ABSTRACT

Title of Document: MANUFACTURING SECTOR PRODUCTIVITY IN INDIA: ALL INDIA TRENDS, REGIONAL PATTERNS, AND NETWORK EXTERNALITIES FROM INFRASTRUCTURE ON REGIONAL GROWTH

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In this dissertation I examine sources of growth in the formal manufacturing sector in India, from 1970 to 2003. I consider both all-India trends and state-level trends in the growth of resource efficiency, measured by TFP, and the relative contribution of TFP growth to output growth in manufacturing, as compared to capital accumulation. At the state level, I also examine the relationship between per-capita income and trends in output per worker and TFP in the manufacturing sector. Finally, in a spatial econometric framework, I test for the presence and magnitude of network spillovers from infrastructure, including national and state highways, and electricity generation capacity, on manufacturing TFP levels across states.

My work contributes to an on-going debate on the response of manufacturing sector TFP to the implementation of economic reforms in India, in the 1980s and 1990s. At the regional level, this dissertation addresses not only the literature on the causes behind rising income inequality across states, but also on the role of infrastructure on regional growth, restricting attention to the manufacturing sector.

The results of this dissertation show that at the all-India level and at the state level, manufacturing sector TFP growth accelerated in India during periods of economic reform. The contribution of TFP growth to output growth increased in the 1990s relative to earlier periods, and exceeded the contribution of capital accumulation. At the state level, I find evidence of convergence in growth rates of output per worker and TFP in manufacturing. I do not find evidence of a significant correlation between output per worker in manufacturing and state per-capita incomes. Given the relatively small share of the manufacturing sector in state GDP on average, these results imply that the source of rising income inequalities across states may not be manufacturing. Finally, I find some evidence to suggest that there exist positive network spillovers from physical infrastructure on manufacturing sector TFP. The results suggest that doubling the stock of national and state highways, and electricity generation capacity can lead to a nine percent increase in manufacturing sector output.

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Dedication

I dedicate this dissertation to the memory of the late Janaki Mani Iyer, my grandmother, who raised and nurtured me, and to the late Ustad Ali Akbar Khan, who gave me spiritual succor during testing days of my dissertation.

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Chapter 1: Introduction

This dissertation examines the sources of growth in the formal[1] or "registered" manufacturing sector in India, between 1970 and 2003. It is an event study that addresses the on-going debate about the impact of economic reforms instituted in the 1980s and 1990s on the efficiency of resource use (typically measured as Total Factor Productivity or TFP[2]) in the manufacturing sector. Economic reforms coincided with an acceleration of overall economic growth[3], and particularly with output growth in the manufacturing sector, which increased from about 6 percent in the 1970s to more than 8 percent on average in the post-reform period. However, there is disagreement in the literature about the contribution of TFP growth to this acceleration in manufacturing sector output growth.

The economic and policy background against which this debate is situated helps to place this dissertation in context and motivates its questions. While rapid economic growth characterizes the overall achievement of the Indian economy in the past few

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[1] The formal sector refers to firms to that are registered under the Factories Act of 1948 and are subject to reporting requirements. For this reason, this sector is often referred to as the "registered" manufacturing sector. For the purpose of this dissertation, I use the terms "manufacturing" and "formal/registered manufacturing" interchangeably.

[2] TFP is identified with the Solow residual, and is typically measured as the excess of value added growth over the income-share weighted growth rate of primary inputs.

[3] The growth rate of GDP increased from about 3 percent per year in the 1970s, to between 5 and 6 percent in the 1980s and 1990s, and now over 7 percent in the 2000s.

years, the issue that is central in the minds of policy makers is <u>sustainable</u> growth. The latest budget document for the fiscal year 2010-11 states early in its preamble that the "first" economic goal is to sustain a growth rate of over 9 percent per year or higher, over the medium term[4]. Considering that the incidence of poverty is still very high in India[5], sustained high growth rates would play a crucial role in bringing down poverty in India, and for overall development. The budget document also highlights the "second" economic goal of inclusive growth. In various forms, the goal of inclusive growth has been a consistent feature of Indian development policy. This goal is often articulated in the form of balanced regional growth, a central tenet of development policy right from the first Five Year Plan for the years 1951-1956[6]. In the achievement of these objectives, namely sustained high growth balanced across regions, Indian policy makers have emphasized the importance of the manufacturing sector at various points, and physical infrastructure is understood to be a critical input in this regard (as discussed briefly below).

This forms the policy backdrop against which the questions and findings of this

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[4] http://indiabudget.nic.in/ub2010-11/bs/speecha.htm

[5] Estimates range from a low of 28.3 percent for 2004-05 as estimated by the Planning Commission to a significantly higher 37.2 percent estimated recently by the Suresh Tendulkar committee. There is a lively recent debate on the various poverty estimates due to their implications especially for food security policy. http://www.livemint.com/2009/12/13213528/The-poverty-estimates-debate.html

[6] The Plan states that "[T]he need for attaining a rate of investment ... which could form the basis of more rapid advances in the following years and lay the foundation for balanced regional development in the next planning period has been an important consideration in determining the development programme in this Plan."

dissertation may be interpreted. The need for sustainable growth raises the question of how it may be achieved, and for this purpose, sorting out sources of growth is important from a development policy point of view. If output and income (in growth and level terms) are driven by TFP, this suggests a policy response that encourages innovation and diffusion of new technologies, whereas factor accumulation led growth suggests policies aimed at raising the rate of savings and investment. Secondly, if capital is subject to diminishing returns and innovation-led growth is not, this has implications for the sustainability of growth in the long run. Efficiency growth may serve as the engine that drives sustained growth rates. However, this requires appropriate policies that may serve to accelerate the creation and diffusion of new ideas and innovations that can drive efficiency growth. In this regard, India experienced economic reforms in the 1980s and 1990s that paved the way for a transition from a state-led growth model to a market oriented model. In conjunction with the observed acceleration in economic growth, this has led to an examination of whether economic reforms were coincidental with acceleration in output and efficiency growth, in particular within the manufacturing sector.

On this issue, the debate on TFP growth in Indian manufacturing has largely been inconclusive. I re-examine this issue with methodological improvements in price measurement, and make use of a longer time series on manufacturing sector aggregates, that takes into several years into the post-1991 reform period. As a result of these efforts, I find that TFP growth in manufacturing indeed accelerated in the reforms era, both in the 1980s and again in the 1990s, and its contribution to manufacturing output growth also increased.

These results on TFP growth acquire importance when viewed against the literature examining cross-country sources. A growing body of evidence suggests that TFP is an important determinant of levels of development across countries, which justifies our focus. Hall and Jones (1999) find that the correlation between levels of TFP and output per worker (closely related to per-capita income) was 0.9, and that differences in TFP explain the major share of the difference in output per worker between the richest and poorest countries[7]. Klenow and Rodriquez-Clare (1997) show that more than half the difference in per-capita income levels and growth rates can be attributed to differences in TFP. More recently, Hulten and Isaksson (2007) show that differences in relative levels of TFP are the dominant factor accounting for differences in income per capita. They also find that TFP growth accounted for more than half the growth in output per worker in the Newly Industrialized Economies (NIEs) and other emerging Asian economies including India. This evidence contrasts the empirical findings of Mankiw, Romer and Weil (1992), and Allwyn Young (1995) that suggested capital accumulation as the main sources of growth[8].

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[7] Hall and Jones find that output per worker was more than 30 times higher in the five countries with the highest levels of output per worker than in the five countries with the lowest levels. Of this difference, a factor of more than eight was attributable to TFP, and about two for both capital intensity and capital per worker, which explains the rest of the difference.

[8] In this context, it is interesting to note that Hseih (1999) did not find declining rates of return to capital in the East Asian "miracle" economies, which should have been in

This study focuses to the manufacturing sector on account of the importance that has consistently been attached to it in India's development policy, despite its relatively small share in GDP[9]. The stated intention of policy makers and chambers of commerce to raise the share of manufacturing in GDP to 25 percent in the next few years signals this emphasis[10]. Limiting this analysis to the registered sector (as opposed to the entire manufacturing sector, which includes the informal/unregistered sector) is motivated by considerations of data. As the registered sector is subject to reporting requirements, a consistent time series on inputs and output are available, whereas data for the informal sector can problematic. In terms of coverage, registered manufacturing accounted for about 84 percent of total inputs, 82 percent of gross output, and 76 percent of gross value added in the entire manufacturing sector in 1999-00 (Ray 2004)[11]. The registered sector is not a major source of employment; the informal sector employs the major share of the total industrial workforce[12].

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evidence if growth in these countries was indeed driven by capital accumulation as suggested by Young (1995).

[9] About 17 percent of GDP, compared with 27 percent in Korea, and 43 percent in China (nominal terms).

[10] http://machinist.in/index.php?option=comcontent&task=view&id=1237&Itemid=2

[11] Ray uses ASI data for 1999-00 and National Sample Survey (NSS-56th Round) data for 2000-01. Note that Bosworth, Collins and Virmani (2007) place the share of organized manufacturing in sector GDP at 60 percent, not 76 percent as in the above study.

[12] According to Bosworth et. al. (2007), about 98 percent of manufacturing sector

The all-India level growth-decomposition exercise facilitates comparison with the extensive literature on the timing of growth in registered manufacturing. In addition to this, I extend the sources of growth framework to the regional (state) level[13]. This extension is motivated by the sustained emphasis on balanced regional growth in Indian development policy. The second Five Year Plan (1956-61) had, among others, the following main objectives – (i) growth led by rapid industrialization especially in basic and heavy industries and (ii) reduction in income inequalities and even spread of economic power, which was articulated in the form of balanced regional growth[14].

However, despite several years of emphasis on these objectives (extending up to the Eleventh Plan that is currently in sway) income inequalities have increased across Indian states. Figure 1 shows that the Gini coefficient for per capita state domestic

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employment is in the unregistered sector.

[13] The all-India aggregates for formal manufacturing sector used in this study are constructed from state-level series, as the sum of 17 major states, that account for 98 percent of the formal manufacturing sector.

[14] In early years of development planning, balanced regional growth was pursued through both state-led investment in industries as well as regulation/restrictions imposed on private activity, and through fiscal inducements. However, post-reform strategies place emphasis on private sector investment, and balanced growth objectives are articulated through policies such as establishment of Special Economic Zones (equivalent to the Export Processing Zones in China), whereby the state provides infrastructure to attract private industries. See Reddy, Prasad and Kumar (2009).

product has increased over time, according to Planning Commission estimates[15]. Moreover, the level of penetration of the manufacturing sector in state GDP is on average only around 12 percent, with most states falling below the average (Table 1).

Against this backdrop, this study inquires into the role of the manufacturing sector with regard to regional income inequality. It focuses on convergence across states in growth rates of output per worker as well as TFP, and examines whether these productivity measures have any relationship with per-capita state incomes. The results of this study show that there is indeed convergence in the growth rates of output per worker and TFP growth across states, especially in the 1980s and also in the 1990s. In the case of TFP growth, again convergence is observed strongly in the 1980s, whereas in the 1990s it appears that TFP growth rates across groups of states are very similar if not identical.

However, there is little correlation between a state's rank in terms of income per capita and its rank in manufacturing output per worker, indicating that the manufacturing sector has had little impact on income levels in states. Perhaps this is driven by the relatively low penetration of manufacturing in state economies. While I do find a positive correlation between TFP levels and per-capita income, I do not take this to indicate the effect of differences in manufacturing sector TFP levels across states on relative state incomes. TFP may well be influenced by levels of development, through the impact of income on health, education, and other

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[15] Eleventh Plan (2006-11), chapter 7.

environmental factors that are not directly related to the inputs and outputs of the manufacturing sector. In other words, the causation may run from income to TFP rather than vice-versa.

An important conclusion from the findings on regional growth in manufacturing is that if one is to examine the causes for widening income inequalities across states, then one may have to look at other sectors, namely agriculture and services, in order to explain the causes for divergent levels of income per capita. The results show that levels of output per worker do not correlate with state per-capita income levels, and growth rates of output per worker have converged. Further, given the low penetration of manufacturing in state GDP, it is unlikely that income inequalities have widened on account of the manufacturing sector.

In addition to the focus on regional inequalities, I also examine in parallel the contribution of TFP growth to state manufacturing sector output growth, relative to the contribution of inputs. This addresses the issue of sustainable growth, for even if manufacturing is currently small as a proportion of the state economy, its role is envisaged to expand, as mentioned above. I find that while TFP growth had relatively little role to play in the convergence of output per worker growth, its contribution to output per worker has indeed increased over time, and is now larger than the contribution of capital intensity to growth.

In the final part of this dissertation, I examine the impact of infrastructure provision on state manufacturing TFP levels in an econometric framework. Infrastructure provision is an important policy problem especially in India. Not only is it recognized as a bottleneck to high growth rates, in the context of balanced regional growth, infrastructure has consistently found a place of high importance development policy. In this regard, it is noteworthy that the 1st Five Year Plan (1951-56) recognized that in the absence of adequate ancillary services and social overhead capital, it would be difficult to woo investment to relatively less industrialized locations[16].

More generally, infrastructure is considered to be a critical input for development of the manufacturing sector. In the words of Albert Hirschman, private production activities cannot be undertaken without social overhead capital (infrastructure), including physical infrastructure such as roads and electricity, and services such as water, communications, public administration, education, and health. He assigns transportation and energy infrastructure to the "hard core of the concept" of social overhead capital, as "[I]t is widely assumed that enlarged availabilities of electric power and transportation facilities are essential preconditions for economic development practically everywhere."

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[16] First Five Year Plan, Chapter 29, paragraph 49. http://planningcommission.nic.in/plans/planrel/fiveyr/default.html

Not only does infrastructure have a role as a direct input in private production, but it may contribute to output growth via spillover benefits, over and above its contribution to growth as an input. To illustrate what is meant by such spillovers, take the case of physical infrastructure like roads[17]. Roads are a direct input for the transportation industry, when combined with trucks and drivers, produce transport services, which firms pay for, in effect paying for the infrastructure indirectly as embedded in the transportation services consumed by firms. In addition, good road networks may reduce travel time for all firms, as well as wear and tear on transport equipment, and help promote better inventory management, which may increase resource use efficiency for firms. Similarly, regular and high quality electricity may promote introduction of new technologies that require reliable power supplies, again increasing efficiency.

Moreover, physical infrastructure is often a spatial network, and a reduction in congestion in one state (due to an improvement in the stock of infrastructure *within* that state), may also reduce congestion in an adjoining state since road networks and traffic flow are linked spatially. Stated another way, a state may derive spillover benefits from the infrastructure stock of its neighbours. We may term these kind of benefits from infrastructure as “network spillovers”, which could be “own” spillovers when a state’s own stock of infrastructure increases (say) manufacturing output within that state, or “spatial” spillovers when output growth is impacted by changes in infrastructure stock and/or quality in adjoining states. It is these types of spillovers

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[17] This example is due to Hulten, Bennathan and Srinivasan (2006).

that are captured by TFP (for the registered manufacturing sector) whose presence we seek to establish.

Two points are worth emphasizing here. Firstly, the type of network effect whose presence we seek to establish are pure spillovers, over and above the contribution to growth (in registered manufacturing output) via infrastructure's role as an intermediate input. This should be kept in mind when interpreting the magnitudes of elasticities (of output to infrastructure stock) that we find in this study. Secondly, the effects, such as we do find here, only pertain to spillovers accruing to registered manufacturing, they exclude any such benefits that may accrue from infrastructure to any other sector in the economy.

If spillovers of this nature are significant, this has implications for infrastructure policy. Given the special characteristics of infrastructure goods, determining the existence and magnitude of infrastructure spillovers can be a useful exercise. Infrastructure goods are typically in the nature of public goods or club goods, provided outside the market mechanism through government spending. For goods provided through the market mechanism, it is believed that the private and social marginal benefits are equated, and the price reflects the entire benefit from the good. On the other hand, infrastructure goods are typically provided on a cost-benefit basis, and if significant network spillovers are not accounted for, the direct rate of return may understate the total benefit, leading to under-provision. Especially in the presence of spatial spillovers, this factor may have a bearing on how decisions for regional infrastructure provision are made.

The literature on infrastructure spillovers on growth is marked by considerable debate, with estimates ranging from very high, such as Aschauer's (1989) estimates for the US, to faint or non-existent. Also, the results are mixed in a cross-country setting; we refer the reader to Chapter 2 for a fuller discussion of this literature. Based on the empirical analysis presented here, there appears to be some evidence of spillovers from highways and electricity infrastructure in Indian states.

In this study I use the growth accounting methodology incorporating infrastructure spillovers developed by Hulten and Schwab (1991), and applied to Indian manufacturing sector data in Hulten, Bennathan and Srinivasan (2006), hereafter referred to as HBS. The main contributions of this study are as follows. Firstly, I extend the time period of the HBS study to take into account several years of data in the important post-1991 economic reform period. The HBS study extends from 1973 to 1993, which leaves an opportunity to explore in more depth what happened to manufacturing sector growth several years into the second wave of economic reforms. Secondly, I expend considerable effort to address the issue of price deflation, as it is clear from the literature that different assumptions about underlying prices can lead to qualitatively very different results on sources of growth, thus making it difficult to draw conclusions about the pattern of TFP growth in Indian manufacturing. The reader is referred to an extensive discussion of the methodology employed to construct price deflators in this study, in Chapter 3 (sections 2 and 3), and the

Appendix. Finally, I extend the work done by HBS in studying network spillovers from infrastructure on manufacturing sector growth, by implementing spatial econometric techniques developed by Kelejian and Prucha (1998, 1999), that allow us to test not only for the presence of own spillovers and spatial spillovers. To the best of my knowledge, this is the first such application of spatial econometric techniques to data from Indian states.

WHY INDIA

India is an important country to study from a development perspective, given that despite rapid economic growth, it still houses a third of the world's poorest, and ranks 122nd in the world on per-capita income. As a case study, its regions are heterogeneous in terms of geography, ethnicity, and socio-economic structure, but at the same time share common institutional features and statistical systems, that render it relatively free of problems that make comparisons and interpretation difficult in a cross-country setting. Thus, India is sufficiently large and diverse, and at the same time homogenous to the extent that may allow the findings of such a study to have some general validity (HBS 2006).

