (2006*b*)), though there was no discernible impact at the industry level. De-licensing also appeared to raise the demand for skilled labor in Indian industry (Chamarbagwalla & Sharma (2008)), and may have contributed to growth differences across regions (Aghion et al. (2005) and Aghion et al. (2008)).

A number of studies have analyzed the complicated web of tariff and non-tariff barriers that were used to restrict foreign trade in order to pave the way to national self-sufficiency. As Topalova & Khandelwal (2010) describes, the regime consisted of high tariffs, a complex import licensing system, an "actual user" policy that restricted imports by intermediaries, restrictions of certain exports and imports to the public sector, phased manufacturing programs that mandated progressive import substitution, and

[10] As Panagariya (2008), Sharma (2006*a*) and Sharma (2006*b*) discuss in detail, the purpose of licensing was to direct capital into desirable industries. Every five years, the Planning Commission would issue demand projections for various sectors and commodities. The Ministry of Industry was then supposed to allocate capacity via the licensing system in a way that was consistent with these projections. This meant that some plants were output-constrained at some point in almost all industries. That is, they wished to produce more but they were not allowed to do so.

government purchase preferences for domestic producers. There were some attempts to liberalize the system in the late 1980s. It was the 1991 balance of payments crisis, however, that led to major changes in both tariff and non-tariff barriers. Non-tariff barriers were rationalized and scaled down (for example, Topalova & Khandelwal (2010) finds that 26 import licensing lists were removed and one "negative" list was established). Tariffs fell by 43 percentage points between 1990 and 1996, and the standard deviation of tariffs dropped by 50% as well. The rationalization of tariff and non-tariff barriers continued into the late 1990s - early 2000s. Topalova & Khandelwal (2010) and Das (2003) are the only two studies that have used detailed data on tariff and non-tariff barriers to assess the impact on productivity in Indian manufacturing. Using data on listed firms from 1987 to 2001, Topalova found that a 10% fall in tariffs lead to a 0.5 % increase in total factor productivity of the average firm calculated using the Olley-Pakes methodology. But Das did not find any positive impact of the trade reforms on TFP at the industry level. In fact, productivity performance worsened as the pace of trade reform increased.[11]

The third aspect of the industrial policy regime operational in India from 1970s onwards was control of foreign direct investment. As Sivadasan (2009) reports, prior to 1991 foreign ownership rates were restricted to below 40% in most industries. In addition, restrictions were placed on the use of foreign brand names, on remittances of dividends abroad, and on the proportion of local content in output. After the 1991 balance of payments crisis, foreign ownership of up to 51% was allowed for a group of industries and the restrictions on brands, remittances and local content were relaxed. Sivadasan (2009) finds mean industry-level aggregate productivity growth of 22% following FDI and 59% following tariff liberalization (in the 1994-95 period compared to the pre-reform 1987-90 period).[12]. The growth of average plant productivity was the single largest contributor to the increase in aggregate productivity growth, contributing 25% in FDI-liberalized industries and about 55% in tariff-liberalized industries. That is, intra-industry reallocation played only a small role in the change in aggregate productivity between the 1994-95 and pre-reform periods.

Another Indian policy was the promotion of small-scale industry (SSI). In 1967 the government began a policy of reserving the manufacture of certain products exclusively for small producers (a plant was defined as "small" if its capital stock was under a certain threshold). Once a product was placed on the SSI list, no new medium or large enterprises were allowed to enter, and the production capacity of existing medium and

[11]Note that Das (2003)'s results are based on correlations between productivity and the trade regime.

[12]The source of tariff data is the WITS database.

large enterprises was capped. Panagariya (2008) points out that the bulk of SSI items were labor-intensive products, in which India presumably had a comparative advantage. SSI reservations may have kept India out of the world market for these products, and may have reduced the incentive of SSI plants to produce high-quality products. The SSI list began with 47 items but steadily expanded until tens of thousands of products were reserved. The market-oriented reforms of the 1980s and 1990s did not do much to dismantle this reservation policy, and it was in the early part of the twenty first century that de-reservation of industries began in earnest.

4.2 Policy regressions

Each of the four industrial and trade policy reforms that took place during the 1980s and 1990s had the potential to boost aggregate productivity. De-licensing of industry created the opportunity for productive plants, including new entrants, to raise their market share. And de-licensing may have induced all plants to invest more in raising their productivity as they could more easily scale up production if such investments paid off. Trade and FDI reforms could increase aggregate productivity through a number of channels. Examples include reallocation and entry selection as in Melitz (2003), endogenous innovation of incumbents as in Atkeson & Burstein (2010), and increased availability of high quality imported inputs as in Goldberg et al. (Forthcoming*a*). More controversially, the presence of FDI on Indian soil may have been generated productivity spillovers from foreign-owned plants to competing Indian plants or to vertically related Indian suppliers/buyers of their products. De-reservation of SSI industries could realize scale economies, reallocate inputs from less to more efficient plants, and promote innovation.

With this motivation in mind, in this section we regress the log level of industry productivity (TFP) on measures of each of the four policies, controlling for both year and industry fixed effects. De-licensing the textile industry in 1991, for example, might show up in higher TFP in the textile industry in 1991 (relative to other industries in that year and relative to the norm for that industry). The policies are measured as (0,1) for fraction of industry output licensed, the tariff rate (a 100% tariff corresponding to a 1), the fraction of the industry open to FDI (0,1), and the fraction of the industry not subject to SSI reservations (0,1). Tables 6, 7, 8 and 9 present these results. In Column 1 of each table we present results without correction for heteroskedasticity. Column 2 shows results once the inverse of plant-level noise is used to weight each year, Column 3 shows estimates once the inverse of sector-level noise is used to weight each sector, and Column 4 shows results with correction for both plant and sector noise. In Column 5 we test the robustness of our results to removal of outliers. In particular, we censor cumulative productivity such that we only allow plant TFP to rise or fall by at most 100% per year.