India also underwent a shift in its approach to development policy, over a period that falls within the time-frame of this study. In the early years of post-Independence development policy, the main vehicle for implementing development strategies was central planning. The emphasis lay on import substitution, and development of domestic capacity in heavy industries, as documented in the Second Plan (1956-7 to 1960-1), also known as the Nehru-Mahalonobis plan after its main architects. The Plan also placed emphasis on balanced regional growth that was to be pursued both through incentives and through restrictions on industrial scale and location. This period was characterized by strong presence of the state in production activities, directly through state owned enterprises and indirectly through industrial licensing, quotas and permits, and import controls, all of which combined to restrict the scope of activity in the private sector. On account of the restrictive nature of controls, this period is often referred to as the License-Quota-Permit Raj, evoking British colonial rule in India.

Subsequently, economic reforms were initiated in the 1980s, largely aimed at the manufacturing sector, involving partial de-licensing and deregulation of industries, along with a measure of import liberalization[18]. These were followed by another wave of reforms, after a balance of payments crisis in 1990-91, in which virtually all manufacturing industries were de-licensed, along with further relaxation of controls on imports of capital goods and inflows of foreign direct investment. Conventional wisdom suggests that freeing up the private sector would results in absorption of new technologies through imports, and encourage innovation spurred by fewer entry

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[18] Ahluwalia (1991) noted that: "[T]he most important changes have related to reducing the domestic barriers to entry and expansion to inject a measure of competition in domestic industry, simplifying the procedures, and providing easier access to better technology and intermediate material imports as well as more flexibility in the use of installed capacity with a view to enabling easier supply response to changing demand conditions."

restrictions, which would be captured in higher TFP. The results on the timing of TFP growth thus provide indirect evidence on the efficacy of market-oriented reforms in India.

To summarize, this dissertation consists of 3 inter-related sections. The first section is a sources of growth analysis of the registered manufacturing sector at the all-India level. The second section carries this analysis to the state level, and also examines the relationship between output per worker and TFP in manufacturing and per capita state incomes. The final section looks at a policy issue, namely infrastructure provision, and tries to ascertain the presence and magnitude of network spillovers from infrastructure on state level manufacturing growth, in a spatial econometric framework.

The plan of this study is as follows. In Chapter 2, I review the literature on the three central questions of this dissertation. In Chapter 3, I undertake the sources of growth decomposition, laying out the model, describing the data, and discussing the all-India and state level results. Chapter 4 is devoted to network spillovers from infrastructure. This section includes data description and preliminary explorations, a description of the econometric model, and a discussion and interpretation of the results. Chapter 5 concludes.

Chapter 2: Literature Review

2.1. Sources of growth in all-India manufacturing

Table 2 summarizes various results on trends in TFP growth (TFPG) in registered manufacturing, especially whether the acceleration (if any) coincided with economic reforms. Evidently the literature is not conclusive. Ahluwalia (1991) was one of the first to document a turn-around in TFPG from negative to positive in the 1980s, which she attributed to liberalization policies. Similar evidence of a turn-around was found by Dholakia and Dholakia (1994). However, Balakrishnan and Pushpangadan (1994) – hereafter referred to as B-P – pointed out methodological problems in Ahluwalia's procedure, and using an alternative procedure of estimating real value added[19], showed that TFP growth in manufacturing decelerated in the 1980s, a result which stood at odds with the liberalization efforts of the day.

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[19] The debate over deflation methodology is really a debate over pricing intermediate inputs when estimating real value added from gross output data. In "single deflation", both gross output and intermediate input prices are assumed to grow at the same rate. But if intermediate input prices grow faster than output prices, real value added growth is under-estimated relative to its true rate (and vice-versa if intermediate input prices grow slower than output prices. B-P (1994) showed that output and input prices growth often diverge in the data. They adopted an alternative procedure known as double deflation, whereby gross output and gross intermediate inputs are separately deflated by two different price indices. The latter has to be constructed from several input price indices, to reflect the basket of intermediate inputs used by the manufacturing sector. They thus used input-output data on commodity flows to intermediate input consumption in the manufacturing sector for 1973-74, and derived a set of weights with which to combine intermediate commodity's price series into an aggregate intermediate price index, which was then used to estimate real intermediate input growth. However, double deflation is also not free of bias (see Rao 1996).

Since both the Ahluwalia and B-P procedure for estimating TFPG is potentially biased, Rao (1996) used the Tornqvist-Divisia procedure for estimating the productivity residual based on the Solow-Jorgenson-Griliches growth model that at the sectoral level, takes the form of a "KLEMS" model, an acronym for capital-labour-energy-materials-services. We refer to this measure as "total productivity" or TP, to distinguish it from the TFP concept that is based on value added and is suitable to analyze the aggregate economy[20]. TP is derived as the income share-weighted difference in real gross output growth and the growth rate of real primary and intermediate inputs, which includes energy, materials, and services. Unlike the value-added based model, productivity changes impact not only primary inputs, but also intermediate inputs in the KLEMS framework. This feature of the model makes it particularly suitable in the context of developing countries, where shocks to intermediate inputs can impact manufacturing output. Hence, economies from intermediate inputs may be a significant source of productivity growth. Using this framework, Rao also finds that TP growth decelerated in the 1980s.

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[20] At the level of aggregate economy, the consumption of intermediate goods is equal to their output, and thus intermediate flows cancel out. From the national income accounting identity, GDP equals gross domestic income (GDI), which equals the income of labour and capital. Hence TFP, which measures the excess of real value added growth over the income-share weighted growth of primary inputs, is appropriate at the level of the aggregate economy. However, at the industry/sector level, it is not necessary that purchases of intermediate inputs equal to sales of intermediate outputs. Thus the appropriate underlying production is a gross output function that includes intermediate inputs. Moreover, the efficiency parameter in the gross-output framework is typically modeled as augmenting not only primary inputs but also intermediate inputs, which can also be a significant source of efficiency. For a detailed discussion on this issue, see Hulten (2009).

A feature of both B-P (1994) and Rao (1996) is that their intermediate input price deflator uses fixed base weights, derived from one single year of input-output information for the Indian economy[21]. This is equivalent to a fixed-base weighting scheme, and thus subject to the criticisms that apply to such indices. Specifically, fixed weights derived from only one year of information on the flow of goods may miss out on changes in the underlying structure of inputs and outputs over time. To get around this problem, using state-level manufacturing data, HBS (2006) constructed a price deflator that varies by time and state[22], and find that TP growth remained more or less unchanged in the pre and post-reforms periods.

Hence, the spectrum of results covers acceleration, stagnation, and deceleration in manufacturing TFP in the 1980s relative to the 1970s and earlier. A big boost to liberalization efforts came in 1991, in the wake of a balance of payments crisis, leading to a bigger push towards market oriented economic policies, including widespread de-licensing and deregulation of industry, and further liberalization of the current account. A fresh literature emerged re-examining the timing of growth

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[21] Input-output tables for the Indian economy are generally available every five years, starting from 1973-74.

[22] They derive implicit input prices at the 2-digit industry group level by assuming that within each industry group, the ratio of real input to real output is constant, and given this constant and the price of output, the implicit price of intermediate inputs at each industry group level can be determined, and aggregated to the all-manufacturing level using the relative weights of intermediate consumption in the given industry groups.

question, and again, while new methodological issues came to light, the results as to trends in productivity growth in manufacturing were inconclusive. For example, Unel (2003) uses the value added framework and finds manufacturing TFP growth to have accelerated in the 1990s compared to the 1980s. On the other, Goldar (2007), and Banga and Goldar (2007), using the gross output framework, find the opposite trend. Notwithstanding the mixed results, the potential importance of the role of services as an intermediate input was brought to light as a methodological issue. In previous studies, services prices were not included in measures of intermediate input prices, but over time, services have gained in importance as intermediate inputs, and therefore pricing intermediate inputs accurately requires that the weight of services be factored in. Banga and Goldar (2007) show that if the contribution of services is not taken into account, this leads to an overstatement of productivity growth in the post-1990s period, perhaps on account of the faster growth of services-use in the 1990s relative to the 1980s.

The results discussed above are confined to the registered or formal sector within manufacturing, consisting of firms registered under the Factories Act of 1948, which are subject to reporting requirements. Bosworth, Collins and Virmani (2007) point out that although this sector accounted for 60 percent of manufacturing output in 1999-00, bulk of manufacturing sector employment lies within the unorganized or informal sector, accounting for as high as 98 percent of manufacturing employment. For the manufacturing sector as a whole (including both registered and unregistered manufacturing), they find that TFPG is distinctly higher over 1980-2004, compared to the 20 years prior. They also find TFPG slowed down in the 1990s, though it picked up again after 1999[23].

Taken as a whole, the literature on All-India manufacturing TFPG is not conclusive about trends in the post reform period. However, it identifies a variety of issues that need to be addressed while estimating TFP growth, as highlighted above. In this study, we synthesize the lessons from the literature in a number of ways. Firstly, we adopt the Tornqvist-Divisia (T-D) index numbers procedure for estimating TP growth based on a gross output framework that includes intermediate inputs, and allows the productivity parameter to enhance all inputs, including intermediate inputs. Our use of this framework helps to guard against the biases that may creep into TFPG estimates due to single or double deflation. Secondly, we adopt a flexible weighting strategy for pricing intermediate inputs, and derive the weights by using several years of commodity-flows information for the Indian industrial sector. Thirdly, we incorporate the services sector in a KLEMS model, in view of its increasingly important role as an input. The methodology is described in more detail in Chapter 3 as well as the Appendix.

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[23] Bosworth et. al. (2007) assume fixed shares for capital and labour in value added, according to proportions that are observed in OECD countries (60:40 share for labour and capital respectively). This is important, since the growth rates of capital and labour may differ significantly in different periods, the choice of factor shares can have a strong influence on measured TFPG. Their choice may be justified owing to their coverage of both the organized and unorganized sector, as reliable data are difficult to find for the latter. In our case, we do not make this fixed shares assumption, since we deal only with registered manufacturing, which presumably has better quality data.

2.2. Regional growth and infrastructure

Given the variation in regional development levels, development plans have consistently emphasized balanced regional growth[24], and industrialization was given an important role in this objective. Prior to liberalization, industrial location policies were pursued with a combination of fiscal incentives to industrialize so-called "backward" areas, and industrial licensing and quota restrictions that prevented already industrialized regions from entering markets and expanding scale freely. Over time, it was recognized that this approach might be detrimental to overall growth, as articulated in the Sixth Plan (1980-85): “[I]t should be generally accepted that the fulfillment of the objective *[of balanced regional growth]* required upgrading the development process in backward regions rather than curtailing the growth of these regions that have acquired a certain momentum.” Current planning strategies have evolved considerably, now emphasizing inter-state competition for investment, and improvement in governance to create an enabling climate for industrialization[25].

Despite the focus on balanced growth, and notwithstanding the shift in strategy, regional income inequalities have widened in the post-reform era, as acknowledged in the current (Eleventh) Plan. This has raised concerns that the shift in approach to

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[24] This objective finds mention in virtually all Five Year Plans. See Balanced Regional Development in India - Issues and Policies, Anita Kumar (ed.), 2006, for excerpts on balanced regional growth policies and problems, covering the First Plan to the Tenth Plan (spanning 1950-2007).

[25] See Chapter 7 of the latest (Eleventh) Plan document.

regional development might contribute to widening income inequalities. A recent study by Misra (2007) focuses on inequality in the post-reform period, and finds that inequality in per-capita state domestic product (SDP) worsened over the 1980s and 1990s (Gini-coefficient rising from 0.14 in 1981 to 0.18 in 1995), and after 1995 this gap has not narrowed. This lends support to the rising inequality documented by the Planning Commission study as seen in Figure 1.

In this context, infrastructure is often identified as both a cause and a solution for the problem for regional income inequalities. Testing for sigma convergence[26] in income in Indian states, Ghosh and De (1998) found an increase in the coefficient of variation in state per-capita income, and a high correlation between an index of state infrastructure[27] and per-capita income. They also find that the position of states relative to national average per-capita income, and the relative position of states in terms of infrastructure provision has remained unchanged over 1971-1994, implicitly attributing to lack of infrastructure provision, the failure of state incomes to converge. In another study, using state level manufacturing sector data from 1976-1992, Mitra, Varoudakis and Veganzones (1998) finding that infrastructure[28] has a significant

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[26] Sigma convergence is said to occur when the dispersion (in income) falls over time.

[27] Constructed by principal components.

[28] Their measure is a composite indicator constructed using principle components, including core infrastructure, services infrastructure, and human capital. They include measures of electricity, roads, railways, vehicles per capita, postal system, primary and secondary education enrolment, infant mortality, bank branches per 1000

positive impact on TFP growth in 14 out of 18 industry groups. HBS (2006) find evidence of a positive elasticity of manufacturing sector growth to highways and electricity generation capacity.

The interest in spillover effects from infrastructure was sparked by the finding by Aschauer (1989) that a one percent increase in the stock of public capital in the US led to a 0.4 percent increase in private output. Based on the stock of public capital and value of private output, this implied that an investment of US $10 billion in infrastructure would produce an additional US $7 billion in GNP the following year, and that public capital is 4 times more productive than private capita, at the margin. However, Munnell (1990b) estimated the direct contribution of infrastructure stock to private output using pooled state data, and found a significant, though much smaller elasticity of 0.15 percent.

This difference in the aggregate and panel estimates was attributed to the presence of infrastructure externalities that may not be captured in state level data. However, Hulten and Schwab (1984, 1991) found no evidence that regional differences in productivity were driven by differences in stocks of public goods; in fact they found that productivity levels and growth rates were quite similar across reasons, implicitly ruling out any explanatory role for infrastructure. Holtz-Eakin and Schwartz (1995) also found no evidence of spatial spillovers from US national highways on state level

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population, and deposits and loans as percent age of income.

private output growth.

There is some evidence of spatial spillovers in other countries. Pereira and Roca-Sagales (2002) estimate a 5.5 percent rate of return to public capital at the national level in Spain, and a significantly positive return in 14 out of 17 Spanish regions. Similar to Munnel's findings about the US, they also find that the sum of regional estimates (based on within-region stocks on infrastructure) account for less than half of the total effect of public capital, as estimated at the national level. Upon allowing for spatial spillovers, this sum exceeds the national estimate. In cross-country data[29], Canning and Fay (1993) estimate normal to high returns from public capital in industrial countries, high returns in industrializing countries, and low returns in under-developed countries, suggesting that countries with relatively low infrastructure stocks get higher returns from additional stocks, as opposed to developed countries that already have dense infrastructure networks[30].

The evidence on developing countries suggests there may exist sizable infrastructure benefits within Indian states, since India as a whole is an infrastructure-shortage country. However, spillovers effects such as spatial spillovers may be

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[29] See Gramlich (1994) for a review of the literature.

[30] This point was earlier made by Hulten, (commenting on Munnel 1990b), that "adding to an existing [infrastructure] network will rarely have the same return [as constructing the original network]: at the some point, the increasing returns to scale aspects of infrastructure are exhausted, and...marginal additions bring increasingly smaller benefits."

harder to detect. Indian states can be quite large in terms of area and certainly in terms of population, comparable to the largest European countries. For example, the population of one of the most industrialized states (Maharashtra) is over 96 million, and its land area is over 310,000 sq km. It compares with Germany, which has a population of 82 million, and a land area of more than 350,000 sq km. To put the problem in perspective, searching for spatial externalities across Indian states is equivalent to searching for them across large European countries, and it is possible that over such vast areas, these effects tend to diminish and may be difficult to detect. This may limit the strength of our results.

Chapter 3: Sources of Growth

3.1. Theory

We adopt a non-parametric index-number approach to measuring manufacturing sector efficiency[31]. We implement the model developed for the US by Hulten and Schwab (1991), and applied to Indian manufacturing sector data by HBS (2006). The model relates gross manufacturing output to primary and intermediate inputs, and a Hicks neutral shift parameter that captures efficiency. This is the "KLEMS" framework, which is the form taken by the Solow-Jorgensen-Griliches framework for estimating resource efficiency as one moves from the aggregate economy to the sectoral level. As mentioned earlier, we refer to the measure of resource efficiency derived from this model as Total Productivity or TP. The shift parameter is modeled as a function of infrastructure stock[32]. The production function can be written as:

Suppose $Q_{i,t} = A_i(t)F(K_{i,t}, L_{i,t}, M_{i,t}, B_{i,t}),$ and this production function exhibits constant returns to scale over the private inputs. Then, under the assumption of competitive markets where each private factor is paid its marginal product, the growth rate of the residual can be expressed as $\dot{A}_t = \dot{Q}_t - \pi_K \dot{K}_t - \pi_L \dot{L}_t - \pi_M \dot{M}_t,$

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[31] As opposed to assuming a specific functional form for the manufacturing sector production (gross output) function and estimating its parameters, we disaggregate the sources of growth based on the contribution of each input to real output growth.

[32] Hulten and Schwab (1991) discuss the issues and implications of this formulation for the role of infrastructure. In this form, infrastructure is an "environmental" factor that can enhance the efficiency of any or all inputs, and captures its indirect or spillover impact on manufacturing output growth. Infrastructure can also directly contribute to growth as a paid input, and should thus be an argument in the production function.

$$(1) \qquad Q_{i,t} = A(B_{i,t}, t)F(K_{i,t}, L_{i,t}, M_{i,t}),$$

where $Q_{i,t}$ represents real gross output in state i in year t, $K_{i,t}$ and $L_{i,t}$ represent capital and labour stocks, and $M_{i,t}$ is real intermediate inputs, including materials, fuels and power, and services. $A(\cdot)$ captures exogenous changes in efficiency that shift the production function, and $B_{i,t}$ is the stock of infrastructure in state i at time t. The term also contains an independent time variable t to capture autonomous technical progress. We can give this function a specific functional form as follows:

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where $\pi_X = A_i(t) \cdot \frac{F_X(t)X_i(t)}{Q_i(t)} = A_i(t) \cdot \frac{P_i^X(t) \cdot X_i(t)}{P_i^Q(t) \cdot Q_i(t)}$. But if the production function does not show constant returns to scale over private inputs (e.g., it shows constant returns over private and public inputs), then the omission public capital leads to two sources of bias. The first source is the contribution of public growth to output growth, analogous to the contribution to growth of private inputs. This is equal to $\varepsilon_{i,t}^B = A_i(t) \cdot \frac{F_B(t)B_i(t)}{Q_i(t)}$. The second source of bias comes from the fact that the price of private capital is not observed, but imputed by assuming constant returns to private inputs, and ignoring public capital.