Table 6: Log Productivity on De-licensing
Independent variable: Fraction of sectoral output de-licensed

	(1)	(2)	(3)	(4)	(5)
Noise weighting:	None	Plant noise	Sector noise	Both	Censored [-100, 100]
			A. $L \geq 200$ balanced panel		
Sectoral productivity	-2.51	-5.35	-12.43	-10.51	-2.61
	(11.99)	(12.98)	(11.82)	(12.59)	(11.93)
Plant efficiency	-2.78	-6.45	-8.65	-9.20	-3.33
	(9.63)	(10.34)	(8.64)	(9.27)	(9.60)
Within-sector reallocation	0.27	1.09	-4.24	-3.02	0.27
	(5.47)	(5.96)	(4.99)	(6.00)	(5.47)
Sector FEs	74	74	74	74	74
Year FEs	22	22	22	22	22
Observations	1628	1628	1628	1628	1628
			B. Census balanced panel		
Sectoral productivity	4.94	3.69	-3.18	-8.20	4.44
	(11.47)	(10.25)	(12.50)	(9.53)	(11.27)
Plant efficiency	1.90	-0.22	-6.41	-7.61	0.85
	(9.05)	(8.58)	(8.73)	(7.55)	(8.91)
Within-sector reallocation	3.04	3.91	-1.86	-0.86	3.04
	(5.61)	(5.52)	(3.74)	(3.75)	(5.61)
Sector FEs	87	87	87	87	87
Year FEs	22	22	22	22	22
Observations	1914	1914	1914	1914	1914

* $p < 10\%$, ** $p < 5\%$. Standard errors clustered by sector in parentheses. Six regressions per column—each row is a new dependent variable. Dependent variables are cumulative growth rates, in percentage points, from 0 in 1980. All regressions weighted by sectoral value-added share (1980 observations weighted by 1980–1981 shares and plant growth variances).Independent variable is output-weighted sectoral average of 4-digit NIC1987 de-licensing indicator from Sharma (2008). Sample runs from 1980–2004.

In most entries, the reforms do not have a statistically (as opposed to economically) significant relation to industry productivity or its components (plant efficiency and reallocation). There are a few notable exceptions. After correcting for sector noise (Column 3) or both sector and plant noise (Column 4) in Table 8, fully opening an

Table 7: Log productivity on Tariffs
Independent variable: Average nominal tariff fraction

Noise weighting:	(1) None	(2) Plant noise	(3) Sector noise	(4) Both	(5) Censored [-100, 100]
	A. $L \geq 200$ balanced panel				
Sectoral productivity	-16.87	-15.69	-19.27	3.63	-17.29
	(12.23)	(12.68)	(13.39)	(15.48)	(12.24)
Plant efficiency	-11.76	-11.37	-2.83	6.73	-12.57
	(11.10)	(11.87)	(11.07)	(13.16)	(11.40)
Within-sector reallocation	-5.11	-4.33	-7.27	-2.17	-5.11
	(4.49)	(4.06)	(3.44)**	(5.38)	(4.49)
Sector FEs	74	74	74	74	74
Year FEs	11	11	11	11	11
Observations	814	814	814	814	814
	B. Census balanced panel				
Sectoral productivity	-8.12	-3.15	-1.38	8.38	-7.42
	(9.30)	(7.75)	(8.97)	(11.69)	(9.09)
Plant efficiency	-3.71	-0.14	5.88	2.10	-3.55
	(8.86)	(8.90)	(9.83)	(9.82)	(8.69)
Within-sector reallocation	-4.41	-3.01	-6.24	-3.51	-4.41
	(4.33)	(3.87)	(3.51)*	(3.17)	(4.33)
Sector FEs	87	87	87	87	87
Year FEs	11	11	11	11	11
Observations	957	957	957	957	957

* $p < 10\%$, ** $p < 5\%$. Standard errors clustered by sector in parentheses. Six regressions per column—each row is a new dependent variable. Dependent variables are cumulative growth rates, in percentage points, from 0 in 1980. All regressions weighted by sectoral value-added share (1980 observations weighted by 1980–1981 shares and plant growth variances).Independent variable is negative of output-weighted sectoral average of 3-digit NIC1987 average nominal tariff from Topalova & Khandelwal (2010). Due to data limitations, the sample runs from 1987–2000, vs. 1980–2004 for other policies.

industry to FDI is associated with 27-34 percentage points higher aggregate TFP, with standard errors of less than 10 percentage points. This is mostly via growth in existing plant efficiency, not reallocation. These results do not (statistically) survive correction for outliers in Column 5. In Table 9, freeing up a fully reserved industry seems to go along with significantly *worse* allocative efficiency (30-60 percentage points lower resulting TFP, with standard errors on the order of 20 percentage points).

Of course, it could take time for the policy reforms to affect industry productivity. And the reformed industries could have had lower productivity growth to begin with.

Table 8: Log productivity on FDI liberalization
Independent variable: Fraction of sectoral output open to FDI

Noise weighting:	(1) None	(2) Plant noise	(3) Sector noise	(4) Both	(5) Censored [-100, 100]
			A. $L \geq 200$ balanced panel		
Sectoral productivity	15.77	20.13	27.07	34.72	15.54
	(13.00)	(15.00)	(8.86)**	(9.37)**	(12.99)
Plant efficiency	17.85	23.01	22.24	25.54	17.51
	(12.06)	(13.35)*	(4.98)**	(6.36)**	(12.07)
Within-sector reallocation	-2.08	-2.89	4.20	3.56	-2.08
	(7.79)	(8.72)	(4.95)	(5.28)	(7.79)
Sector FEs	74	74	74	74	74
Year FEs	22	22	22	22	22
Observations	1628	1628	1628	1628	1628
			B. Census balanced panel		
Sectoral productivity	20.63	20.42	28.40	32.60	20.34
	(11.24)*	(11.53)*	(8.78)**	(7.23)**	(11.15)*
Plant efficiency	20.17	19.92	20.84	18.08	19.67
	(10.60)*	(10.84)*	(5.46)**	(6.39)**	(10.52)*
Within-sector reallocation	0.45	0.50	5.78	2.65	0.45
	(7.31)	(7.83)	(3.31)*	(4.06)	(7.31)
Sector FEs	87	87	87	87	87
Year FEs	22	22	22	22	22
Observations	1914	1914	1914	1914	1914

* $p < 10\%$, ** $p < 5\%$. Standard errors clustered by sector in parentheses. Six regressions per column—each row is a new dependent variable. Dependent variables are cumulative growth rates, in percentage points, from 0 in 1980. All regressions weighted by sectoral value-added share (1980 observations weighted by 1980–1981 shares and plant growth variances).Independent variable is output-weighted sectoral average of 4-digit NIC1987 indicator of being opened to FDI in 1992 from Sivadasan (2009). Sample runs from 1980–2004.

But we obtain similar results to Tables 6, 7, 8 and 9 when we include several annual lags of the policy variables, or change the dependent variable from industry-year productivity levels to growth rates. Industry productivity trends apart from the reforms should be absorbed in the industry fixed effects when the dependent variable is industry productivity growth.

In Tables 10 and 11, we regress industry log productivity levels on all four reform variables simultaneously rather than one by one. Though there are concerns about the effect of multi-collinearity (particularly for policies that were changed in 1991) on

Table 9: Log productivity on De-reservation
Independent variable: Fraction of sectoral output de-reserved

	(1)	(2)	(3)	(4)	(5)
Noise weighting:	None	Plant noise	Sector noise	Both	Censored [-100, 100]
			A. $L \geq 200$ balanced panel		
Sectoral productivity	-4.03	-13.45	-53.37	-24.84	-3.64
	(47.15)	(55.62)	(86.15)	(66.60)	(46.98)
Plant efficiency	32.81	29.79	44.15	40.51	33.02
	(44.24)	(53.92)	(38.74)	(47.85)	(44.08)
Within-sector reallocation	-36.84	-43.24	-47.26	-63.60	-36.84
	(14.93)**	(17.74)**	(22.84)**	(26.67)**	(14.93)**
Sector FEs	74	74	74	74	74
Year FEs	22	22	22	22	22
Observations	1628	1628	1628	1628	1628
			B. Census balanced panel		
Sectoral productivity	21.55	16.18	-6.61	-0.35	20.78
	(34.49)	(38.42)	(62.68)	(63.06)	(34.90)
Plant efficiency	48.10	48.76	69.09	47.07	46.79
	(41.85)	(50.75)	(29.76)**	(47.64)	(42.96)
Within-sector reallocation	-26.55	-32.58	-48.97	-56.84	-26.55
	(19.70)	(25.36)	(16.60)**	(13.44)**	(19.70)
Sector FEs	87	87	87	87	87
Year FEs	22	22	22	22	22
Observations	1914	1914	1914	1914	1914

* $p < 10\%$, ** $p < 5\%$. Standard errors clustered by sector in parentheses. Six regressions per column—each row is a new dependent variable. Dependent variables are cumulative growth rates, in percentage points, from 0 in 1980. All regressions weighted by sectoral value-added share (1980 observations weighted by 1980–1981 shares and plant growth variances).Independent variable is output-weighted sectoral average of 5-digit ASICC product code—see Data Appendix for details. Sample runs from 1980–2004.

the standard errors in this specification, the results continue to suggest that industry productivity growth in the period 1980-2004 was not significantly related to industry reforms, at least statistically.

Now, absence of evidence is not evidence of absence. Our standard errors are sizable (tens of percentage points). We cannot reject the hypothesis of substantial productivity benefits of reforms. We therefore set aside the issue of statistical insignificance, and calculate the magnitude of the effects of policy changes between 1980 and 2004 (between 1987 and 2004 for tariffs) implied by the point estimates in Tables 6, 7, 8 and 9. This presumes causality. As a robustness check, we also consider the impact implied by the coefficients plus one standard error. This seems generous, probability wise, in that we do this for all of the coefficients at once.

Table 12 reports these calculations. For example, the opening up of 38% of output to FDI between 1980 and 2004 was generously responsible for an 11 percentage point increase in TFP over that period. Even if we consider the effect of all policy changes together, only 25-33% points of TFP growth can be explained. As Figure 4 shows, this is in the context of around 150% points of cumulative TFP growth from 1980 and 2004. Thus policy reforms seem to account for less than a quarter of cumulative TFP growth between 1980 and 2004 (33/150 < 0.25). It is in this sense that most of India's manufacturing miracle remains mysterious to us.

An important caveat here is that for our full 1980–2004 sample we only have 2-digit industry deflators. It is possible that 3-digit reforms raise productivity at the 3-digit level, but also lower the 3-digit deflator. Having policy measures more disaggregated (3-digit) than our industry deflators (2-digit) could be attenuating our estimated policy effects. To gauge the potential importance of this bias, we estimate policy effects on the 1980–1994 subsample for which we have 3-digit deflators. Figure A7 shows that the results are little affected: the estimated effects of policy are small relative to cumulative productivity growth.

Table 10: Log productivity on all policies, $L \geq 200$ balanced panel

	(1)	(2)	(3)	(4)	(5)
Noise weighting:	None	Plant noise	Sector noise	Both	Censored [-100, 100]
		A. Sectoral productivity			
Fraction de-licensed	1.94	0.19	-6.54	-8.26	1.75
	(9.20)	(9.72)	(6.91)	(7.13)	(9.13)
Tariff fraction	1.15	-0.17	1.28	3.73	0.97
	(7.93)	(9.47)	(5.48)	(6.89)	(7.94)
Fraction open to FDI	16.37	20.21	24.08	32.16	16.09
	(11.89)	(13.67)	(7.26)**	(8.04)**	(11.85)
Fraction de-reserved	6.65	2.59	10.09	-6.21	6.87
	(45.53)	(53.26)	(53.01)	(72.42)	(45.40)
		B. Plant efficiency			
Fraction de-licensed	2.28	-0.08	-3.12	-5.86	1.58
	(8.73)	(9.62)	(5.24)	(5.48)	(8.82)
Tariff fraction	1.68	0.66	4.06	8.98	1.28
	(7.52)	(8.90)	(5.77)	(6.49)	(7.53)
Fraction open to FDI	18.87	23.50	21.12	22.84	18.34
	(11.82)	(13.31)*	(5.33)**	(6.38)**	(11.84)
Fraction de-reserved	45.12	48.55	59.43	51.14	45.06
	(40.79)	(48.94)	(33.93)*	(46.64)	(40.75)
		C. Within-sector reallocation			
Fraction de-licensed	-0.34	0.27	-2.21	-3.58	-0.34
	(5.67)	(6.21)	(5.09)	(5.11)	(5.67)
Tariff fraction	-0.53	-0.83	-2.71	-0.53	-0.53
	(2.94)	(3.06)	(3.95)	(3.15)	(2.94)
Fraction open to FDI	-2.50	-3.29	3.47	1.66	-2.50
	(7.95)	(8.99)	(4.99)	(5.25)	(7.95)
Fraction de-reserved	-38.47	-45.96	-35.88	-54.98	-38.47
	(16.45)**	(19.79)**	(19.99)*	(23.16)**	(16.45)**
Sector FEs	74	74	74	74	74
Year FEs	22	22	22	22	22
Observations	1628	1628	1628	1628	1628

* $p < 10\%$, ** $p < 5\%$. Standard errors clustered by sector in parentheses. A single regression per column (with independent variables in the rows). Dependent variables are cumulative growth rates, in percentage points, from 0 in 1980. All regressions weighted by sectoral value-added share (1980 observations weighted by 1980–1981 shares and plant growth variances). Dummy variables (not shown) are included for all missing policy values, which are replaced with zeroes.