Thus, $P_i^K(t)K_i(t) = P_i^Q(t) \cdot Q_i(t) - P_i^L(t)L_i(t) - P_i^M(t)M_i(t)$. However, the residual attributed to private capital's share in income also includes the share of public capital, as an unpaid input $B_i(t)$. Thus the share of private capital is over-estimated, introducing a bias. Note that if the production function does exhibit constant returns to private inputs, then this source of bias vanishes. In the case of Indian manufacturing, Fikkert and Hassan (1998) have shown that by and large Indian industry shows constant returns to scale, mitigating our concerns of bias from this source.

There remains the possibility of infrastructure being a direct input into manufacturing. Like Hulten and Schwab (1991), I assume that the manufacturing sector buys intermediate inputs (services) from service-producing sectors such as transportation and communications, which in turn consume infrastructure as a direct input. Hence infrastructure is an indirect input for manufacturing industries.

(2) $$Q_{i,t} = A(\cdot)L^{\alpha}_{i,t}K^{\beta}_{i,t}M^{\gamma}_{i,t},$$

where $\alpha + \beta + \gamma = 1$. Hence we assume that the production function exhibits constant returns in the private inputs. Taking logs, differentiating with respect to time, and rearranging, we obtain the Divisia index for TP growth:

(3) $$\dot{TP} = \tfrac{\dot{A}}{A} = \tfrac{\dot{Q}}{Q} - \alpha\tfrac{\dot{L}}{L} - \beta\tfrac{\dot{K}}{K} - \gamma\tfrac{\dot{M}}{M},$$

Under the assumption that factors are paid their marginal products, the elasticity parameters α, β, γ can be estimated as the share of input costs in gross output, i.e. $\alpha = \frac{wL}{pQ}$, $\gamma = \frac{p_M M}{pQ}$ where p_M is the price of intermediate inputs, and $\beta = 1 - \alpha - \gamma$ is the share of private capital income[33]. This is a continuous time index of TP growth, but we use its discrete time approximation known as the Tornqvist-Divisia (TD) index:

(4) $$\Delta \ln TP_{i,t} = \Delta \ln Q_{i,t} - \sum_{j=K,L,M} \pi_{i,j} \Delta \ln X_{i,j},$$

where Q_i is real gross output, $X_{i,j}$ is the level of (real) input j (labour, capital, and

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[33] Our estimate of capital stock is a Divisia aggregate of sub-components, based on ASI data on nominal investment in structure, and plant, machinery and equipment. Details are provided in the Data section of this chapter.

intermediate inputs), and $\pi_{i,j}$ is the share of the jth input in gross output, calculated as the average of the share in two adjacent periods[34].

Let p_t and μ_t be the price of output and intermediate inputs respectively in period t. Divisia indices of real output and intermediate input growth were obtained as:

(5) $\Delta \ln Q_{i,t} = [\ln(p_t Q_{i,t}) - \ln(p_{t-1} Q_{i,t-1})] - [\ln(p_t) - \ln(p_{t-1})]$, and

(6) $\Delta \ln M_{i,t} = [\ln(\mu_t M_{i,t}) - \ln(\mu_{t-1} M_{i,t-1})] - [\ln(\mu_t) - \ln(\mu_{t-1})]$

These growth rates are substituted back in (4) to obtain TP growth rates. An index is then constructed by incrementing (decrementing) using these growth rates and a base year.

For the regional analysis, we also estimate TP levels using the procedure developed by Jorgenson and Nishimizu (1978) and generalized by Caves-Christensen-Diewert (1982), whereby the estimated growth rates of TP are applied to a base year estimate of the TP level of each state, which is relative to the all-India

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[34] For example, the share of labour in year t is calculated as:
$\pi_{L,t} = 0.5[\pi_{L,t} + \pi_{L,t-1}]$
where $\pi_L = wL / pQ$

average level. An estimate of the base year level is obtained as:

$$(7) \quad \ln \tfrac{TP_i}{TP^*} = \ln \tfrac{Q_i}{Q^*} - \overline{\pi}_K \ln \tfrac{K_i}{K^*} - \overline{\pi}_L \ln \tfrac{L_i}{L^*} - \overline{\pi}_M \ln \tfrac{M_i}{M^*}$$

where starred variables are Divisia indices of all-India output and inputs, and $\overline{\pi_j}$ is the arithmetic mean of the share of expenditure on input j in state i, and the corresponding all- India share[35]. Finally, we normalize the state-wise estimates by $\overline{TP_0}$, the average level in 1970, our base year. This base year productivity relative is then incremented (decremented) by the TP growth rates estimated above.

3.2. Data

Data on manufacturing is taken from the Annual Survey of Industries (ASI) of the Central Statistical Organization (CSO), which covers all establishments (factories or units) registered under section 2m(i) and 2m(ii) of the Factories Act (1948). This includes factories employing 10 or more workers and using electricity, or 20 or more workers without electricity, on any day of the preceding 12 months. The population of eligible factories is split into a census sector and a sample sector for which the

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[35] This method was employed by HBS (2006). Banga and Goldar (2007) estimated TP levels normalizing by geometric averages of the Divisia indices of state output and inputs. We also experimented with this method and found very similar results to those obtained by the former method.

sampling probability has been revised at different points in time[36]. Therefore, while certain medium and large factories figure consistently in different survey years, those in the sample sector change over time.

There have been three revisions to the industrial classification system since the first sample year (1970), which raises questions of data comparability across multiple survey rounds. This particular data set was compiled by the EPW Research Foundation (EPWRF), who attempting a concordance between the various series (NIC 1973, NIC 1987, NIC 1998), so that series obtained using NIC 1973-74 are as closely comparable as possible with data from subsequent rounds, at least at the 2-digit level.

The data for the all-India manufacturing sector were constructed by aggregating 2-digit industries data at the state level, from 17 states[37], excluding the north-eastern

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[36] Until 1986-87, the census sector was defined as 50 or more workers with power, and 100 or more workers without power, and the sample sector as 10-49 workers with power, 20-99 workers without power. Firms in the former group were enumerated every year, while those in the latter were enumerated every other year on the basis of a 50 percent probability sample.

This methodology was replaced in 1987 by a new sampling method whereby any establishment employing in excess of 100 workers would be part of the census sector regardless of the use of power, whereas the rest would be part of the sample sector. There have been subsequent changes in the coverage of the census sector, but the definition of the sector as that employing more than 100 workers remains as of date.

[37] These include Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal. In the subsequent econometric section, we leave out two mountain states of Himachal

states and other union territories that constitute a very small fraction of the manufacturing sector and do not have consistent time series data. In addition to ASI data on industrial aggregates, National Accounts Statistics (NAS) data on gross fixed capital formation was employed for constructing a capital stock series, and data from the input-output Transactions Tables (IOTT) for the Indian economy were used to construct prices deflators. How these additional data were used is described below.

Construction of Price and Quantity Series

Price Indices: We made extensive use of input-output information for the Indian economy to construct price deflators for ASI manufacturing output and intermediate inputs respectively. This approach builds on existing approaches for estimating real values of these quantities in the following ways.

Firstly, with respect to output, the price deflator is a Divisia-type price index that weights the wholesale price index of each 2-digit ASI commodity by its share in total deliveries to final demand of all ASI-covered commodities. This is a refinement over using the official (CSO) wholesale price index for the aggregate manufacturing sector, since it excludes certain commodities (such as primary and processed primary goods) that are not covered by the ASI but are included in the official aggregate manufacturing price index. Secondly, with respect to intermediate inputs, we follow

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Pradesh and Jammu and Kashmir on account of issues of reliable infrastructure data and small share of manufacturing in state GDP in the case of Jammu and Kashmir.

Goldar (2004) and include services into the intermediate inputs category, as the share of services in inputs has growth considerably over time as shown below. Finally, our approach differs from the standard approach by using time-varying weights, making use of several different years of input-output information. Between 1973-74 and 1998-99, we consider 5 different rounds of input-output (I-O) commodity flow information as brought out by the Central Statistical Organization. The details of how I-O information was used to devise a set of commodity-wise weights to construct the aggregate price deflators are contained in the Appendix, while an overview of the method is provided below. In the existing literature, when I-O information has been used, the typical approach has been to use a single year of commodity flows data from the absorption matrix to derive weights, which overlooks changes in the input and output mix of the industrial sector especially when considering long spans of more than thirty years. The standard practice for deflating output or value added has been to use the overall manufacturing wholesale price index.

We construct a Divisia-type output deflator as follows. Using I-O data over five survey rounds (1973-74, 1983-84, 1988-89, 1993-94, and 1998-99) we derive a series of time-variant weights for each commodity covered by the ASI, based on the share of a commodity's deliveries to final demand in total deliveries of all ASI commodities. Therefore, we obtain the proportion of output in the 25 2-digit ASI industry-groups delivered to final demand (consumption, investment, and exports). The publication of import-flow matrices in the 1989 and 1993 rounds makes it possible to identify the exact proportion of final demand met only by domestic output.

For other survey years, this information is not available, hence for years before 1989 (and after 1993), an approximation was employed, by imposing the proportion of deliveries to final demand from domestic output for 1989 on domestic production data from 1983 and 1973, and the proportion obtained from the 1993 data to the 1998 data. Using this method, we are able to obtain final-demand based weights for the ASI output price deflator. For years between I-O rounds, we apply linear interpolation. Table A.1 in the Appendix lists the two-digit industries covered in this paper, their weight in total deliveries to final demand, and the WPI series closest to the industry group. Figure 2 graphs the percentage difference between the official manufacturing and our Divisia output price deflator.

From the input-flow matrix of the I-O tables, the values of flows of 21 input commodities/services to ASI industries were aggregated. Each input was then assigned a weight based on its share in total flows of all inputs to intermediate consumption by ASI industries. Weights for years between survey rounds were linearly interpolated (Appendix, table A.2 shows the estimated weights for each input). The use of I-O information for constructing an input deflator is common (see for example B-P 1994 or Rao 1996), but these studies use a single year of I-O information which amounts to fixed base weights, that might overlook changes in the structure of inputs. Flexible weighting guards against this. Table A.2 shows for example, that primary food articles and cotton textiles have declining shares in inputs, while mineral oils, chemicals, electricity, and services (especially transport, banking, and communication) have gained in importance. In Table A.3, we can see that the share of services in intermediate inputs has doubled over time.

Capital Stock: We construct an estimate of capital stock using the perpetual inventory method (PIM). The series is estimated as: $K_t = \left[\sum_{s=0}^{t-1}(1-\delta_j)^{t-s}K_s + I_t\right]$, where K is gross capital stock, δ is the rate of depreciation, and I is gross investment. In our approach, we distinguish between structures (STR), and plant, machinery and equipment (PME), and obtain the final estimate of capital stock by summing the two series.

An estimate of investment in each kind of capital stock was obtained as follows. ASI data provides only nominal investment figures, which have to broken down into real investment in either kind of capital. Using All-India National Accounts Statistics (NAS) data on aggregate investment (1974-1997) in PME and STR, we obtained the proportion of investment in PME and STR respectively by the public, private corporate and household sector. Since ASI data on investment is available by ownership, we apply the proportions by type of investment and type of ownership obtained from NAS data to the ASI series on investment by ownership, and add up the weights for each type of investment to obtain a final set of annual weights for splitting ASI nominal investment into investment in PME and STR (see Table A.4 in the Appendix). Based on NAS data, on average about 60 percent of nominal investment falls on PME and the remainder on STR for the period between 1974 and

1997. These averages were used as weights for years prior to 1974 and after 1997[38].

Using these nominal series, Divisia growth rates of real investment in PME and STR were obtained separately, using the Electrical and Industrial Machinery WPI and Construction GDP deflator respectively, and applied to base-year level of stock to obtain our estimates of real investment. The base year stock was set at the deflated book value of gross PME and STR stock in 1970. Applying a depreciation rate of 3 percent for structures, and 15 percent for equipment, the aggregate capital stock series was obtained as $K_t = \sum_{j=pme,\,str} \left[\sum_{s=0}^{t-1} (1-\delta_j)^{t-s} K_{js} + I_{jt} \right]$, where j indexes the two types of capital[39].

Our method for constructing a series on capital stock is one among several alternatives that have been used for constructing this variable. However, while most studies employ the perpetual inventory method, they do not differentiate between

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[38] Rao (EPW, Jun 1994) provides data on book value of fixed assets by type, which shows 64 percent of ASI capital stocks in 1960 as PME and the balance as STR (in current prices).

[39] Alternative approaches were also tried, such as a depreciation rate of 7.5 percent for PME, based on the idea that repair services in the developing economy may be cheaper, increasing the life of capital. Also, instead of deflating the split investment series, another option was to deflate the aggregate series by a Divisia deflator with flexible annual weights for PME and STR prices, and then split the series into two kinds of capital, apply the PIM, and re-aggregate for the final stock series. These approaches yielded very comparable stocks, so they were not eventually used. Note that the implied depreciation rate for the stock as a whole is just over 10 percent, twice the assumed value in some of the literature.

types of capital. Differences in the assumed rate of depreciation, the initial level of stock, and the appropriate investment deflator can yield different estimates. The typical assumption is a five percent depreciation rate, and a deflator which could be either the machinery and equipment price index, or the implicit price derived from current and constant price investment data for the aggregate economy (see for example Virmani 2004 or Goldar 2004). Our improvement consists of making a basic distinction between plant, machinery and equipment (PME) stock, and structures (STR), both for the assumed rate of depreciation and the price of investment. We are unable to use finer classifications of capital, or rental rates to accurately measure prices, due to the lack of data. Appendix Table A.5 shows the indices of real output and inputs obtained by these methods. We can observe the relatively rapid accumulation of capital stocks in mid-to-late 1990s, and the subsequent easing in investment.

Several issues need to be highlighted in the measurement of labour input. The first is how to measure labour input. The definition of labour we use is referred to as `total persons engaged' in the ASI data, which apart from workers, managerial and other staff also includes unpaid members of the proprietor’s family who work in the factory. Thus, we include all employees that are directly or indirectly connected with the production process. We assume that the flow of labour services is proportional to the number of total persons engaged. There are other approaches in the literature that attempt to adjust the labour input for enhancements in labour quality over time, say via education. For example, Bosworth et. al. (2007) adjust for improvements in labour quality by taking the average years of education in each of the three main sectors (agriculture, industry and services), and assume a seven percent return to each year of schooling so that $L^* = e^{as}L,$ where a is the assumed rate of return and s is the years of schooling. They are able to do so since they use quinquennial survey data for the entire economy, which contains details about educational attainments of the labour force. Lacking similar data on workforce characteristics within the ASI sector, as well as data on hours worked, we prefer to use the simpler formulation in which labour input is assumed to be proportional to the number of workers. Also, since we analyze state level trends, labour quality changes might differ by state, and to accurately adjust for these differences one would require state-by-state characteristics of the ASI workforce, which we do not have. Moreover, to the extent that improvements in labour quality are not paid-for, or occur on-the-job, they constitute enhancements in productivity and will be picked up by the productivity measure.

A second important issue with labour in growth accounting is its share in total output. In our exercise, the contribution of labour to output is weighted by the share of payments to labour in total output. Labour income is measured by `total emoluments' that include wages and salaries, as well as the cash value of benefits. Under the competitive markets assumption, an input's share in total output measures its marginal product. This has important implications for growth accounting since incorrectly weighting a particular input can distort the results on productivity growth. Particularly for labour in developing countries such as India, the issue of measuring the share of labour in output becomes problematic since a large number of workers are self-employed, whose income reflects partly a payment to their own labour and partly to their ownership of capital. Since the mixed-income sector in India is quite large (accounting for 45 percent of net domestic product (NDP) in 2002-03, and 79 percent of the income of the unorganized sector (CSO 2005), see Bosworth et. al. (2007)), assigning a share in income to wages equal to that observed in the formal sector may be misleading. In studies of the aggregate Indian economy, one expedient has been to simply assume a fixed income share for labour and capital, using observed shares in OECD countries, since these countries have relatively unchanged shares over time. However given, the structural differences between OECD and emerging economies, it is not clear whether this is a good assumption to make.

In this study, we do not assume a fixed labour share in income. This is for several reasons. Firstly, this study deals only with the formal manufacturing sector, in which mixed income of the self-employed is not likely to be a big component, since the coverage of firms rules out very small firms in which mixed income is likely to have a significant share in output. Secondly, due to reporting requirements that ASI firms are subject to, the concern that the data are systematically incorrect are mitigated. What we observe in the data time is that the growth rate of labour has declined over time, as has its share in total output. In Table 3 we see that the share of labour costs in total value of output has fallen from about 11 percent on average in the 1970s, to about 6 percent in the 1990s, and the average annual growth rate has fallen from more than 4 percent to about half a percent in the 1980s and 1990s. The declining share of labour income is ASI *value added* was also documented by Goldar (2004), falling from 42 percent in 1981 to about 28 percent in 1997. Goldar attributes the observed decline in the income share of labour to a labour saving bias in technological change, based on estimated elasticities from a translog production function. However, if labour is a relatively cheap and plentiful resource, it is not clear why the bias of technological change should be labour saving.

There may be other factors at play that might lead to a falling share of labour in output. For example, if Indian industry was over-manned prior to economic reforms, then with liberalization of the manufacturing sector, an adjustment towards a more appropriate factor mix may have taken place, to correct for that over-manning, which would appear as a fall in the growth rate of labour. Moreover, with modernization of industry, diversification of the output mix, and improvement in quality of goods, the technology may call for greater capital intensity per se, compared to prior periods.

Finally, the impact of reforms on the manufacturing sector employment also appears to depend on industry and state-specific factors. A recent study by Gupta, Hasan, and Kumar (2009) finds that labour intensive industries did not benefit much from reforms, and that states with relatively inflexible labour regulations have relatively lower growth rates in labour intensive industries, including employment growth.

3.3: Results

3.3.1. All-India manufacturing

Figure 3 gives a snapshot of the growth rates of output and inputs. Average real output growth increased from about 6.5 percent over 1973-79 to 8.5 percent between 1990-99, accompanied by an acceleration in capital accumulation from six percent to 8-10 percent, over the same time frame. On the other hand, intermediate inputs growth declined from nine percent to 6.5-7 percent, while the growth rate of labour declined from almost five percent in the 1970s to between 0.5-1 percent in the 1980s and 1990s.

Several factors acting in conjunction may explain the slow-down in labour growth. One possible cause may be a shift in the product mix, from labour-intensive to more capital intensive goods, which is supported by the observed increase in the rate of capital accumulation. Another explanation may be that Indian industries were relatively over-manned in the pre-reform era, especially in public sector enterprises, whereas the greater play of market forces led to an adjustment towards a more efficient level of labour in existing industries. A third hypothesis is that in the post-liberalization phase, Indian industry adopted relatively labour-saving technologies (Goldar 2007).