Table 11: Log productivity on all policy measures, Census balanced panel

	(1)	(2)	(3)	(4)	(5)
Noise weighting:	None	Plant noise	Sector noise	Both	Censored [-100, 100]
			A. Sectoral productivity		
Fraction de-licensed	10.66	8.33	0.62	-1.22	10.06
	(8.73)	(8.04)	(7.36)	(6.04)	(8.56)
Tariff fraction	2.45	3.08	4.06	1.82	2.41
	(7.01)	(8.00)	(6.93)	(5.02)	(6.98)
Fraction open to FDI	23.66	22.85	30.34	33.02	23.21
	(10.78)**	(11.07)**	(7.37)**	(6.51)**	(10.64)**
Fraction de-reserved	34.72	31.90	8.17	5.66	33.77
	(31.74)	(35.15)	(60.77)	(60.76)	(32.04)
			B. Plant efficiency		
Fraction de-licensed	7.29	4.06	-2.92	-4.39	6.03
	(8.04)	(8.35)	(5.11)	(5.30)	(8.18)
Tariff fraction	2.09	1.92	14.11	15.36	1.64
	(7.53)	(8.36)	(6.41)**	(6.70)**	(7.45)
Fraction open to FDI	22.60	21.63	18.57	16.72	21.75
	(10.24)**	(10.84)**	(5.02)**	(6.24)**	(10.19)**
Fraction de-reserved	61.17	64.38	75.71	69.78	59.53
	(37.94)	(46.11)	(27.66)**	(38.04)*	(39.12)
			C. Within-sector reallocation		
Fraction de-licensed	3.37	4.27	-0.95	-1.14	3.37
	(5.81)	(5.75)	(3.91)	(3.91)	(5.81)
Tariff fraction	0.37	1.17	0.84	-0.07	0.37
	(2.96)	(2.90)	(2.83)	(3.67)	(2.96)
Fraction open to FDI	1.06	1.21	2.82	1.06	1.06
	(7.87)	(8.48)	(3.68)	(3.85)	(7.87)
Fraction de-reserved	-26.45	-32.48	-39.46	-48.11	-26.45
	(20.29)	(26.15)	(9.16)**	(10.65)**	(20.29)
Sector FEs	87	87	87	87	87
Year FEs	22	22	22	22	22
Observations	1914	1914	1914	1914	1914

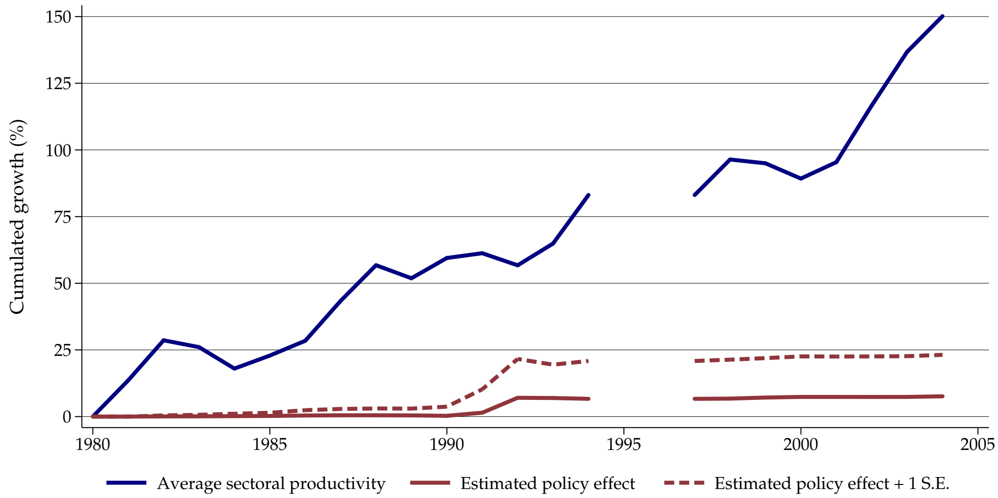
* $p < 10\%$, ** $p < 5\%$. Standard errors clustered by sector in parentheses. A single regression per column (with independent variables in the rows). Dependent variables are cumulative growth rates, in percentage points, from 0 in 1980. All regressions weighted by sectoral value-added share (1980 observations weighted by 1980–1981 shares and plant growth variances). Dummy variables (not shown) are included for all missing policy values, which are replaced with zeroes.

Table 12: Aggregate effects of policy reforms

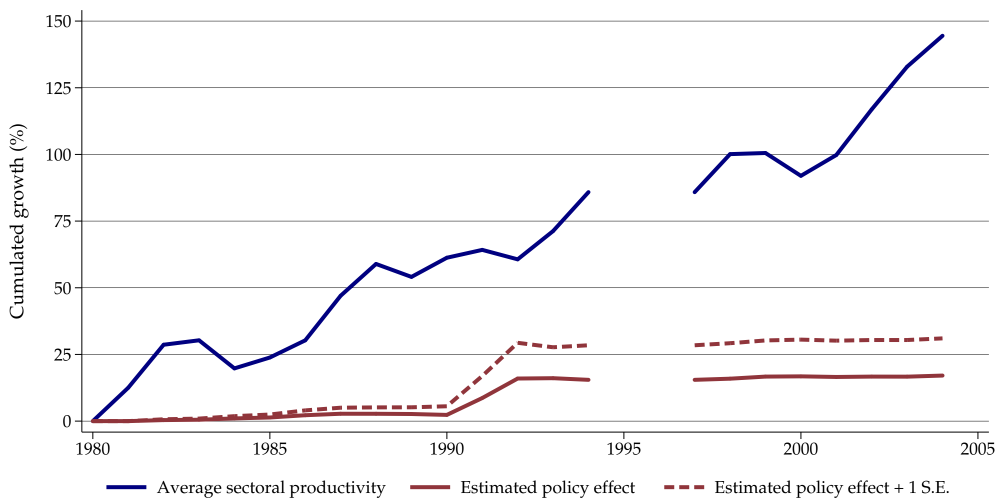
	Policy mean		Sectoral productivity		Technical efficiency		Within-sector reallocation	
	1980	2004	$\Delta \cdot \beta$	$\Delta \cdot (\beta + \sigma)$	$\Delta \cdot \beta$	$\Delta \cdot (\beta + \sigma)$	$\Delta \cdot \beta$	$\Delta \cdot (\beta + \sigma)$
A. $L \geq 200$ balanced panel								
Fraction de-licensed	0.12	1.00	-2.2	8.3	-2.4	6.0	0.2	5.0
Tariff fraction*	0.90	0.31	10.0	17.3	7.0	13.6	3.0	5.7
Fraction open to FDI	0.00	0.38	5.9	10.8	6.7	11.3	-0.8	2.2
Fraction de-reserved	0.966	0.973	-0.0	0.3	0.2	0.6	-0.3	-0.2
All policies			7.2	24.8	8.5	25.3	-1.2	8.6
B. Census balanced panel								
Fraction de-licensed	0.11	1.00	4.4	14.6	1.7	9.7	2.7	7.7
Tariff fraction*	0.93	0.31	5.0	10.7	2.3	7.7	2.7	5.4
Fraction open to FDI	0.00	0.36	7.3	11.3	7.2	10.9	0.2	2.8
Fraction de-reserved	0.963	0.968	0.1	0.3	0.3	0.5	-0.2	-0.0
All policies			16.6	32.6	13.6	29.2	3.0	12.9

* For Tariffs, the years are 1987 and 2000 (rather than 1980 and 2004) due to data limitations, and we use $\Delta \cdot \beta - \Delta \cdot \sigma$. Policy coefficients are taken from the first column of single-policy regression tables. "All policies" coefficients are taken from the first column of multi-policy regressions in Tables 10-11. 1980 means weighted by 1980-1981 value added shares, and 2004 means by 2003-2004 shares.

Figure 4: Average sectoral productivity, and estimated policy contribution



(a) $L \geq 200$ balanced panel



(b) Census balanced panel

"Estimated policy effect" plots the sum of cumulative aggregate changes in each policy multiplied by the effect estimated in Tables 10 and 11. "Estimated policy-effect + 1 S.E." does the same, except it takes as its "effect" the point estimate plus one standard error. Series re-initiated in 1997 at 1994 levels due to missing 1995 and 1996 data. All aggregate policy averages are weighted by the same annual value-added shares used to aggregate productivity (1980 observations weighted by 1980–1981 shares, and 1997 policy observations weighted by 1997–1998 shares). Policy effect series differ slightly from totals in Table 12 due to missing 1994–1997 and time-varying weights.

5 Conclusion

Using the Annual Survey of Industries, we document a substantial speedup in manufacturing TFP growth in India: our point estimate is over 6 percentage points for 1993-2004 vs. 1980-1992. This estimate is imprecise, as the standard errors are 2.5-3 percentage points, depending on the exact correction for heteroscedasticity. Almost all of this pickup arises from changes in plant efficiency over time, as opposed to reallocation of inputs across plants. And it can be seen in large, incumbent plants (over 200 workers) rather than coming disproportionately from smaller plants or net entrants.

As this rapid TFP growth occurred amidst a number of policy reforms in India, a natural question is whether reforms produced the manufacturing miracle. The truth may well be yes, but we could not confirm it. Those industries experiencing more liberalization (of licensing, tariffs, FDI, and size reservations) do not display faster TFP growth. Even if we raise all our policy impact estimates by one standard error at once, these reforms account for less than a quarter of cumulative TFP growth from 1980-2004, and none of the acceleration.

It is possible that liberalization made the miracle happen, but not in ways seen in measured growth at the industry level using our incomplete and imperfect reform indicators. This is our presumption. For example, growth outside the sector – say in human capital per worker or the service sector – may have fueled manufacturing's success. The wave of reforms may have triggered investments in skills or technology well in advance of their implementation in specific industries, and with benefits reaped well afterward. Even earlier policies protecting the manufacturing sector may have laid the groundwork by building a manufacturing base primed for a miracle. Our hope is that additional evidence on policies and productivity will clarify the role played by liberalization, which we very much presume to be positive.

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A Data Appendix

The ASI sampling population is all factories registered under Sections 2m(i) or 2m(ii) of the 1948 Factories Act: factories using power employing 10 or more (permanent, production) workers, and factories without power employing 20 or more workers. The Chief Inspector of Factories in each state maintains a list of registered factories, from which the ASI sampling frame is drawn.

All plants employing more than a threshold number of workers, along with plants in certain other categories, are surveyed each year—we call this the "census sample". Smaller plants are sampled randomly. Table A13 outlines how the census sample criteria changed over the period of our data. An observation is single plant for the fiscal year from April to March, with the exception that an owner of two or more establishments located in the same state, industry group and survey division (ie, census sample or not) is permitted to submit a single consolidated return.

To link-up annual plant observations into a panel, we algorithmically link up census sample observations in adjacent years pair-by-pair. To be matched, any two observations must be in the same state-by-industry cell (using 1975 state boundaries). Within each cell, we then attempt to find unique matches on the eight variables which are reported on a consistent basis in every year from 1980 to 2004. There are two static plant characteristics which we expect to remain constant over time: the year of initial production, and four plant ownership categories. We take one match variable as the interaction of these. (No other static plant characteristics are reported using the same definition in every year.) There are also six variables for which opening and closing

Table A13: ASI census sample criteria

1980-81 to 1986-87:	100 or more workers 50 or more workers with power All plants in 12 industrially backward states
1987-88 to 1996-97:	100 or more workers (with or without power) All plants in (same) 12 industrially backward states
1997-98 to 2003-04:	200 or more workers Selected "Significant Units" with fewer than 200 workers which "contributed significantly to the Value of Output" in ASI data between 1993-94 and 1995-96 All plants in (same) 12 industrially backward states All public sector undertakings
2004-05:	100 or more workers All plants in 5 industrially backward states