A number of works often report partial or single productivity measures, typically output per worker. In Table 3, we find that output per worker growth increased from an average of 2.1 percent in the 1970s, to an average of seven percent over the following two decades, even as capital intensity (ratio of real capital stock to workers) and capital-output ratio increased. We find that relative to the 1970s, capital intensity more than doubled in the 1980s, and was more than five times as high in the 1990s. The capital-output ratio almost doubled in the reform era. These trends might reflect the greater ease with which capital could be imported with the gradual elimination of import restrictions in the first wave of reforms.

Turning to the sources of growth decomposition (Table 4), we clearly see that in the reform period, TP growth accelerated. It was negative in the 1970s, and turned around quite sharply to a positive average growth rate of 1.2 percent per year in the 1980s, and an even higher 1.8 percent in the 1990s. Column 4 and 5 compare the 1970s and 1980s. From these figures, it is easy to verify that capital accumulation contributed about 1.5 percentage points to output growth, which is not much higher than the contribution of TP growth. Both capital accumulation and efficiency growth accounted for about 30 percent of output growth, while bulk of the rest was due to intermediate inputs growth[40].

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[40] The TPG numbers estimated here might look “small” when compared to the growth rate of output in manufacturing, and when seen against the growth rate of aggregate output in the economy as a whole. However it must be kept in mind that these are growth rates of the residual of manufacturing output growth over the entire base of inputs, not just the growth rate of value added over the share weighted growth rate of labour and capital. In fact, one can obtain the corresponding TFPG figures from TPG (under the assumption of separability of the gross output function in terms

The negative growth rate of TP in the 1970s resonates with the widely held impression that Indian development policies were misguided, by erecting barriers to trade, propping inefficient industries under state guidance, and stifling private economic activity with cumbersome rules and regulations that raised myriad bureaucratic hurdles to get anything done (Rodrik and Subramanian 2004). The 1970s also witnessed two major oil price shocks that may have contributed to the observed decline in TP growth. Given restrictions on imports of technology and low levels of research and development domestically, firms may have found it difficult to substitute other inputs for more expensive energy, thereby sustaining negative productivity growth.

While the sharp turnaround in TP growth in the 1980s has been attributed to initiation of economic reforms[41], the 1990s witnessed deeper liberalization and market-oriented economic policies, along with almost complete de-licensing of the

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of value added and intermediate inputs), as TFPG = TPG/(1-b), where b = share of intermediate inputs in gross output. Based on the data in Table 3, (1-b) = 0.2, implying TFPG as high as six percent in the 1980s and nine percent in the 1990s.

[41] Ahluwalia (1991) summarizes these changes as: "[T]he most important changes have related to reducing the domestic barriers to entry and expansion to inject a measure of competition in domestic industry, simplifying the procedures, and providing easier access to better technology and intermediate material imports as well as more flexibility in the use of installed capacity with a view to enabling easier supply response to changing demand conditions."

manufacturing sector. In this period[42], TP growth increased to 1.8 percent per year, while capital accumulation slowed down, its contribution to average annual growth falling to roughly 1.25 percentage points. Hence, efficiency gains offset the decline in input growth in the 1990s to hold output growth to the same level achieved in the 1980s[43]. The overall contribution of TP to output growth increased from about 14 percent in the 1980s to 21 percent in the 1990s.

As an additional check on our results, slightly different end-points were used to calculating the decadal average growth rates of TP. We find that the conclusion of accelerated TP growth in the 1980s and 1990s does not change (Table 5).

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[42] The year 1991 was left out from the calculation of average annual trends for two reasons, Firstly, it is the year in which reforms were introduced, and secondly, that year India suffered a balance of payments crisis, and may bias our conclusions about trends for the decade as a whole. Note that the averages in Table 4 included 1991, to show that its exclusion does not change the qualitative conclusions regarding trends in TP growth.

[43] The results presented here are based on state-level manufacturing data, aggregated up from 1973 to 2003. These figures exclude the electricity, gas and water supply (EGW) sector, for which the ASI series were discontinued after 1997. We repeated this exercise using data including the EGW sector that allows us to cover a slightly different period from 1970-1997, based on published ASI data. In addition, data for the EGW sector were extrapolated forward to bring the coverage up to 2003. The results from this exercise are Table 4; qualitatively we find that TP growth accelerated in the 1980s and 1990s, and both capital accumulation and intermediate inputs consumption slowed down in the 1990s. We also find that output growth including the EGW sector was somewhat lower in the 1990s than in the 1980s, and labour growth was slightly negative. However, since the electricity sector in India has been in a process of major transformations since the late 1990s, the way these variables were measured before and after this process was initiated may not be strictly comparable. Hence, the results of this exercise may be seen as illustrative, and should be interpreted with caution.

Our results suggest that economic reforms can lead to gains in resource efficiency, especially since the reforms were in large measure aimed at freeing up the manufacturing sector from the various burdens of the license-quota regime. These results also mesh well with the evident rapid economic growth witnessed in the 1990s, unlike findings in the literature of a slowdown in TFP growth during the reform periods, which were described previously. The main difference in our approach is regarding the appropriate price deflator. Our methodology does not suffer from the biases inherent in "single" and "double" deflation methods described earlier, and the weights for the various inputs and output that make up the manufacturing sector at the 2-digit level are derived extensive input-output information spanning both pre and post-reform years, that allows us to pick up any changes in the industrial structure that may escape attention in a fixed-weights deflation approach. Figure A.1 in the Appendix (based on Table A.8) plots indices of TFP and TP derived under different assumptions and approaches to pricing intermediate inputs. On the left panel, we plot TFP indices derived under single deflation, double deflation, and Divisia-type deflation respectively. A feature of the price deflation method used for the TFP series is that they are based on fixed weights for the various commodities composing intermediate inputs (except in the case of single deflation where intermediate inputs are not separately deflated). We see that single deflation produces a TFP series that shows a decline in the late 1970s and, then remains relatively flat in the 1980s. On the other hand, double deflation produces a series that shows a steep increase in manufacturing TFP in the 1970, and sharp declines in the 1980s. Divisia type deflation by fixed-weights (Rao 1996) also produces a series showing sharp increases in the 1970s but steep declines in the 1980s and in the early 1990s. On the right panel, where we plot indices of TP derived from Divisia type deflation using flexible weighting procedures. In comparison to the TFP series, these series are relatively smoother, and the index derived in this study clearly shows a rising trend in the 1990s.

3.3.2. Regional results

Table 6 presents the sources of growth of real output per worker at the state level. To focus on convergence, the states are divided into three groups of roughly equal size, based on levels of output per worker in the base year (1970). The period under review is divided into the 1970s, and 1980s, and 1990s and beyond. In the first three columns of this table, we note that there is evidence in support of convergence in the 1980s, as output per worker grew faster in the middle and bottom group of states than in the top states. This process appears to continue in the 1990s, albeit only for the bottom group, and at a lower growth differential compared to that observed in the 1980s vis-a-vis the top group. The growth rates of the respective inputs per worker suggest that in the 1980s, faster growth of capital per worker and of materials per worker (especially for the bottom group) drove the convergence in output per worker. In the 1990s, for the bottom group, capital per worker continued to grow faster than for the top group, and TP growth was somewhat higher in the 1990s relative to the top group as well. TP growth appears to have played a smaller role in the observed convergence in the 1980s, as TP growth rates were very only slightly higher in the bottom group relative to the top, in the 1990s.

Even though the contribution of TP growth to convergence in output per worker is marginal, the contribution manufacturing output growth has been quite significant. In the 1980s, across the three groups, roughly 20 percent of the observed output growth could be attributed to TP growth, which increased in the 1990s to almost 25 percent. In contrast, the contribution to growth of capital per worker has stayed roughly constant at 13 percent of output growth for the two top groups, and fallen from 20 percent to 13 percent between 1980s and 1990s for the bottom group. (The remainder of output per worker growth is accounted for growth in material inputs per worker). Thus, TP growth had a larger contribution to growth compared to capital intensity, which echoes the cross-country findings of Hulten and Isaksson (2007)[44].

One can observe convergence across states in TP growth, which show that states that started off with lower initial levels of TP witnessed relatively faster TP growth rates in subsequent periods. We estimated TP levels by extending the methodology used for the all-India sources of growth analysis to state data[45]. In Table 7 we see that firstly, TP levels increased in all states at the end of the 1990s compared to the 1970s,

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[44] The Hulten-Isakkson study is based on TFP growth, using value added data, hence the contribution to growth can exceed 50 percent. Our growth accounting results are based on gross output, which if converted in value added terms, would yield similar ratios.

[45] State-year time series of our estimates of TP levels are available in the Appendix Table A.7

which mirrors the results found at the all-India level. When we examine TP growth rates against initial levels of TP, we observe that over 1970-2003, middle and bottom ranked states (ranked by level of TP in 1970) had higher TP growth rates than the top group (Table 8). This catching up was most noticeable in the 1980s, whereas in the 1990s, the growth rates are virtually identical. A result to note is that the gap in levels between top and bottom, and top and middle states, fell from 13 percent to eight percent and from six percent to 5.3 percent respectively. Thus, although the gap in TP levels has narrowed across states, some gap appears to be persistent.

Given the relatively small share of manufacturing value added in state GDP (average of 11.6 percent[46] in 2003-04), output per worker and relative TP levels across states appear not to be strongly related to levels of state per-capita income across states. We ranked states at two different points in our sample (1970 and 2003, in Table 9 and 10 respectively) according to levels of output per worker, TP, and per capita income, to see if there was a noticeable overlap between the various ranks. For output per worker, we do not find this to be the case. The correlation between output per worker and income per capita ranks was 0.3 in 1970, and negligible in 2003. We do find a higher correlation for TP levels and income per capita, (between 0.65 and 0.70 in 1970 and 2003 respectively). However, this need not imply that higher levels of manufacturing TP cause higher per capita incomes, as they may be themselves be endogenous to per-capita income.

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[46] Reserve Bank of India data for the 17 states includes in this study.

The results on regionalization of manufacturing sector growth can be summarized as follows. Convergence in growth rates of output per worker is noticeable for states with lower initial levels of output per worker in manufacturing. This was especially evident in the 1980s and to a lesser extent in the 1990s. The main force behind convergence appears to have been faster growth in capital intensity and materials per worker, especially in the lowest ranked states (in terms of initial levels of output per worker). TP growth appears not to have had a major role in the observed convergence in output per worker; however, when TP growth rates are examined relative to TP levels in the base year, we find that states with lower initial levels of TP witnessed relatively faster TP growth in the 1980s. In the 1990s, TP growth rates appear to be almost identical, and the gap in TP levels in the 1990s is narrower than that in the 1980s, and TP levels have increased in all states between 1970 and 2003. Finally, there does not appear to be a noticeable relationship between output per worker in manufacturing and state income per capita, on account of the relatively small share of manufacturing in state GDP. One important implication of these results may be that the observed increase in income inequalities may not be driven by differences in manufacturing sector growth. Given that levels of output per worker are have little correlation with income per capita, the convergence in growth rates of output per worker, and the relatively low share of manufacturing in state GDP, the sources of widening income inequalities would have to be from other sectors, namely services and/or agriculture.

Chapter 4: Infrastructure Spillovers

4.1. Description of variables

The task in this section of the dissertation is to explore the relationship between productivity in regional manufacturing (measured by TP) and the level of infrastructure. In particular we are interested in spillover from infrastructure, and these spillovers may exert an effect beyond the geographical boundaries of a given state. Our sample consists of 15 major states[47], from 1970 to 2003.

Infrastructure is widely understood to be a major supply-side bottleneck in India, particularly for the manufacturing sector. The Eleventh Plan (2006-7 to 2011-12) envisages infrastructure investment needs of more than US $500 billion (about 40 percent of India’s current nominal GDP) across 10 infrastructure sectors, in order to meet GDP growth targets of 9-10 percent. Almost 50 percent of the additional

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[47] Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal are included in the sample. These 15 states comprise about 95 percent of the population the country. This set only excludes the small north-eastern states and Union Territories on account of incomplete data for both ASI manufacturing and infrastructure variables. Bihar and Madhya Pradesh were bifurcated in 2000 to form 2 new states, Jharkhand and Chhatisgarh. We continued to treat the two states as undivided, by aggregating the data from 2000 onwards for all the relevant variables. Although Himachal Pradesh and Jammu and Kashmir are included in our study of sources of growth in manufacturing, we exclude them from the econometric analysis as these states are mountainous, with limited additional road-building, and a large proportion of roads are built and maintained by the army and border security forces. Moreover, the data show downward jumps, in highway length, which could either be on account of destruction due to natural disasters, or due to other reasons.

investment is to be directed towards electricity and roads, with electricity itself accounting for more than a third of the total planned investment in all 10 sectors[48]. Given the relative importance attached to roads and electricity we restrict our attention to these stocks. Table 11 and Table 12.1 - 12.2 list the national and state-wise stocks of national and state highways, and installed generation capacity in electric utilities.

Highways: The total road network of India is 3.34 million km, which is the second largest in the world, and at present carries 65 percent of freight and 85 percent of passenger traffic. Roads are classified on the basis of administrative status and by function. In this study we include National Highways (that are built and maintained by the central government), and State Highways (that are managed by states). We consider these two types of roads, and exclude local roads, since from an economic standpoint, highways are important, linking up national and state capitals, ports, rail-heads, and link with roads outside the country. Also, these roads are more likely to be associated with spillovers across state boundaries, than local roads.

However, despite their economic importance, national and state highways are a much smaller subset of total road length, comprising 65,569 km, and 130,000 km respectively[49]. National highways thus comprise less than two percent of the total

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[48] http://infrastructure.gov.in/pdf/IBEF.pdf

[49] Although the responsibility for maintaining national and state highways falls to different bodies (National Highways Authority of India, and state governments

network, but carry 40 percent of the total traffic. Since roads are mostly provided in the public domain, the allocation of funds made available for road building tends to favour the demands of the largest constituency. Moreover, roads construction is the responsibility of state governments (except in the case of national highways). Hence, local road projects such as rural roads and intra-district roads are likely to be preferred over other alternatives, such as multi-laning of state highways or pavement strengthening. Raw data are supportive of this conjecture. Between 1971 and 1991, one-half of the addition to the stock of surfaced roads (265,158 km out of 540,675 km) was local roads. In the second sub-period (1992-2003), total addition to the sum of National and State highways, and public works department (PWD) roads in 17 major states was 249,254 km (not differentiating between lane-km), of which 22,766 km were National highways, 6,453 km were State highways, and the balance 232,287 km were PWD local roads. As pointed out above, most of the traffic moves on highways although bulk of the additional roads is not in this category.

Since 2001, the National Highway Development Project (NHDP) was launched under the aegis of the National Highway Authority of India (NHAI), to undertake major upgrades and add to the National Highway network of the country. In all, the programme has a total outlay of roughly US $40 billion. The first pieces of this network were the Golden Quadrilateral and The East West-North South corridor, comprising long stretches linking major metropolitan cities and state capitals along

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respectively), there may be significant overlap between the two categories, as they constitute a continuous physical network. For this reason, we considered the aggregate of both national and state highways in this study.

the route. We are unable to include the data from this project in our analysis as it falls outside our reference period.

Electricity: The supply of uninterrupted, high quality power is a prerequisite for industrialization. However, India's electricity generation is frequently reported to fall short of demand. For the year 2009-10, peak power deficit is expected to reach 12.6 percent of demand, up from 11.9 percent the previous fiscal year[50]. There has been significant growth in captive or own-account power generation by firms over the years, which may be seen as a sign that utilities power is not sufficient for industrial users. Estimates of captive power generation range between 14,000 and 20,000 MW, amounting to 20-25 percent of the installed capacity of utilities. This is up from between 10-12 percent over 1972-92 (HBS 2006). We do not include captive generation in our analysis, as we lack adequate data at the state level.

In the sample of 15 major states considered here, installed generation capacity in electric utilities alone has gone up from about 13,000 MW in 1970 to about 50,000 MW in 1991, and to more than 75,000 MW in 2003. Aggregate installed capacity was 104 GW in 2002, comparable to the generating capacity of UK and Germany, but in per capita terms, India's consumption (363 kWh per capita) is less than a thirtieth of that in the US, and about one-fifteenth of that in UK.

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[50] http://in.reuters.com/article/domesticNews/idINDEL44867220090710

Bulk of the generating capacity in India (about 60 percent in 2002) falls under the management and ownership of State Electricity Boards (SEBs). These SEBs suffer from routinely high losses, and face a number of problems. Firstly the average plant load factor (PLF) at which state-owned utilities run is only 65 percent, leading to high costs. Secondly, states cross-subsidize agriculture at the expense of industrial power, and vested interests make it increasingly hard to levy user charges on this politically powerful segment.

For instance, in 2001-02, domestic and agricultural users consumed a total of 50 percent of generated power. Domestic users paid 195.6 paise[51] per kWh, and agricultural users paid a subsidized rate of 41.6 paise per kWh. In contrast, industrial consumers used 29 percent of generated power and paid almost twice the domestic rate (378.7 paise per kWh). Industry thus subsidizes domestic and agricultural power consumption. Thirdly, there are large transmission and distribution (T&D) losses[52], which amounted to 28 percent of generated power in 2001-02. In certain states, the losses are almost a half of generation, such as Haryana (40 percent), Rajasthan (43 percent), Andhra Pradesh (45 percent), and Orissa (51 percent).

A few caveats are in order for the electricity variable. For our purposes, the ideal measure would be the actual amount of electricity transmitted to the manufacturing

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[51] One paise = 100th of one Indian rupee. 40 Indian rupees are roughly equivalent to one US dollar.

[52] These losses are often on account of weak enforcement and outright theft of electricity, for which reason they are often referred to as “theft and dacoity” losses.

sector. Installed capacity in utilities is only a proxy, as the amount of power actually generated and delivered can vary significantly from state to state and over time. Moreover, it excludes captive power generation. Thus, this measure may be noisy, and not give us an accurate picture of the impact of electricity on regional manufacturing productivity and growth. Secondly, the electricity sector has witnessed significant institutional changes since the enactment of the Electricity Act of 2003. Among other things, an important aspect of the changes envisaged under this Act is the setting up of a mechanism to help deepen and develop the power-sharing market, whereby electricity can be traded across regions in a quick and timely manner depending on varying demand and supply conditions. This may have a bearing on our results, since prior to this (including in our sample period), while power trading may have taken place across state boundaries, it may not have been rapidly responsive depending on demand and supply conditions. Thus, spatial spillovers from electricity generation capacity may be harder to detect in the data from Indian states.