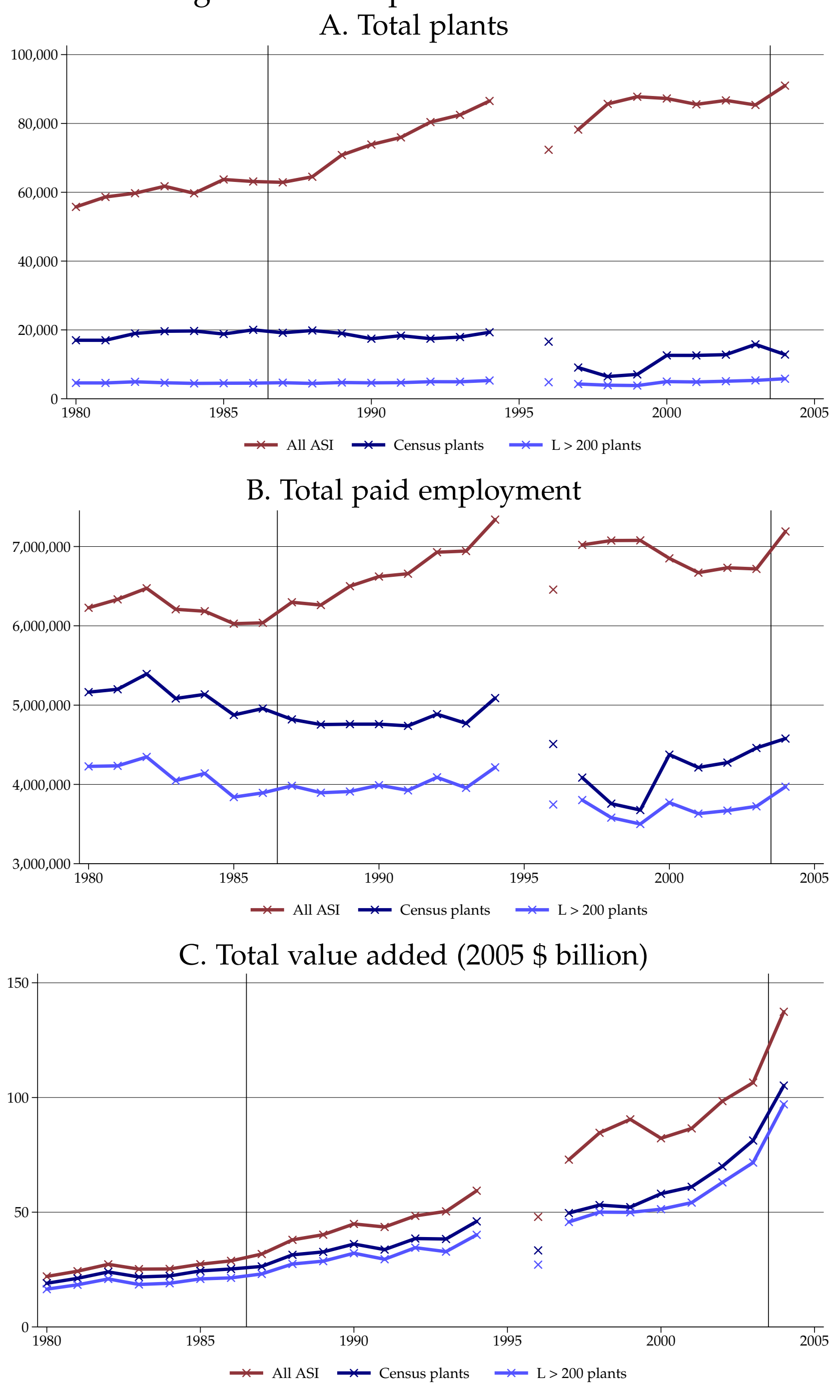
values are available in every year: fixed assets, working capital, raw materials, outstanding loans, finished goods and semi-finished goods. We try to match closing values to the opening values in the next year, rounded initially to six significant figures. Observations are never matched on the basis of sharing zero or missing values.

The algorithm proceeds as follows. For each year-to-year transition, within each state-by-industry cell, try to match observations which match uniquely on all seven matching variables. Next drop one matching variable at a time, starting with the variable with the most missing or zero values, and attempt to uniquely match remaining observations on six matching variables. Iteratively continue, dropping more variables (in the same order), but never match observations on fewer than four non-missing, non-zero variables (including state and industry). Next, round all opening/closing variables to one fewer significant figure, and repeat the above. In total, there are 720 iterations for each year-to-year transition.

All deflators come from the Reserve Bank of India's Handbook of Statistics on the Indian Economy. We use 2-digit output deflators together with a primary-sector deflator to construct industry-specific material deflators. To do this, we develop a concordance between our industry codes and the ASICC product codes reported for major inputs and outputs of each plant from 1996-97 onwards, and then use the information on the value of input products to construct input-output tables. For each industry-pair we take the median input-output share for these years, and then use this information together with the manufacturing output deflators and a deflator for non-manufacturing primary-sector output to construct an industry-specific materials deflator as a weighted average.

Total compensation—including benefits, bonuses and any in-kind payments—is only reported for all employees, and so we assign all non-wage compensation between skilled and unskilled workers in proportion to the plant's wage payments to each of these groups. Fixed assets growth is calculated from the difference between opening and closing balance sheet values.

Figure A5: Sample totals over time



All open manufacturing ASI plants with positive factors of production and output. Vertical lines indicate changes in sampling frame in 1987 and 2004. Gaps indicate missing data in 1995 and anomalous data in 1996.

B Robustness Appendix

Table A14: Previous estimates of productivity growth (%)

A. Hulten & Srinivasan (1999, Table 6)			
	1973–1992	1973–1982	1983–1992
Real Value Added	7.1	6.8	7.5
Labor	2.1	2.8	1.4
Capital	6.8	5.9	7.7
Total Factor Input	5.0	4.6	5.3
Total Factor Productivity	2.2	2.2	2.1

B. Bosworth & Collins (2008, Table 3 Industry series)			
	1978–2004	1978–1993	1993–2004
Output	5.9	5.4	6.7
Employment	3.4	3.3	3.6
Output per worker	1.4	1.3	1.5
Contribution to output per worker:			
Physical capital	1.5	1.4	1.7
Education	0.3	0.4	0.3
Factor productivity	0.6	0.3	1.1

B. Bosworth & Collins (2008, Unpublished Estimates: Industry series)			
	1980–1990	1990–2000	2000–2008
Output	6.2	5.6	8.1
Employment	3.6	2.2	3.7
Output per worker	2.5	3.3	4.2
Contribution to output per worker:			
Physical capital	1.6	1.9	1.6
Education	0.3	0.4	0.2
Factor productivity	0.5	1.1	2.4

In the World Development Indicators, the share of manufacturing in industry value added averaged only 61% from 1980 to 2007.

Table A15: Average annual growth rates over two periods using total-cost-based Divisia value added (%)

	1980 – 1992			1993 – 2004		
	ASI totals	Census panel	$L \geq 200$ panel	ASI totals	Census panel	$L \geq 200$ panel
Output	7.8	5.6	5.1	6.6	4.5	4.7
Value added	5.2	2.2	2.1	19.7	12.4	13.7
Fixed assets	10.1	3.1	3.3	5.2	1.5	1.4
Unskilled labor	0.5	-0.8	-0.8	1.0	-1.8	-1.8
Skilled labor	1.7	0.6	0.4	-0.2	-1.3	-1.3
Total factor inputs	3.5	0.6	0.7	2.4	-0.3	-0.3
Aggregate productivity	1.7	1.6	1.4	17.3	12.7	14.0
Plant efficiency		0.5	0.5		11.6	13.2
Reallocation		1.1	0.9		1.1	0.8

"ASI totals" are growth rates of annual aggregates, other columns are aggregated averages of plant-level growth rates. *Source:* ASI—see Data Appendix for sample construction details.

Table A16: Estimates of the annual trend in productivity growth, $L \geq 200$ panel

	(1)	(2)	(3)	(4)
Noise weighting:	None	Plant Noise	Sector Noise	Both
	A. Aggregate productivity			
Annual data	0.37	0.38		
	(0.21)*	(0.19)*		
	B. Plant efficiency			
Annual data	0.34	0.34		
	(0.19)	(0.18)*		
Sectoral data	0.34	0.34	0.38	0.43
	(0.17)*	(0.17)*	(0.14)**	(0.16)**
Plant data	0.34	0.34	0.44	0.46
	(0.17)*	(0.17)*	(0.18)**	(0.18)**
	C. Reallocation			
Annual data	0.03	0.04		
	(0.02)	(0.02)**		

* $p < 10\%$, ** $p < 5\%$. The dependent variable is $100 * (logTFP_{jt} - logTFP_{jt-1})$. Heteroskedasticity-robust standard errors, clustered by year and sector in sectoral data, and by year, sector and plant in plant data. (In the annual data, conventional standard errors are substantially smaller.) All p-values evaluated from t-distribution with 19 degrees of freedom. Sectoral and plant data regressions weighted by Basu-Fernald aggregation weights.

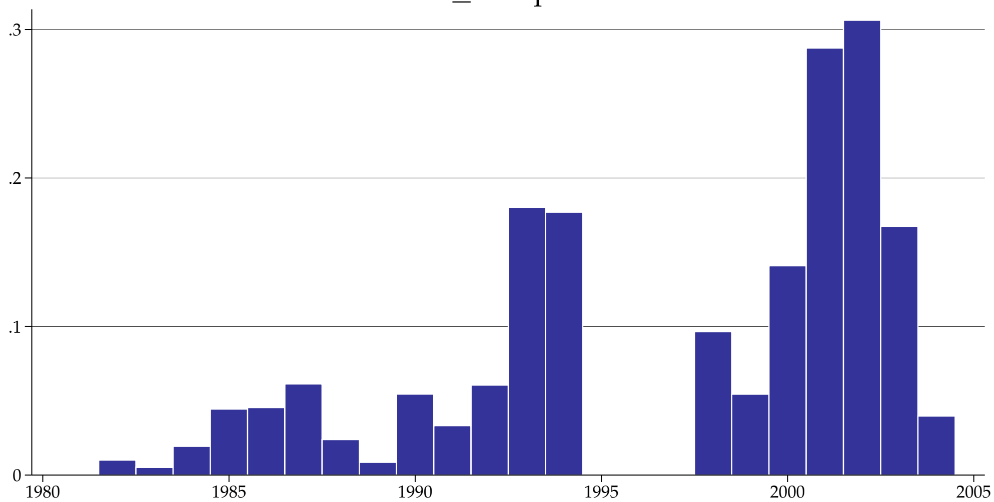
Table A17: Estimates of the annual trend in productivity growth, Census panel

Noise weighting:	(1) None	(2) Plant Noise	(3) Sector Noise	(4) Both
		A. Aggregate productivity		
Annual data	0.29	0.30		
	(0.19)	(0.18)		
		B. Plant efficiency		
Annual data	0.26	0.25		
	(0.18)	(0.17)		
Sectoral data	0.26	0.25	0.29	0.34
	(0.14)*	(0.13)*	(0.12)**	(0.12)**
Plant data	0.26	0.25	0.35	0.38
	(0.14)*	(0.13)*	(0.16)**	(0.16)**
		C. Reallocation		
Annual data	0.03	0.04		
	(0.02)	(0.02)**		

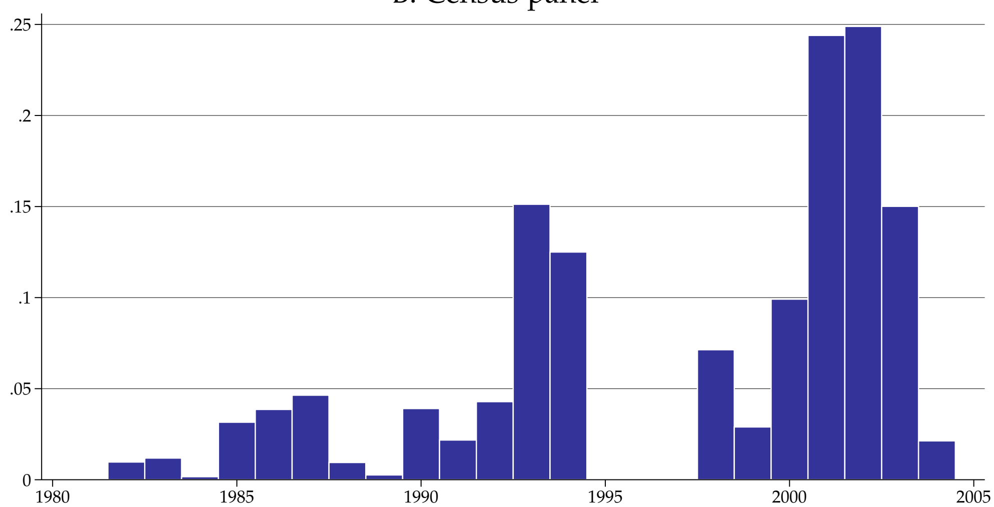
* $p < 10\%$, ** $p < 5\%$. The dependent variable is $100 * (logTFP_{jt} - logTFP_{jt-1})$. Heteroskedasticity-robust standard errors, clustered by year and sector in sectoral data, and by year, sector and plant in plant data. (In the annual data, conventional standard errors are substantially smaller.) All p-values evaluated from t-distribution with 19 degrees of freedom. Sectoral and plant data regressions weighted by Basu-Fernald aggregation weights.

Figure A6: R^2 of single breaks in aggregate productivity growth, by first post-break year

A. $L \geq 200$ panel



B. Census panel



Graphing R^2's from regressions of annual aggregate productivity growth on dummy for year $\geq x$ and a constant.

Table A18: Estimates of changes in aggregate productivity growth, $L \geq 200$ panel

				Automatic break-points			
	Mean	Trend	1993	1	2	3	4
Constant	6.10 (1.68)**	2.06 (2.51)	3.34 (1.95)	4.40 (1.66)**	4.99 (1.90)**	3.62 (1.93)*	4.34 (1.98)**
Year - 1981		0.37 (0.21)*					
1993 onwards			6.46 (3.22)*				
2002 onwards				11.90 (2.24)**			
1999 to 2000					-7.19 (1.91)**		
2001 onwards					9.43 (2.84)**		
1994 to 1998						10.30 (2.19)**	
1999 to 2000						-5.82 (1.94)**	
2001 onwards						10.81 (2.90)**	
1992 to 1992							-12.01 (1.98)**
1993 to 1998							7.28 (3.01)**
1999 to 2000							-6.54 (2.00)**
2001 onwards							10.09 (2.99)**
R^2	0.00	0.13	0.18	0.31	0.36	0.52	0.61
BIC	147.4	147.6	146.3	142.8	144.0	141.2	136.6

* $p < 10\%$, ** $p < 5\%$. Heteroskedasticity-robust standard errors in parentheses. 22 observations. Each regression has 22 observations. "BIC" is Bayesian Information Criterion—smaller numbers are better.