4.2. Descriptive statistics and preliminary exploration

Some of the problems in estimating infrastructure spillovers in our panel become evident from the descriptive statistics. One issue is the presence of a strong time trend in the productivity and infrastructure variables. As shown in Table 12.1, within each state, correlation between the time trend and the highways variable ranges from 0.47 to 0 96, and the correlation between electricity generation capacity and the time trend ranges from 0.90 to unity (Table 12.2). This points to potential problems in distinguishing the time trend from the infrastructure variables, notably electricity, in our estimates.

There is also a high degree of correlation among the infrastructure variables themselves, as shown in Table 13, which presents the average (across states) of cross-correlations among the independent (infrastructure) variables. We have defined two variants of the infrastructure variables; "own" stocks refer to levels of road and electricity generation capacity within a given state's borders, whereas "contiguous" stocks are the (appropriately normalized and weighted) level of roads and electricity in states adjoining a given state[53]. Both the own and contiguous levels of highways, and own and contiguous levels of electricity generation capacity are also highly correlated, apart from the high correlation of each of these with the time trend. This suggests that multicollinearity might lead to estimation problems, if we use within-state variation over time, to identify the relevant coefficients.

In the cross-sectional dimension, there appears to be some evidence that states with higher stocks of infrastructure also have higher levels of TP. We present scatter plots of the state-wise time-average of TP levels stocks of highways and electricity generation capacity. Looking at own stocks, Figure 4 and Figure 5 show that across states, on average, states with higher TP levels also had bigger stocks of highways

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[53] The weighting procedure is described in the next section that lays out the econometric methodology.

and electricity. When we consider combined own and contiguous stocks, the relationship with roads still appears to be positive (Figure 6), whereas the relationship with electricity looks relatively flatter (Figure 7).

Though the positive relationship suggested by these figures is not very strong, it may yet raise questions about the direction of causality, that higher productivity drives infrastructure levels, rather than vice-versa. We note here that the provision of infrastructure is not based on the requirements of any one sector alone; rather it serves a wider constituency including households, agriculture, and services, and hence is unlikely to be "caused" by purely changes in manufacturing sector productivity alone. The registered manufacturing sector that we are considering is itself a subset of the industrial sector, which accounts for less than a fifth of GDP. There is also the policy thrust of balanced regional growth, which would tend to push infrastructure provision towards relatively under-developed states, than to states with a relatively well-established manufacturing sector.

4.3. Model specification

Recall that the Hicks-neutral shift parameter of the production function described in Section 3 was modeled as a function of infrastructure stock, and a time trend that captures the autonomous rate of technical change. We now give this parameter a specific functional form:

(8) $A(B_{i,t},t) = A_{i,0}e^{\lambda t}B_{i,t}^{\gamma}$,

$B_{i.t}$ is the stock of infrastructure in state i $(i = 1...N)$ at time t $(t = 1...T)$, the initial level of productivity is given by the constant $A_{0,i}$, λ is the exogenous rate of technical change, and γ measures the infrastructure externality. The total productivity measure $TP_{i,t}$ derived from the regional growth decomposition exercise is our measure of A. Substituting $TP_{i,t}$ into (8) and take logs:

(9) $\ln TP_{i,t} = \ln TP_0 + \lambda t + \gamma \ln B_{i,t}$.

In this form, γ measures the elasticity of TP with respect to infrastructure stock within a state, and this equation forms the key building block of our estimating equations. In this form, the term γ captures the "own" spillovers from infrastructure.

We employ the spatial econometric model developed by Kelejian and Prucha (1998, 1999), to expand the basic equation in order to take into account spatial spillovers from infrastructure. The spatial framework is useful for modeling various types of spatial effects, including spatial correlations in the dependent variable (known as the spatial lag model), spatial spillovers from the independent variable(s), and spatially correlated errors (known as the spatial errors models). A model may include any or all of these types of effects. In our application, we incorporate spatial spillovers from the independent variable (infrastructure), given that physical infrastructure is essentially a network and can thus exert an effect beyond where it resides in space. The natural criterion for considering spatial spillovers in this context is adjacency, since states that share borders are most likely to experience spillovers from each other's infrastructure, than states not linked, or those at one remove from the immediate vicinity.

Adjacency effects can be modeled by augmenting equation (9) in the following way. Let W be an N x N weighting matrix where the elements of row $i = 1...N$ assign weights to state i's neighbours $j \neq i,\ \ i, j \in N,$ based on some notion of `distance'. In this study, weights are assigned as $w_{i,j} = 1$ if i, j share a contiguous border, and 0 otherwise. The weighting matrix is then "row-normalized", such that $\sum_{j=1}^{N} w_{i,j} = 1,$ where $w_{i,j}$ is the weight assigned to state j by the state in row i. The value assigned to the diagonal is zero, that is, a state is not considered its own neighbour.

In our scheme, weights are assigned in a uniform way, depending on the number of neighbours that a state has. However, the ideal weighting matrix for our purposes might take into account, for example, the density of traffic flow between two adjacent states to weight the neighbourhood stock of national and state highways, rather than uniformly weighing the stock of all neighbours. Similarly, we may prefer to weight the electricity stocks of adjacent states depending on actual power-trading data, or based on the sharing of transmission infrastructure. Unfortunately, these alternatives are not available to us on account of lack of data. Moreover, for our purposes, while the simpler weighting scheme may not be able to pick out how important some states are in a neighbourhood to each other, it will not overlook them altogether. Hence as a first approximation of a weighting scheme for these types of variables, the uniform weighting may be adequate.

Let B_t denote an $N \times 1$ vector of the stock of infrastructure in each state for a given year t. We then define $[W \bullet B_t]$ as an $N \times 1$ vector containing weighted sums of neighbourhood infrastructure stock in year t, appropriately normalized[54]. This natural log of this term, $\ln[W \bullet B_t]$ is the additional term included in equation (9) that controls for adjacent levels of infrastructure. The $i-th$ element of this vector is the log of the weighted sum of (normalized) infrastructure stocks in state $i's$ neighbours, for year t. Let γ_1 denote the coefficient of within-state infrastructure stock $(\ln B_t)$ and γ_2 the coefficient of the `neighbourhood stock' $\ln[W \bullet B_t]$. In addition to these regressors, we include a time trend variable τ which captures exogenous technical change. Thus our estimating equations becomes (including the constant term):

$$(9) \quad \ln TP_t = e_N + [e_N \otimes t]\lambda + \gamma_1 \ln B_t + \gamma_2 \ln[W \bullet B_t] + u_t;\; t = 1...34$$

The error u_t is a combination of a spatially correlated component and an idiosyncratic component, to capture the possibility that spatially contiguous states

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[54] In the case of national and state highways, we normalize by the area in square kilometers of the state, and for electricity, by population (per kilowatt of generation capacity).

may experience spatially correlated shocks. Let u_t and ε_t be $N \times 1$ vectors of error terms, and u_t is drawn from the following process:

$$(11) \quad u_t = [W \bullet u_t]\lambda + \varepsilon_t, \text{ where } \varepsilon_t \sim i.i.d(0, \sigma^2 I(N)) \quad \forall t \in \tau = 1, 2, ..., 34.$$

One implication of this assumption is $\text{var}(\varepsilon_{i,t}) = \sigma^2$, and $\text{cov}(\varepsilon_{i,t}\varepsilon_{j,t}) = 0$, unless $i = j$ and $s = t$. The scalar parameter λ is assumed to be time-invariant, and represents the spatial correlation across error terms. This specification allows errors to be correlated within t across space, but uncorrelated over time. This variant is also known as the Spatial Errors Model, or SEM.

We can now stack the data by year. Let $T = (1, 2, 3, ..., 34)'$, I_T be an identity matrix, $e_T = (1,1,...,1)'$ be a $T \times 1$ unit vector, D be an $(N-1) \times (N-1)$ matrix of dummy variables, and $\ln TP$ be the $NT \times 1$ vector of productivity levels in each state and $\ln B$ be the $NT \times 1$ vector of infrastructure stock in each state. This gives us:

$$(13) \quad \ln TP = e_N \otimes e_T + [T \otimes e_N]\lambda + \gamma_1 \ln B + \gamma_2 \ln[(I_T \otimes W) \bullet B] + u;$$

where $u = [I_T \otimes W]u + \varepsilon$, where u and ε are $NT \times 1$ vectors. I estimated this model using Jim LeSage's Spatial Econometrics Toolbox for Matlab, which is based on a GMM estimation approach as detailed in Kelejian and Prucha (1998, 1999).

4.4. Regression results

The results of this exercise are presented in Table 14. The baseline regression of TP on a constant and the time trend shows the time trend is positive and significant, and implies an autonomous rate of technical change of approximately one percent per year, that remains fairly stable in the various specifications. HBS (2006) find lower estimates of 0.4 percent per year, but this may be attributed to our extension of the data to include several years after reforms in 1991, whereas HBS covers the period from 1974 to 1993.

The remaining columns consider the infrastructure variables. In column 2 we introduce own stocks of national and state highways. The coefficient is positive and significant, and although the size of this coefficient varies somewhat in the different specifications, it remains significant in all specifications in columns 1-9 where the variable appears. The magnitudes of implied elasticities for own highways are small, ranging from 0.07 – 0.1 percent in the different equations. Thus, a 10 percent increase in the "own" stocks of national and state highways would have a spillover impact of at most one percent increase in TP/output levels. But it is worth keeping in mind that these are spillover effects, over and above the direct contribution of infrastructure to manufacturing output as an intermediate input.

In column 3 we consider only adjacent stocks of highways. The estimated coefficient is positive and significant, but the size of the coefficient is quite small.

When both own and adjacent stocks of highways are introduced into the equation (column 4), the adjacent stocks variable becomes negative (and significant), whereas the own stock variable becomes somewhat bigger than in column 2. When all infrastructure variables are considered together (column 9), contiguous highways have a positive impact, but the coefficient is not significant.

Column 5 shows the effect of including only the own stocks of electricity generation capacity, along with the constant and time trend. Again, we find a small positive and significant impact, which remains significant and almost of the same magnitude when adjacent electricity stocks are introduced in the equation (column 7). In contrast, adjacent stocks of electricity appear to have a negative and significant impact in all specifications, though the magnitude of the effect is quite small, implying a negative elasticity of TP to *adjacent* stocks of electricity of roughly 0.3 percent, which is similar in magnitude to the positive elasticity of TP to *own* electricity stocks.

Finally, we introduce both highways and electricity variables together. In column 8 we consider own stocks of highways electricity. Both variables have a positive and significant coefficient. In the final column, we control for all four infrastructure variables. Contiguous highways are not significantly correlated with TP, and own electricity, though positive, is no longer significant. Own highways continue to be positive and significant and adjacent electricity is still negative and significant.

4.5. Interpretation of results

Given that our estimates of spillover effects from infrastructure may suffer from problems due to features of the data, the results given above need to be interpreted with caution. Based on these results, there appears to be some evidence to suggest that own highway infrastructure may have positive spillover effects on TP, though as shown; the effect size is quite small, ranging between 0.07 – 0.1 percent. At best, the results in column 9 of Table 14 would imply that ceteris paribus, if the stock of national and state highways within a state was doubled, the level of TP and manufacturing output would go up by around nine percent. Similarly the impact of own electricity generation capacity on TP also appears to be positive, though it is even smaller in size (elasticity ranging from 0.2 to 0.4 percent), and the coefficient is not significant in the full model including all infrastructure variables.

In terms of adjacency effects, the coefficient on adjacent highway stocks changed signs between specifications, making it difficult to interpret. However, adjacent electricity stocks entered with a negative sign, the effect size implying a negative elasticity of around 0.3 percent. As pointed out earlier, various studies and planning documents have pointed out the scarcity of electricity in India, and one would expect that additional electricity in the immediate neighbourhood would have a positive impact on TP and manufacturing output. Thus, one would need to exercise even more caution in interpreting this particular finding. It is possible that part of this negative impact reflects the sorting of high productivity firms to states that are comparatively electricity-rich. This is especially likely if states cannot freely trade electricity across state lines. In fact, attempts to deepen and develop the market for power trading are relatively recent in India, marked with the passing of the Electricity Act in 2003[55] as highlighted earlier. The lack of a well-developed market in power trading in prior periods may therefore explain in part our finding of a negative spatial spillover from electricity.

A related issue is that the amount and quality of electricity available to manufacturing industry across states may be insufficient to spur innovations, especially of the type that require uninterrupted and high quality power supply. In other words, the first problem in India may be to achieve adequacy in electricity generation, given existing manufacturing technology. The current level of electricity available to manufacturing may be below what is required even for running existing technology efficiently, and thus we do not observe positive spillovers that are spurred by relative abundance. Finally, as mentioned earlier, generation capacity in utilities may not be a good proxy for the amount of electricity transmitted to the manufacturing sector. Installed capacity must be used to supply agriculture, services, and households, apart from manufacturing industries. Moreover, electricity transmission and distribution losses in India are quite high, as high as 50 percent in some states[56]. The substantial growth of own-account power generation by firms may reflect this insufficiency. Thus, our results should not be interpreted to imply that

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[55] http://www.electricityindia.com/powertrading.html

[56] http://www.teriin.org/upfiles//pub/papers/ft33.pdf

electricity has no spillover benefits; rather the results may be pointing to a shortage relative to requirements, due to which the kind of spillovers we expect are not observed. Last but not least, it is worth remembering the sheer size of Indian states, which might rule out large spillover effects per se.

4.6. Other specifications

This section contains results from other specifications that were also attempted, in addition to the spatial errors model that I chose to interpret. I considered a fixed effects estimator, and a "between" estimator, but the resulting coefficients either had implausible signs and magnitudes, or were not robust. Table 15 presents the results from the fixed effects estimator. Reading across the columns, the coefficient on own national and state highways stock is positive, but not significant in all specifications. On the other hand, the adjacent highways variable appears to have a much larger magnitude than own highway stocks. It seems counterintuitive that spatial spillovers from roads would exceed own spillovers, considering the fairly large size of Indian states. Also, both electricity variables enter with a negative sign, and both are highly significant. The magnitude of the coefficient on adjacent electricity appears to be too large to be plausible, as does the negative sign on own electricity stocks.

Results from the "between" estimator are in Table 16. As can be seen, in this specification I did not find any evidence of spillover effects from infrastructure, which is contrary to earlier findings on Indian states by HBS (2006). Finally, I also considered a variant of the spatial errors model, which included a full set of state dummy variables (Table 17). The inclusion of state dummy variables leads to the implausible result that own spillovers from highways are not significant in most specifications, whereas spatial spillovers from adjacent highways are positive, and significant. Similar to the findings from the fixed effects model, both own and adjacent electricity variables enter with a negative sign, and while the own electricity variable is in general not significant, the adjacent electricity variable is highly significant, and has a large negative sign, implying very high negative spillovers from neighbourhood stocks of electricity.

Chapter 5: Summary and Conclusions

Industrial development is believed to hold the key to rapid and sustained economic growth in India. While this was well-recognized by policy-makers at an early stage as reflected in various planning documents, the approach to the problem has changed considerably over time. The issue of sustainable growth raises questions about what policies can help to achieve this objective. Concurrently, India is undergoing a transformation from a planned economy characterized by industrial regulation and licensing, administered prices, and restrictions on private activity to a more market-driven economy more encouraging of entrepreneurship.

Focusing on the formal manufacturing sector, one of the main questions that we sought to answer is one that has triggered much debate, namely whether liberalization of the economy had a positive impact on productivity growth, and we found that the answer was affirmative. This contributes to a long-running debate generated by the contentious finding of some research that liberalization led to a distinct deceleration in productivity growth, especially in the 1990s, which was the era of significant economic liberalization. We highlighted the methodological problems that arose in the literature, mainly dealing with the appropriate deflator for manufacturing sector aggregates. Correcting for these, we found that at the All-India level, manufacturing sector TP growth increased substantially in the 1980s and 1990s, relative to the 1970s. This is in contrast to findings by Balakrishnan and Pushpangadan (1994) and Rao (1996) with respect to productivity growth in registered manufacturing in the

1980s over the 1970s, and in contrast to Rodrik and Subramanian (2004), Goldar (2004), and Banga and Goldar (2007), who report negative TFP growth rates for economy and for the manufacturing sector in the 1990s. Compared with these findings of slowing productivity growth, our results seem to be more plausible when seen against the observed high growth rates of the Indian economy the 1990s.

In the second part of this study we examined trends in output per worker and manufacturing sector TP growth at the state level. We found evidence of convergence in output per worker growth, though the difference in growth rates was higher in the 1980s than in the 1990s, between the top group and bottom group of states, as ranked by initial levels of output per worker. The data indicate that this convergence was driven mostly by capital intensity and only to a small extent by differences in TP growth. Examining trends in TP growth in greater detail, we found that TP growth had a bigger contribution to growth in output per worker than capital intensity, which accords with the recent findings of Hulten and Isaksson (2007), where they find that in a cross-country setting, TFP growth accounted for a major share of output growth in the aggregate economy. In terms of TP levels, we find that all states have higher TP levels in 2003 than in 1970. One interesting finding was that states with lower initial levels of TP had higher rates of TP growth, especially in the 1980s. By the 1990s, however, TP growth rates appear to be more or less equal across groups of states (ranked by initial levels of TP).

Several studies have documented the increasing disparity in income levels across states, and we use our evidence to explore the relationship between trends in state-wise income per capita and manufacturing sector growth. We related trends in state income per capita with output per worker and TP levels in manufacturing, and found that there was little evidence that states with higher levels of output per worker in manufacturing had higher levels of per capita income. This is perhaps due to the relatively small share of manufacturing in state GDP. Moreover, state-wise growth rates of output per worker in manufacturing appear to have converged in the 1990s. Read together with the evident lack of correlation between levels of output per worker and per capita income, and the low penetration of manufacturing in state GDP, it appears that the rising income inequalities across states are not driven by manufacturing sector trends, but may perhaps be on account of differences in other sectors.

Finally we addressed the issue of infrastructure and productivity growth. In pursuit of balanced growth, and for sustained high growth rates particularly in the industrial sector, infrastructure development has been identified as a vital input. While physical infrastructure plays a key role in manufacturing as an intermediate input, we hypothesized that roads and electricity may also affect manufacturing productivity through network spillover effects on manufacturing output via their impact on TP levels across states. We also incorporated the possibility of spatial spillovers.

Due to limitations in the data, it is hard to draw firm conclusions from the results of this exercise. However, despite the lack of robustness in the results, and problems with the underlying data on account of collinearity among various explanatory variables, the evidence does seems to suggest the presence of small spillover effects from a state's own stock of roads, the elasticity of TP to own national and state highways (in length per square kilometer of state area) of around 0.07 – 0.1 percent. Own stocks of electricity generation capacity also appear to have a positive and significant impact on TP, though the effect is smaller than that estimated for highways. The elasticity of TP to additional electricity generation capacity (in kW per capita) was found to be around 0.02 – 0.04 percent.

Electricity generation capacity in neighbouring states appears to have a negative impact on state TP, i.e. spatial spillovers from electricity appear to be negative, contrary to our expectations. On reflection, this may be driven a variety of factors. It may reflect in part a dynamic sorting of high TP firms to areas with relatively abundant electricity, and may also reflect certain weaknesses in our measure of electricity. The ideal measure in this context would be the amount of electricity transmitted to the manufacturing sector, given the prevalence of leakages in transmission and distribution, installed capacity may be less than ideal for our purposes. Secondly, the market for sharing power across state boundaries is still evolving in India, thus one may observe the expected positive spatial spillovers as this market matures. On a related note, the relatively small size of positive spillovers from own-installed capacity might reflect the extent of electricity shortage; existing power generation is short of demand to such an extent that additional capacity does not attain a level necessary to spur technological improvements of the type that require a relative abundance of high quality and uninterrupted power.

Appendices

Appendix 1: Text tables and figures

Table 1. Share of manufacturing in state GDP, 2000[1]
(In percent)

Gujarat	24.3	Andhra Pradesh	10.3
Haryana	18.7	Himachal Pradesh	9.6
Maharashtra	17.1	Assam	9.6
Tamil Nadu	15.5	Madhya Pradesh	9.5
Karnataka	14.5	Rajasthan	9.2
Punjab	12.9	West Bengal	8.5
Uttar Pradesh	11.1	Kerala	7.6
Bihar	10.9	Orissa	5.7
Mean	***12.2***		
St. Dev.	***4.8***		

[1] *Sample excludes Jammu and Kashmir on account of small size in GDP (2.8%)*

Table 2. Summary of Results for Registered Manufacturing Productivity Growth

Author(s)	Period	Deflation Method	Productivity Trends		
Ahluwalia	1965-85		1965-80	1980-85	
1991		Single Deflation[1]	-0.3	3.4	
Balakrishnan - Pushpangadan	1970-88		1970-79	1980-89	1970-89
1994		Single Deflation[1]	-0.71	1.47	0.38
		Double Deflation[2]	3.5	0.19	1.84
Dholakia and Dholakia	1970-88		1970-79	1980-89	1970-89
1994		Single Deflation[1]	-1.69	1.89	-0.11
		Double Deflation[2]	0.56	2.86	1.58
J M Rao	1970-92		1973-79	1980-92	1973-92
1996		Single Deflation[1]	0.33	1.51	1.14
		Double Deflation[2]	6.6	0.02	2.09
		Divisia deflator[3]	8.37	-1.78	1.43
Hulten and Srinivasan	1973-92		1973-82	1983-92	1973-92
1999		Divisia Deflation[4]	2.2	2.1	2.2
B. Unel	1979-97		1979-90	1991-97	1979-97
2003		Single Deflation[1]	1.8	2.5	1.8
B. Goldar	1979-00		1979-90	1991-97	1991-99
2004		Double Deflation[2]	2.14	1	1.57
Banga and Goldar	1980-99		1980-89	1990-99	1980-99
2007		Double Deflation[2]	1.3	0.5	0.8
This study	1970-03		1973-80	1981-90	1992-03
2010		Divisia Deflation[5]	-1.2	1.2	1.8

[1] *Based on manufacturing price index*

[2] *Input deflator based on Input-Output 1973-74 weights for input commod*

[3] *Divisia-type deflation with fixed weight price indices using Input Output 1993-94 da*

[4] *Divisia-type deflation with flexible weight price indices*

[5] *Divisia deflation with flexible Input-Output matrix weights*

Table 3. Partial Productivity Measures

	Output per worker[1]	Capital intensity	Capital-output ratio
1970-79	2.1	0.6	0.31
1980-89	7.1	1.4	0.44
1990-03	6.9	4.1	0.55

[1] *Average annual growth rate*

Table 4. Sources of Growth (1973-2003) - All India Aggregates[1]
(In percent)

	1973 - 2003	1973 - 1990	1991 - 2003	1973 - 1980	1981 - 1990	1992 - 2003
Gross Output	7.5	7.5	7.5	6.2	8.4	8.4
Materials	6.9	7.6	5.9	8.1	7.3	6.5
Labour	1.4	2.0	0.6	4.3	0.4	0.5
Capital	8.8	9.3	8.3	6.7	11.1	8.2
TP	0.8	0.2	1.5	-1.2	1.2	1.8
Share in Nominal Gross Output						
Intermediates	78.2	77.6	78.9	76.5	78.5	78.9
Labour	8.0	9.4	5.9	10.6	8.5	5.8
Capital	13.9	12.9	15.2	12.9	13.0	15.3

[1] *Excluding electricity, gas and water supply sector*

Table 5. Averages of TP Growth Rates

(In percent)

	1970-79	1973-79	1980-89	1990-97	1990-99	2000-03	1990-03
Series A[1]		-1.01	0.80		1.50	1.49	1.50
Series B[2]	0.03		1.17	1.70			
Series C[3]	0.03		1.17		1.88	1.68	1.82

[1] *1973-2003, excluding electricity, gas, and water supply sectors.*

[2,3] *Including electricity, gas, and water supply sectors. Data for this sector are from ASI published series in Series B (1970-1997), and imputed for years after 1997 in Series C.*

Table 6. Sources of growth of output per worker in state level manufacturing
(Average annual growth rates)

	Output per worker			Capital per worker		
	1970-79	1980-89	1990-03	1970-79	1980-89	1990-03
Top group[1]	2.7	6.8	8.0	3.0	6.1	6.2
Middle group[1]	2.4	7.6	7.2	3.4	6.8	5.7
Bottom group[1]	2.2	8.6	8.5	2.6	9.6	7.1
	Material per worker			Total productivity (TP)		
	1970-79	1980-89	1990-03	1970-79	1980-89	1990-03
Top group[1]	6.0	5.0	7.0	-0.3	1.4	1.9
Middle group[1]	1.9	5.4	6.8	-0.1	1.6	1.6
Bottom group[1]	4.5	9.0	6.1	0.8	1.5	2.1

[1] *Groupings are based on level of output per worker in 1970*

Table 7. State-wise TP Levels and Ranks[1]

		TP level		Rank		% change
		1970[2]	2003[3]	1970	2003	
1	Andhra Pradesh	1.021	1.385	7	5	36
2	Assam	1.015	1.302	9	15	28
3	Bihar	1.011	1.367	10	7	35
4	Gujarat	1.089	1.376	2	6	26
5	Haryana	1.048	1.423	5	4	36
6	Himachal Pradesh	0.947	1.450	14	1	53
7	Jammu and Kashmir	0.859	1.345	16	10	56
8	Karnataka	0.985	1.249	11	16	27
9	Kerala	0.981	1.337	13	12	36
10	Madhya Pradesh	1.016	1.353	8	8	33
11	Maharashtra	1.141	1.440	1	3	26
12	Orissa	0.833	1.049	17	17	26
13	Punjab	1.052	1.442	4	2	37
14	Rajasthan	0.938	1.315	15	14	40
15	Tamil Nadu	1.040	1.338	6	11	29
16	Uttar Pradesh	0.982	1.328	12	13	35
17	West Bengal	1.052	1.353	3	9	29

[1] *Data for electricity, gas and water supply sector based on extrapolations after 1997*

[2] *Average over 1970-75*

[3] *Average over 1998-03*

Table 8. State TP Growth Rates - Evidence of Convergence[1]

(By tercile of TP level in 1970, in percent)

	TP Growth Rates[2]						TP Levels[2]	
Tercile	1970-03	1970-90	1991-03	1970-80	1981-90	1992-03	1970	2003
Top	1.1	0.6	1.8	-0.3	1.4	2.2	1.1	1.4
Middle	1.3	0.9	1.9	-0.4	2.1	2.3	1.0	1.3
Bottom	1.4	1.1	1.8	-0.4	2.6	2.1	0.9	1.3
% Gap in TP level								
Top - Bottom							**13.0**	**7.9**
Top -Middle							**5.7**	**5.3**

[1] *16 major states, excluding Jammu and Kashmir from original sample*

[2] *Average of states in tercile*

Table 9. Manufacturing Output per Worker, TP, and Per-capita Income (1980)

		Output per worker rank[1]	TP rank[1]	Per capita income rank[2]	Per-capita income[2]
Top					
	Maharashtra	1	1	2	2422
	Punjab	2	4	1	2664
	Haryana	3	5	3	2350
	Bihar	4	10	16	911
	Madhya Pradesh	5	8	11	1348
Middle					
	Gujarat	6	2	4	1931
	Orissa	7	16	12	1309
	Uttar Pradesh	8	12	14	1274
	Tamil Nadu	9	6	9	1494
	Rajasthan	10	15	15	1210
	Karnataka	11	11	7	1510
Bottom					
	Assam	12	9	13	1277
	West Bengal	13	3	5	1764
	Andhra Pradesh	14	7	10	1372
	Himachal Pradesh	15	14	6	1683
	Kerala	16	13	8	1505

[1] *Based on 1970 levels*

[2] *For 1980-81, Reserve Bank of India (in 1980-81 prices)*

Table 10. Manufacturing Output per Worker, TP, and Per-capita Income (2003)

		Output per worker rank[1]	TP rank[1]	Per-capita income rank[2]	Per-capita income[2]
Top					
	Gujarat	1	6	6	22491
	Himachal Pradesh	2	1	3	24830
	Maharashtra	3	3	4	24767
	Bihar	4	7	16	7735
	Madhya Pradesh	5	8	13	12226
Middle					
	Uttar Pradesh	6	12	15	10324
	Haryana	7	4	1	28071
	Karnataka	8	15	9	18289
	Rajasthan	9	13	11	15299
	Orissa	10	16	14	11802
	Assam	11	14	12	13734
Bottom					
	Punjab	12	2	2	26891
	Tamil Nadu	13	10	7	20570
	West Bengal	14	9	10	17915
	Kerala	15	11	5	22786
	Andhra Pradesh	16	5	8	19062

[1] *Based on 2003 levels*

[2] *For 2003-04, Reserve Bank of India (in 2000-01 prices)*

Table 11. All-India Highway and Electricity Stock[1]

	National and state highways (km)	Electricity generation capacity (mw)
1973	112574	13896
1974	113465	15050
1975	114263	16772
1976	114932	18130
1977	117823	20322
1978	119788	22938
1979	119561	24581
1980	121388	26122
1981	122087	27543
1982	122448	30232
1983	124561	32468
1984	124849	35306
1985	127065	38636
1986	127626	40039
1987	128144	41859
1988	142943	44132
1989	150703	46507
1990	152306	48445
1991	155522	49667
1992	156516	50386
1993	157975	52565
1994	160806	55418
1995	161960	55971
1996	163217	57580
1997	165409	60580
1998	168498	63799
1999	179751	66703
2000	179813	67585
2001	185950	70184
2002	188851	74467

Correlation with time trend:

Roads	0.97
Electricity	1.00

[1] *Sum of 17 states in current sample.*

Table 12.1. State-wise Highway Stock Over Time

(Sum of national and state highways; in

	Andhra Pradesh	Assam	Bihar	Gujarat	Haryana	Himachal Pradesh	Jammu & Kashmir	Kerala	Karnataka	Maharashtra	Madhya Pradesh	Orissa	Punjab	Rajasthan	Tamil Nadu	Uttar Pradesh	West Bengal
1973	7771	3351	6293	9835	3457	3516	1202	2792	7973	17553	13310	3893	2839	10809	3597	10610	3773
1974	7812	3351	6293	9957	3752	3575	1205	2792	8054	17703	13310	3893	2839	10828	3610	10715	3776
1975	7812	3351	6294	10007	3772	3638	1232	2857	8058	17715	13855	3844	2869	10831	3610	10740	3778
1976	7812	3617	6302	10061	3779	3683	1238	2857	9522	17975	13932	3825	2877	9354	3610	10664	3824
1977	7812	3617	6307	10116	3779	3944	1238	2857	9583	20324	14074	3803	2877	9375	3610	10683	3824
1978	7815	3620	6309	10329	3788	3944	1302	2859	9620	21843	14074	3820	2877	9375	3663	10676	3874
1979	7815	3620	6309	10405	3791	4002	1302	2859	9770	21461	14134	3833	2877	9375	3678	10456	3874
1980	7815	3627	6309	10518	3791	4004	1281	2865	9770	21786	14168	4465	2877	9375	3679	10440	4618
1981	7815	3727	6309	10579	3791	3837	1281	2892	9781	21894	14179	4465	2877	9786	3681	10441	4752
1982	7815	3727	6309	10579	3791	3840	1281	2918	9781	22072	14319	4465	2877	9786	3681	10430	4777
1983	9422	4002	6309	10626	3791	3912	1281	2918	9880	22026	14382	4458	2877	9786	3681	10433	4777
1984	9422	4029	6309	10706	3791	3916	1281	2883	9880	21999	14411	4458	2877	9978	3697	10435	4777
1985	10898	4090	6310	10808	3792	4128	1336	2860	9880	22007	14393	4470	2877	9978	3719	10434	5085
1986	10976	4100	6310	10863	3792	4128	1336	2841	9880	22197	14393	4552	2940	9978	3747	10508	5085
1987	10976	4114	6310	10954	3792	4128	1336	2841	9880	22479	14509	4552	2940	9981	3764	10503	5085
1988	11018	4122	6310	10954	3792	4241	1336	2861	13167	33503	14589	4552	2927	9981	3768	10737	5085
1989	11238	4122	6310	16996	3792	4454	1336	2865	13223	32913	14650	4552	3146	10075	3768	12178	5085
1990	11238	4122	6310	18002	3792	4392	1336	2865	13228	33215	14686	4552	3146	10075	3779	12483	5085
1991	11238	4122	6310	20620	3792	4392	1336	2865	13279	33543	14693	4552	3146	10087	3917	12524	5106
1992	11238	4122	6310	20962	3792	4402	1336	2865	13285	34249	14711	4552	3146	9982	3922	12536	5106
1993	11333	4149	6310	21061	3792	4385	1336	3059	13285	34249	14731	5633	3154	9997	3931	12531	5039
1994	11726	4149	6310	21181	3792	4390	1336	3059	13392	34900	14731	5640	3154	11566	3931	12510	5039
1995	11726	4149	6310	21227	3792	4399	1336	3059	13392	34900	14736	5640	3154	12656	3935	12510	5039
1996	11726	4149	6310	21289	3792	4404	1336	3372	13392	35207	14765	5985	3154	12852	3936	12509	5039
1997	11755	4149	6310	21333	3792	4415	1336	4780	13392	35317	14765	6209	3364	12893	3936	12530	5133
1998	11813	4257	6739	21798	4074	4536	1336	4780	13403	35480	15169	6280	3364	13148	4493	12704	5124
1999	12403	4547	7271	22037	4497	4755	1426	4779	13255	36849	16783	6565	3494	14128	7897	13751	5314
2000	12265	4601	7731	21620	3822	4870	1426	5343	13223	36838	17136	6913	3494	13279	7897	14169	5186
2001	12063	4731	9107	21590	3822	4870	1511	5368	13399	36838	18400	7351	3719	13195	7926	16874	5186
2002	12239	4731	9107	21624	3822	4870	1511	5289	13399	37031	18400	7351	3719	13113	10936	16225	5484
Correlation with time trend:																	
	0.94	0.94	0.58	0.91	0.47	0.96	0.88	0.75	0.91	0.95	0.80	0.92	0.90	0.76	0.64	0.83	0.87
Min	**0.47**																
Max	**0.96**																

Table 12.2. State-wise Expansion in Electricity Generation Capacity Over Time
(In megawatts)

	Andhra Pradesh	Assam	Bihar	Gujarat	Haryana	Himachal Pradesh	Jammu & Kashmir	Kerala	Karnataka	Maharashtra	Madhya Pradesh	Orissa	Punjab	Rajasthan	Tamil Nadu	Uttar Pradesh	West Bengal
1973	670	197	604	954	504	51	82	625	967	1882	777	684	771	583	1654	1558	1333
1974	890	197	604	1173	557	53	94	625	967	2070	776	803	886	581	1654	1841	1279
1975	990	167	604	1361	617	52	102	755	1056	2480	895	863	999	581	1764	2087	1399
1976	1200	160	712	1595	617	53	101	1013	1056	2600	895	923	976	581	1764	2499	1385
1977	1520	162	890	1711	742	113	136	1012	1145	2822	1135	923	1246	684	1824	2868	1389
1978	1620	162	891	2216	978	113	171	1012	1145	3322	1318	923	1541	820	2119	3076	1511
1979	1930	162	890	2212	1081	114	206	1012	1335	3552	1528	923	1536	820	2329	3340	1611
1980	2240	228	941	2197	1141	129	206	1012	1470	3992	1630	923	1536	810	2329	3612	1726
1981	2240	333	940	2407	1141	127	206	1012	1740	4322	1631	1032	1586	810	2539	3751	1726
1982	2678	334	1051	2576	1213	128	206	1012	1875	4862	1841	1442	1704	1023	2539	3752	1996
1983	2830	349	1160	2786	1266	128	206	1012	2010	5572	2471	1134	1828	1167	2509	3916	2124
1984	3156	432	1374	3106	1311	134	205	1012	2220	5995	2681	1134	2315	1180	2509	4148	2394
1985	3366	432	1595	3316	1429	134	205	1309	2530	6884	2944	1235	2449	1230	2529	4355	2694
1986	3595	507	1595	3526	1553	135	207	1476	2530	7011	2997	1235	2459	1233	2795	4566	2619
1987	3614	507	1549	3863	1569	154	210	1477	2530	7272	3042	1394	2660	1212	3300	4887	2619
1988	3614	537	1549	3973	1787	274	235	1477	2530	7482	3087	1394	3048	1467	3642	5417	2619
1989	4064	537	1549	4220	1795	274	284	1477	2645	8208	3088	1574	3049	1722	3875	5527	2619
1990	4130	537	1549	4395	1780	272	262	1477	2970	8705	3298	1612	3049	1722	4089	5527	3071
1991	4224	537	1544	4737	1780	272	262	1477	2986	9207	3383	1612	3289	1732	4311	5179	3135
1992	4226	537	1548	4891	1780	272	262	1477	3052	9129	3533	1742	3499	1733	4315	5075	3315
1993	4727	577	1550	4938	1780	272	337	1484	3167	9339	3783	1742	3509	1943	4317	5575	3525
1994	5209	597	1765	4939	1780	274	362	1492	3377	9987	3864	1952	3509	1949	4737	6075	3550
1995	5210	597	1768	5329	1780	289	366	1492	3379	10000	3864	1692	3509	1985	5067	6069	3575
1996	5709	597	1983	5457	1780	300	366	1566	3385	10000	3873	1693	3509	1985	5723	6059	3595
1997	6208	617	1988	6520	1780	299	374	1771	3450	10500	3878	1693	3719	1985	5763	6169	3866
1998	6214	622	1988	6973	1780	299	374	1816	3973	11600	4094	1698	3929	2235	5988	6085	4131
1999	6255	622	1988	7223	1780	300	409	2118	4368	12400	4353	1993	3929	2487	6052	6053	4373
2000	6756	622	2108	7223	1990	326	417	2218	4465	12900	4373	2298	4529	2489	3521	6567	4783
2001	7238	622	2228	7352	1990	412	496	2239	4987	13200	4408	2298	4529	2999	3802	6600	4784
2002	7616	622	2228	7323	1990	612	496	2239	5197	13200	4500	2304	4533	3077	7146	6600	4784
Correlation with time trend:																	
	0.99	0.95	0.98	0.99	0.94	0.91	0.97	0.95	0.98	1.00	0.98	0.96	0.99	0.97	0.90	0.97	0.99
Min	**0.90**																
Max	**1.00**																