Table A19: Estimates of changes in aggregate productivity growth, Census panel

	Mean	Trend	1993	Automatic break-points			
				1	2	3	4
Constant	5.92	2.78	3.56	4.49	5.17	3.56	4.54
	(1.57)**	(2.34)	(1.86)*	(1.59)**	(1.79)**	(1.97)*	(1.88)**
Year - 1981		0.29					
		(0.19)					
1993 onwards			5.50				
			(3.04)*				
2002 onwards				9.99			
				(2.47)**			
1999 to 2000					-7.85		
					(1.79)**		
2001 onwards					7.89		
					(2.66)**		
1993 to 1998						8.02	
						(2.30)**	
1999 to 2000						-6.25	
						(1.97)**	
2001 onwards						9.49	
						(2.83)**	
1992 to 1992							-11.71
							(1.88)**
1993 to 1998							7.05
							(2.25)**
1999 to 2000							-7.23
							(1.89)**
2001 onwards							8.51
							(2.81)**
R^2	0.00	0.09	0.15	0.25	0.35	0.50	0.62
BIC	144.4	145.5	144.0	141.4	141.4	139.0	133.1

* $p < 10\%$, ** $p < 5\%$. Heteroskedasticity-robust standard errors in parentheses. 22 observations. Each regression has 22 observations. "BIC" is Bayesian Information Criterion—smaller numbers are better.

Table A20: Publicly- versus privately-owned plants

	$L \geq 200$ panel			Census panel		
	All years	1980–92	1993–04	All years	1980–92	1993–04
	Fraction public					
Plants	0.23	0.26	0.18	0.12	0.13	0.11
Value added	0.30	0.33	0.25	0.24	0.26	0.20
	Average plant efficiency growth					
Private	5.1	2.4	8.3	4.7	2.2	7.8
Public	5.7	2.9	10.7	5.1	3.2	8.4
	Contribution to aggregate reallocation					
Within	0.9	1.0	0.7	1.0	1.2	0.8
Between	0.0	-0.2	0.2	0.1	-0.1	0.3
Total	0.8	0.7	0.9	1.1	1.1	1.1

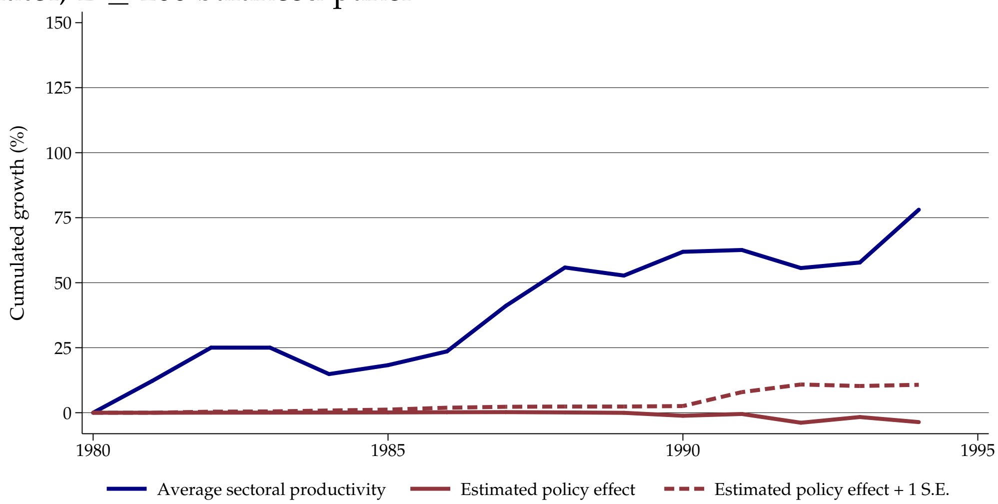
Panel plants categorized as at least partially publicly owned based on first year report, except 1988 and 1987 year reports not considered.

Table A21: Aggregate effects of policy reforms, multivariate version

	Policy mean		Sectoral productivity		Technical efficiency		Within-sector reallocation	
	1980	2004	$\Delta \cdot \beta$	$\Delta \cdot (\beta + \sigma)$	$\Delta \cdot \beta$	$\Delta \cdot (\beta + \sigma)$	$\Delta \cdot \beta$	$\Delta \cdot (\beta + \sigma)$
	A. $L \geq 200$ balanced panel							
Fraction de-licensed	0.12	1.00	1.7	9.8	2.0	9.7	-0.3	4.7
Tariff fraction*	0.90	0.31	-0.7	4.0	-1.0	3.5	0.3	2.1
Fraction open to FDI	0.00	0.38	6.2	10.6	7.1	11.6	-0.9	2.1
Fraction de-reserved	0.966	0.973	0.0	0.4	0.3	0.6	-0.3	-0.2
All policies			7.2	24.8	8.5	25.3	-1.2	8.6
	B. Census balanced panel							
Fraction de-licensed	0.11	1.00	9.5	17.2	6.5	13.6	3.0	8.2
Tariff fraction*	0.93	0.31	-1.5	2.8	-1.3	3.3	-0.2	1.6
Fraction open to FDI	0.00	0.36	8.4	12.2	8.0	11.7	0.4	3.2
Fraction de-reserved	0.963	0.968	0.2	0.4	0.4	0.6	-0.2	-0.0
All policies			16.6	32.6	13.6	29.2	3.0	12.9

* For Tariffs, presenting 1987 and 2000 means, and $\Delta \cdot \beta + |\Delta| \cdot \sigma$. All policy coefficients taken from first column of multi-policy regressions in Tables 10-11 1980 means weighted by 1980-1981 value added shares, and 2004 means by 2003-2004 shares.

Figure A7: Average sectoral productivity, and estimated policy contribution, using 3-digit deflator, $L \geq 200$ balanced panel



"Estimated policy effect" plots the sum of cumulative aggregate changes in each policy multiplied by the effect estimated in Tables 10 and 11. "Estimated policy-effect + 1 S.E." does the same, except it takes as its "effect" the point estimate plus one standard error. All aggregate policy averages are weighted by the same annual value-added shares used to aggregate productivity (1980 observations weighted by 1980–1981 shares).