Table 13. Average of state-wise correlations[1]

	TP	Trend	Own highways	Contiguous highways	Own electricity	Contiguous electricity
TP	1					
Trend	0.89	1				
Own highways	0.79	0.83	1			
Contiguous highways	0.87	0.93	0.82	1		
Own electricity	0.72	0.90	0.72	0.79	1	
Contiguous electricity	0.77	0.95	0.75	0.82	0.93	1

[1] *Average of 15 states incuded in regression sample*

Table 14. Pooled Spatial Errors Model (SEM)

Dependent variable: TP	1	2	3	4	5	6	7	8	9
Trend	0.0118	0.0104	0.0114	0.0103	0.0103	0.0128	0.0114	0.01	0.0115
	*(16.33)****	*(15.96)****	*(15.93)****	*(16.11)****	*(13.13)****	*(15.61)****	*(13.55)****	*(14.70)****	*(15.61)****
Own National + State Highways		0.0862		0.1129				0.0753	0.0908
		*(9.36)****		*(9.11)****				*(7.33)****	*(7.68)****
Contiguous National + State Highways			0.0234	-0.0249					0.0119
			*(3.78)****	*(-3.17)****					*1.35*
Own Electricity					0.0436		0.0416	0.0177	0.0048
					*(6.12)****		*(6.05)****	*(2.33)****	*0.63*
Contiguous Electricity						-0.0298	-0.0284		-0.0449
						*(-6.45)****	*(-6.40)****		*(-8.80)****
Constant	0.9228	1.203	0.9916	1.2166	1.3832	0.6147	1.0686	1.3541	0.8377
	*(63.79)****	*(36.95)****	*(42.93)****	*(37.44)****	*(18.06)****	*(12.15)****	*(11.94)****	*(18.62)****	*(8.60)****
Observations	510	510	510	510	510	510	510	510	510
Number of states	15	15	15	15	15	15	15	15	15
Lambda	0.44	0.42	0.45	0.41	0.49	0.52	0.53	0.42	0.50
t-stat (lambda)	*(8.60)****	*(8.58)****	*(8.64)****	*(8.65)****	*(9.43)****	*(9.22)****	*(9.75)****	*(8.71)****	*(9.73)****
R-squared	0.6484	0.70	0.66	0.70	0.67	0.67	0.70	0.70	0.75

*t statistics in parantheses; *** indicates significant at 1 percent, ** at 5 percent, and * at 10 percent level.*
*error structure: u = lambda*Wu + e, W = weights matrix*

Table 15. Fixed Effects

	1	2	3	4	5	6	7	8
Trend	0.011	0.01	0.009	0.016	0.02	0.02	0.015	0.018
	(25.38)***	(14.83)***	(14.22)***	(27.96)***	(28.22)***	(28.33)***	(23.81)***	(20.45)***
Own National + State Highways	0.038		0.012				0.047	0.031
	(1.74)*		(0.54)				(2.30)**	(1.57)
Contiguous National + State Highways		0.146	0.14					0.135
		(4.01)***	(3.64)***					(4.02)***
Own Electricity				-0.117		-0.044	-0.119	-0.051
				(7.86)***		(2.77)***	(8.01)***	(3.27)***
Contiguous Electricity					-0.221	-0.191		-0.188
					(12.00)***	(9.03)***		(9.03)***
Constant	1.042	1.366	1.386	-0.316	-1.391	-1.549	-0.549	0.451
	(14.58)***	(12.22)***	(11.75)***	(2.01)**	(7.22)***	(4.43)***	(4.43)***	(4.43)***
Observations	510	510	510	510	510	510	510	510
Number of states	15	15	15	15	15	15	15	15
R-squared	0.78	0.79	0.79	0.8	0.83	0.83	0.83	0.83

t statistics in parentheses; * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent level.

Table 16. Between Estimator

	1	2	3	4	5	6	7	8
Own National + State Highways	0.106		0.15				0.092	0.131
	*(2.38)***		*(2.47)***				*(1.7)*	*(2.02)**
Contiguous National + State Highways		0.023	-0.039					-0.02
		(0.73)	*-1.06*					*-0.46*
Own Electricity				0.052		0.06	0.019	0.026
				(1.54)		*(1.72)**	*(0.51)*	*(0.72)*
Contiguous Electricity					-0.013	-0.025		-0.033
					(-0.46)	*(-0.92)*		*-1.13*
Constant	1.445	1.189	1.471	1.641	0.997	1.478	1.588	1.403
	*(10.68)****	*(13.33)****	*(10.75)****	*(4.89)****	*(3.60)****	*(3.88)****	*(5.04)****	*(3.50)****
Observations	510	510	510	510	510	510	510	510
Number of states	15	15	15	15	15	15	15	15
R-squared	0.3	0.04	0.36	0.15	0.02	0.21	0.32	0.46

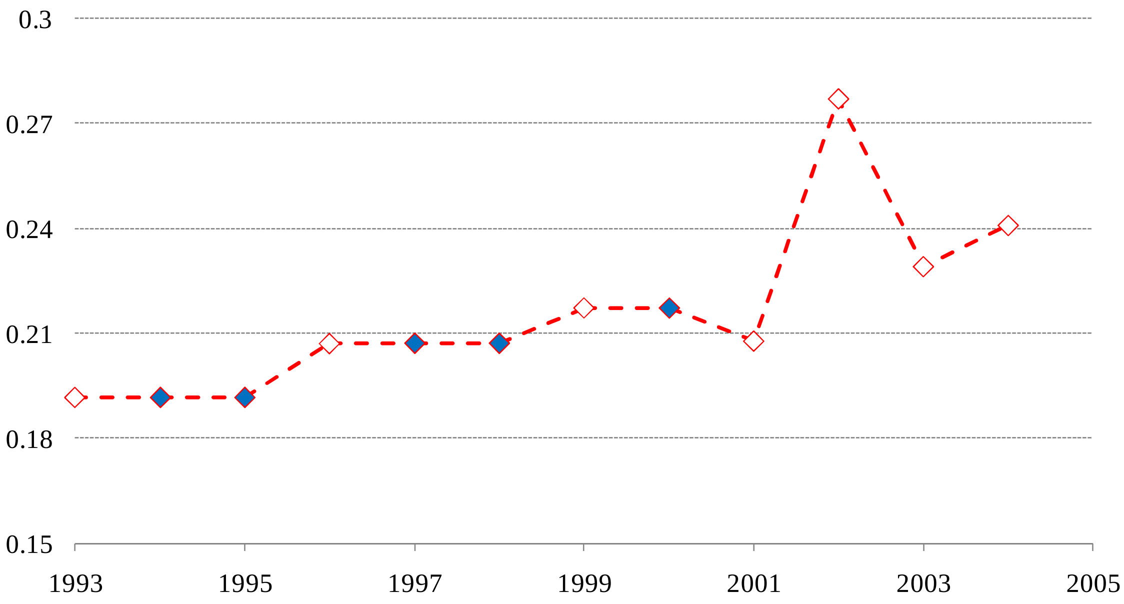
*t statistics in parentheses; * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent level.*

Table 17. Spatial Errors Model (SEM) - including state dummy variables

	1	2	3	4	5	6	7	8
Trend	0.0123	0.0106	0.0113	0.012	0.0162	0.0169	0.0125	0.0161
	*(16.95)****	*(13.14)****	*(12.21)****	*(12.21)****	*(17.62)****	*(15.92)****	*(16.76)****	*(13.94)****
Own National + State Highways	-0.035		-0.0256				-0.0255	-0.0017
	*(-2.18)***		*(-1.53)*				*(-1.44)*	*(-0.10)*
Contiguous National + State Highways		0.0799	0.0624					0.0762
		*(2.44)***	*(1.79)**					*(2.27)***
Own Electricity				-0.0078		-0.0179	-0.0102	-0.0233
				(-0.58)		*(-1.45)*	*(-0.74)*	*(-1.86)**
Contiguous Electricity					-0.1272	-0.1323		-0.132
					*(-5.96)****	*(-6.15)****		*(-6.11)****
Constant	0.9318	1.3041	1.1725	0.9501	-0.3503	-0.5846	0.8558	-0.3771
	*(19.71)****	*(11.47)****	*(8.23)****	*(7.03)****	*(-1.51)*	*(-2.05)***	*(5.93)****	*(-1.25)*
Observations	510	510	510	510	510	510	510	510
Number of states	15	15	15	15	15	15	15	15
Lambda	0.70	0.71	0.71	0.61	0.63	0.64	0.58	0.62
t-stat (lambda)	*(24.71)****	*(24.17)****	*(24.10)****	*(19.05)****	*(18.70)****	*(18.90)****	*(18.03)****	*(17.41)****
R-squared	0.91	0.92	0.92	0.90	0.92	0.92	0.90	0.92

*t statistics in parantheses; *** indicates significant at 1 percent, ** at 5 percent, and * at 10 percent level.*
*error structure: u = lambda*Wu + e, W = weights matrix*
all regression include state dummy variables for N-1 states

Figure 1. Gini coefficient of income inequality across states over time[1]
(Based on per-capita gross state domestic product)

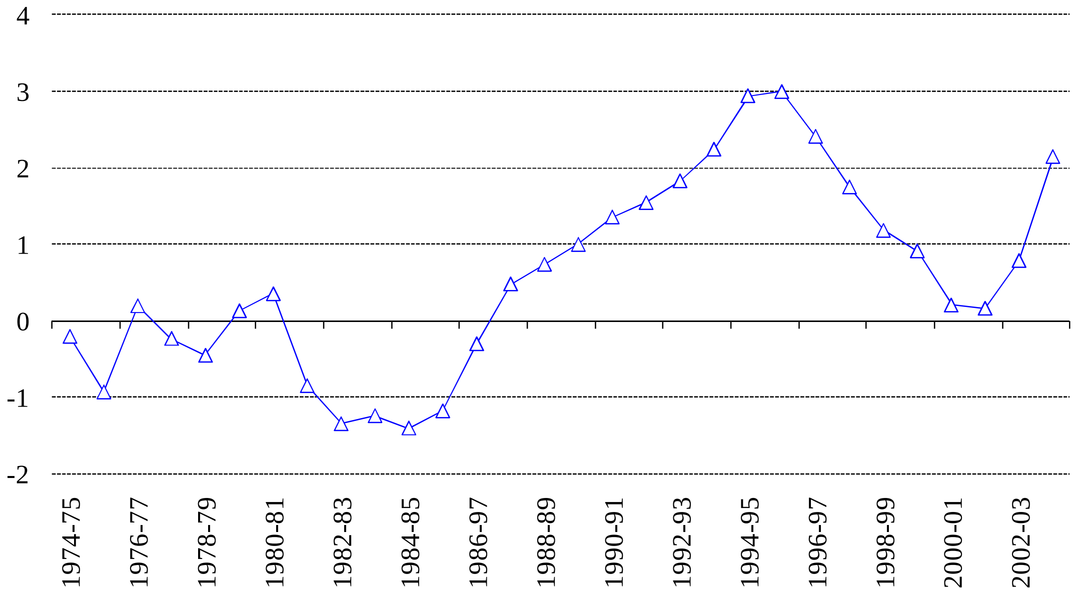


Source: Planning Commission, Eleventh Plan document, Chapter 7

[1] Solid markers indicate gap years.

Figure 2. Divisia Output Price Index vs. Manufacturing WPI[1]

(Difference in percent)



[1] Manufacturing WPI based on official data from Central Statistical Organization (CSO) official series

Figure 3. Growth Rate of Real Output and Inputs
(In percent)

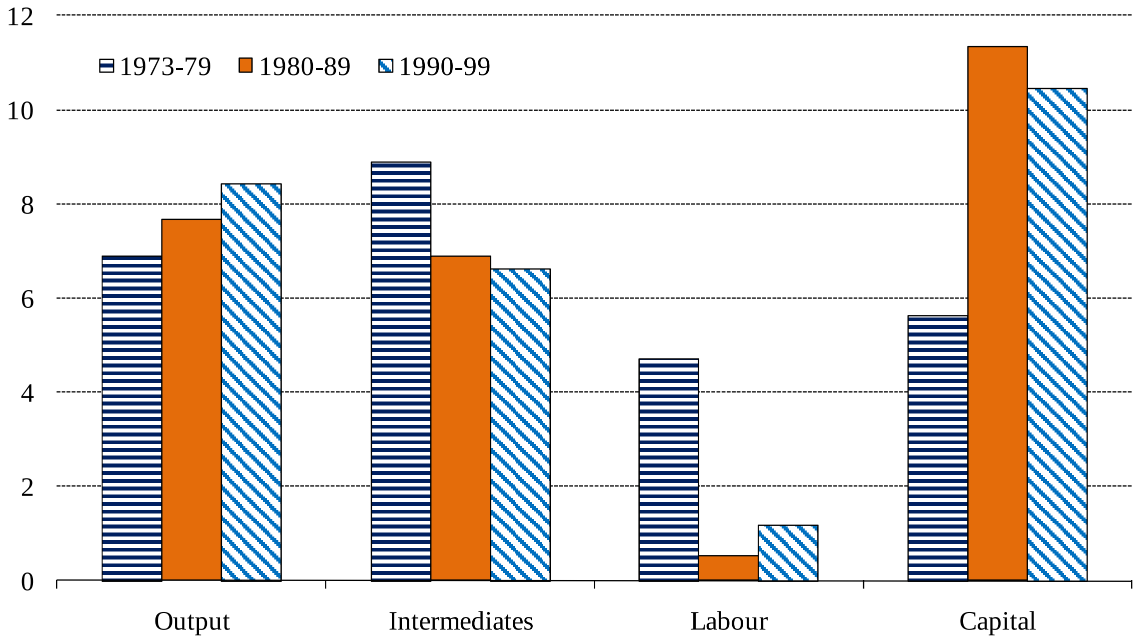
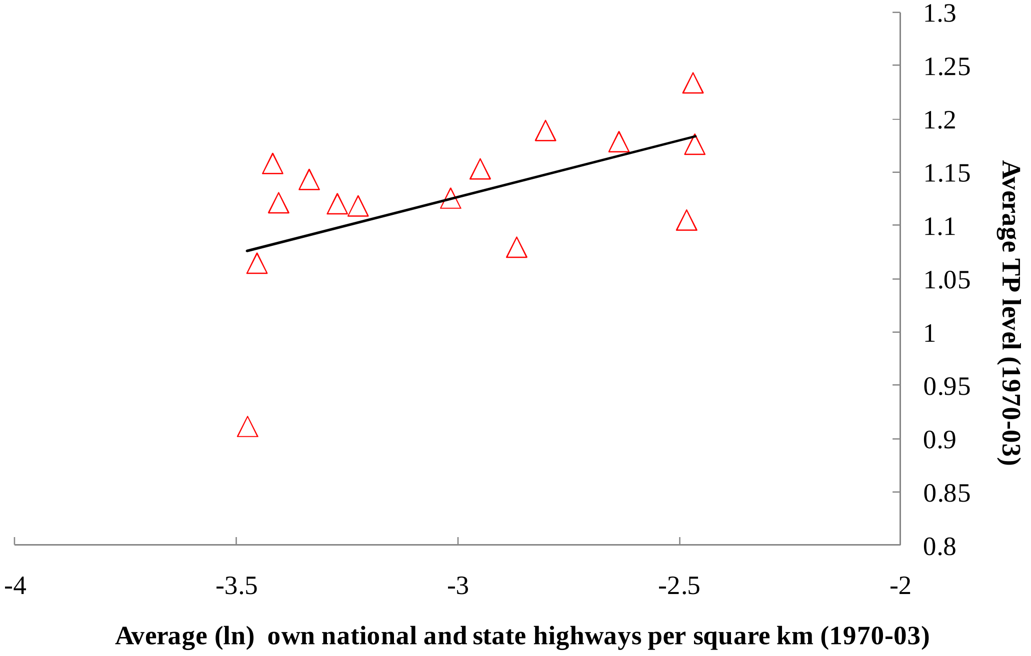


Figure 4. State-wise TP and National + State Highways (1970-03 average)



Figuer 5. State-wise TP and Electricity Generation Capacity (1970-03 average)

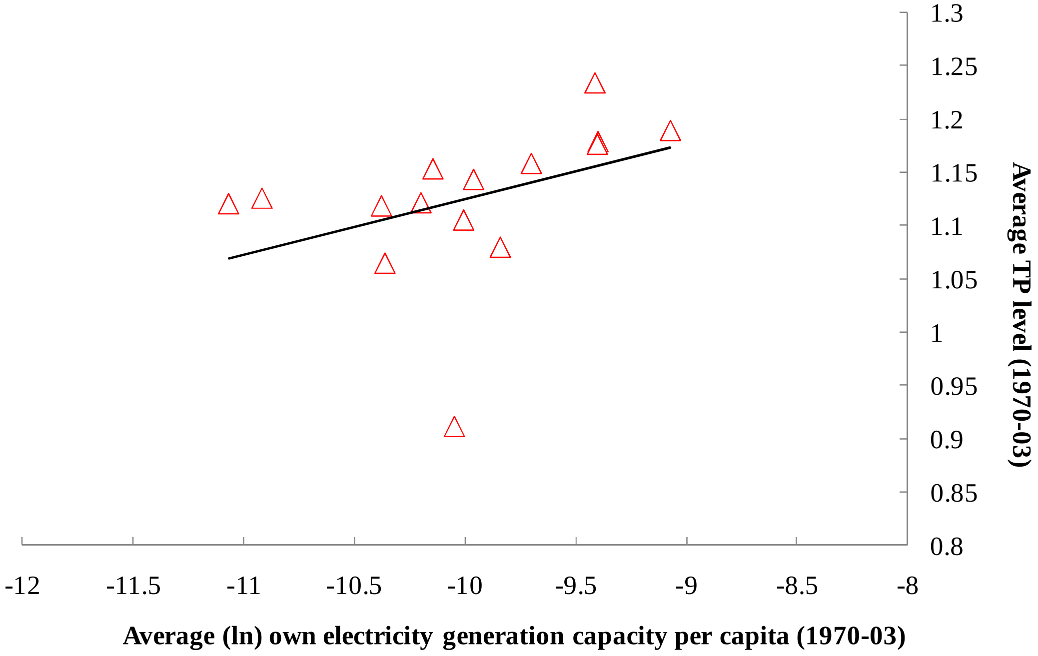


Figure 6: State-wise TP and National + State Highways (contiguous, 1970-03 average)

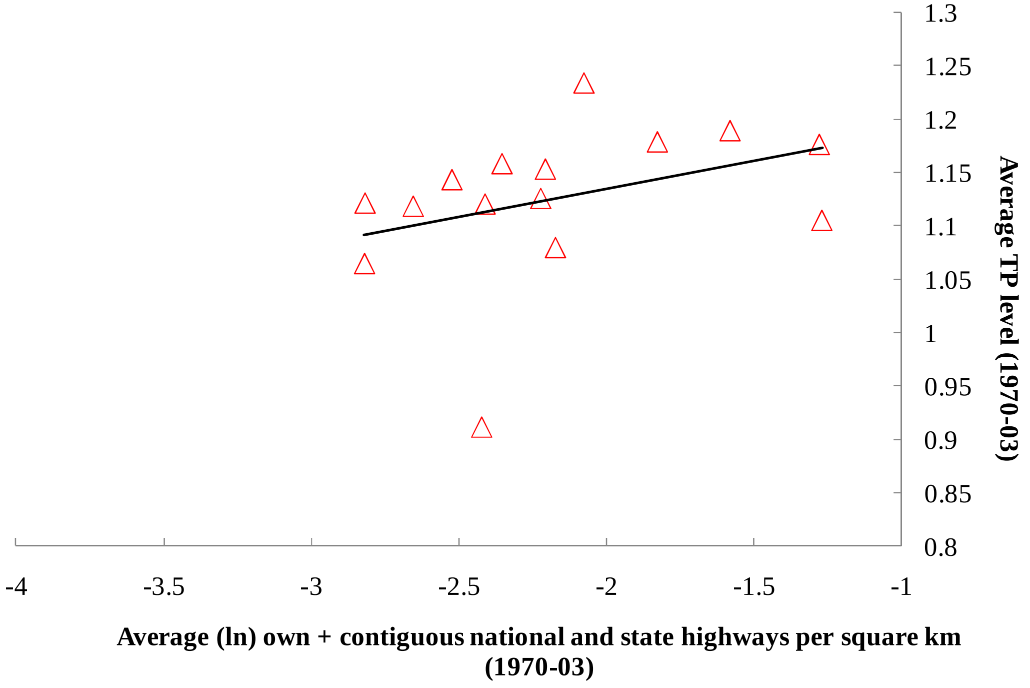
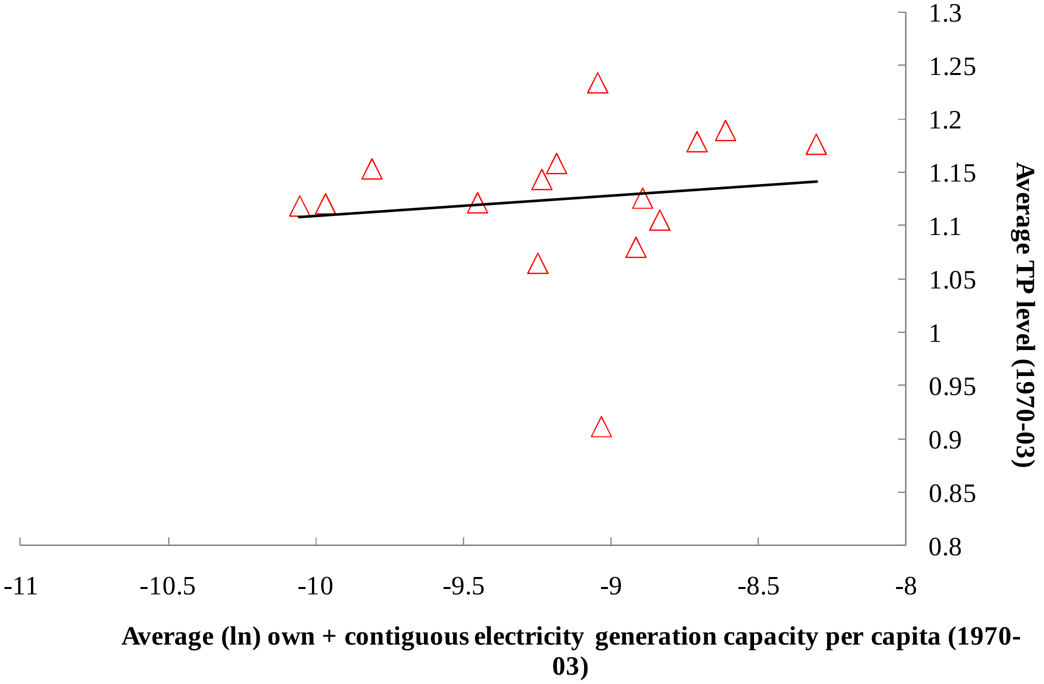


Figure 7: State-wise TP and Electricity Generation Capacity (contiguous, 1970-03 average)



Appendix 2: ASI data definitions, construction of price and quantity indices

1. Data Definitions: Following are the terms and definitions employed by ASI in measuring state-level industrial aggregates. Note that all definitions are taken from ASI 1973-74 -- 2003-04 (Vol. II) published by the EPW Research Foundation. For all variables below, data for the year 1972-73 was not available, and was approximated by linear interpolation.

Total Persons Engaged: was used as the measure of labour input. ASI defines Total Persons Engaged as all persons engaged by the factory whether for wages or not, in work connected directly or indirectly with the manufacturing process and include all administrative, technical, clerical staff as also labour engaged in production of capital assets for factory's own use. This is inclusive of persons holding supervisory or managerial positions or engaged in administrative office, store keeping section and welfare section, sales department as also those engaged in the purchase of raw materials etc. , and production of fixed assets for the factory and watch and ward staff. It also includes all working proprietors and their family members who are actively engaged in the work of the factory even without any pay and the unpaid members of the co-operative societies who worked in or for the factory in any direct and productive capacity. (Note that in summary reports published prior to 1979-80 total persons engaged was termed as employees. Lacking data on Total Persons Engaged before 1980, employee data was used for previous years).

Total Emoluments: measures payment to labour input. Emoluments include wages and salaries, and imputed value of benefits including those paid in kind.

Total Inputs: is the current cost of fuels, electricity, materials, and services (such as freight and transport charges, communication costs, and insurance and banking costs) consumed in production.

Capital Stock: series was built using the perpetual inventory method as in most studies. For this, ASI gross investment data at current prices was employed. For years prior to 1979, the gross investment series was not available, and was estimated using ASI depreciation and net fixed capital stock data[57].

Gross Value of Output: is the measure of output employed for estimating Total Productivity. This is the ex-factory value of ASI "product", which includes all goods except intermediates produced in the year, whether sold or not, and inclusive of fixed capital produced by the factory for its own use.

<u>2. Electricity, Gas and Water Supply Sector:</u> In order to exploit the entire available time series up to 2003 for all other sectors, aggregates for this sector were imputed from 1997 onwards, based on historical growth rates. The imputed aggregates were applied to both the All-India series, and the state-year series. Average growth from 1990-97 was chosen for extrapolation. It is arguable that a more recent average, such as 1993-97

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[57] Gross Investment(t) = Net Stock(t) + Depreciation(t) - Net Stock(t-1)

might have been appropriate, but the growth rate of employment, coming off a trough in the preceding five years, would likely over-estimate labour. The other growth rates from 1990-97 and 1993-97 appear comparable. Also, barring depreciation rates, the 1973-97 averages and 1990-97 averages seem comparable too. Secondly, the average share of the aggregates of this sector in each state's aggregates was estimated using state-industry data (available from 1979-1997), and the imputed values (additions to 1997 stocks) were split up between states based on this share. Imputed addition to capital stock was assigned according to EGW's average share in state net capital stock at book value.

3. Methodology for construction price deflators

The approach to constructing price deflators in this study is to derive a set of weights for the aggregate output and aggregate intermediate input series respectively. These weights are then used to combine wholesale price indices corresponding to the ASI industries at the 2-digit level that were aggregated in this study to for state level (and all-India) aggregate series.

Table A.1 lists the 25 ASI 2-digit industry groups that are included in our measure of aggregate gross output, the weight of the industry group in the output price index, as well as the name of the wholesale price index that most closely maps into the given industry group's output. Similarly, Table A.2 lists 21 ASI 2-digit industry groups that are included in our measure of aggregate intermediate inputs, the weights of each industry group in the input price index, and the corresponding wholesale price series that maps to the given industry. The weights in both tables refer to years for which I was able to obtain I-O information for the aggregate Indian economy. The commodity-flow matrix (or absorption) matrix in the I-O tables details the deliveries of commodities to industries for intermediate consumption, as well as the deliveries of commodities to final demand in the aggregate economy. There are 6 categories of final demand: (i) Private Final Consumption Expenditure (ii) Government Final Consumption Expenditure (iii) Gross Fixed Capital Formation (iv) Change in Stocks (v) Exports and (vi) Imports. Strictly speaking, the commodity/industry table is not symmetric, in the sense that by -- products of given industry are treated as the principle output of the industry that produces this particular as the main product. Hence, row (commodity) totals are not equal to column (industry output) totals. This is not a problem for out price indices, as we are eventually interested in what prices industries receive for their output, whether it be their principle product or a by-product.

An additional note on the I-O tables is that while for 1973-74 we only had a 60-sector classification, this expanded to 115 sectors in subsequent rounds. Not wanting to lose the earliest I-O information, I aggregated all the other years also up to the 60-sector aggregate, using the official aggregation provided in I-O tables. Also, although I have tried to create a price index that refers to only those industries covered in the ASI frame at the 2-digit level, the I-O information itself is based on economy-wide flows, not limited to the registered manufacturing sector. In other words, the weights derived from I-O information are also based on informal sector manufacturing. It is quite possible that the technology of the informal sector even within an industry group is quite different from that of the formal sector, hence the weights are proxies at best. However, this concern is mitigated when one recalls that the formal sector accounts for bulk of the flows of intermediate consumption and gross output in the manufacturing sector as a whole (refer footnote 8 in text).

Deriving weights for output prices:

For each I-O year, I isolated the deliveries to final demand of the 25 ASI industries (commodities) covered in our sample. However, since commodity flows to intermediate and final demand also include imported commodities, these have to be netted out from the flows in order to price only domestic production. Using the import flow matrix (available in I-O tables from 1989-90 onwards, but not for previous rounds), it is possible to distinguish flows of imports to intermediate consumption and to final consumption (PFCE, GFCE, and GFCF) respectively[58].

Having isolated deliveries to final demand in this way, we then weight each industry according to its share in deliveries to final demand, by all 25 ASI industries. Hence, if $Y_i = PFCE_i + GFCE_i + I_i + X_i - M_i^F$, where M_i^F is imports for final demand of

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[58] The import flow tables show no deliveries of imports to Change in Stock; all imports are exhausted between intermediate use and the three categories of final demand above. For years prior to 1989-90, a simple expedient is to calculate the fraction of imports-to-intermediate use over total imports from the closest I-O round for which data are available, and impose that fraction on total imports as given in the absorption matrix of the previous rounds as a best approximation.

commodity i, then industry $i's$ weight in the output price index $w_i = Y_i / \sum_{i=1}^{25} Y_i$. Thus we obtain five sets of weights for industry output, one for each available I-O year. Table A. 1 shows how that the weights for output tend to be relatively stable over time. However, the weights for iron and steel, petroleum products, and miscellaneous manufacturing have gone up in a noticeable way.

Deriving weights for input prices:

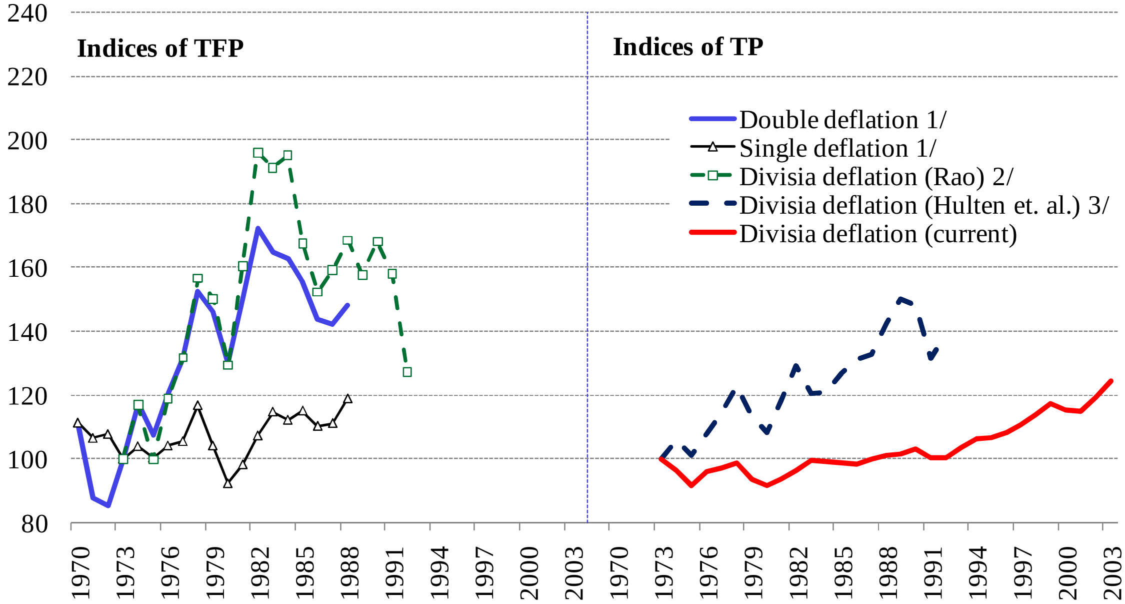
For each I-O year, I isolated flows of the 21 input goods listed in Table A.2 to the 25 ASI industries in our sample. I excluded flows of these input commodities to all industries not covered in the ASI frame, so that the resulting input price deflator is as specific to ASI as possible. I did not in this case net out flows of imports to intermediate demand, as we are interested in prices paid by ASI industries for the consumption of intermediate goods irrespective of the source of origin.

Then, the weight of commodity j in the input price index is simply $\mu_j = M_j / \sum_{j=1}^{21} M_j$, where M_j is the total delivery of commodity j to the 25 ASI industries: $M_j = \sum_{i=1}^{25} m_{ji}$, and m_{ji} is the consumption of intermediate input j by industry i. This exercise shows that intermediate input structure has changed substantially over time. Table A.3 showed that the share of services inputs has increased quite substantially in the 30 year time frame. In addition we can see from Table A.2 that the share of primary articles has fallen dramatically, whereas the share of fuels, coal, chemicals, and electricity has increased. This shows that there could be potentially severe pitfalls from using fixed weights for the input price index, if the growth rates of these commodities differ from each other.

Using the weights derived in the above manners, aggregate output and input price indices could then be constructed by combining the change in individual industry price indices with the weights to derive a Divisia-type growth rate of the aggregate index: $\Delta \ln P_t^Q = \sum_{i=1\,:\,25} w_i [\ln P_{i,t}^Q - \ln P_{i,t-1}^Q]$, where P_t^Q is the aggregate output index and $P_{i,t}^Q$ is the wholesale price index of commodity i. Similarly for intermediate inputs, we get $\Delta \ln P_t^M = \sum_{j=1\,:\,21} \mu_j [\ln P_{j,t}^M - \ln P_{j,t-1}^M]$. We set the value of each price index = ln(100) in the year 1993-94. We can then increment (decrement) this base value by the estimated change in log-levels as shown above. The exponent of this incremented (decremented) value yields the requisite price index. The index levels are given in Table A.6, along with the official manufacturing WPI series as published by the CSO. Note that for the purpose of estimating TPG and TP levels, we only need to know the growth rates of the aggregate price indices.

Appendix 3: Additional figures and tables

Figure A.1 TFP and TP Indices Under Different Deflation Methods
(1973=100)



[1] Data from Balakrishnan and Pushpangadan (1994)
[2] Data from Rao (1996)
[3] Data from Hulten, Bennathan and Srinivasan (2006)

Table A.1. Output Weights in ASI Output Price Deflator

			Input-Output table					
No.	ASI 2-digit industry	Industry description	1973-74	1983-84	1989-90	1993-94	1998-99	**Wholesale price index series**
1	20	Wood and wood products except furniture	0.003	0.004	0.001	0.004	0.004	Wood products
2	21	Furniture and fixtures	0.013	0.007	0.004	0.010	0.020	Wood products
3	22	Paper and paper products	0.003	0.004	0.003	0.009	0.009	Paper products
4	23	Printing, publishing, and allied activities	0.041	0.040	0.029	0.026	0.021	Paper products
5	25	Plastic and rubber products	0.041	0.048	0.043	0.052	0.046	Plastic and rubber products
6	26	Petroleum products	0.032	0.089	0.047	0.045	0.052	Mineral oils
7	28	Inorganic heavy chemicals	0.007	0.006	0.005	0.003	0.004	Chemicals and chemical products
8	29	Organic heavy chemicals	0.002	0.008	0.010	0.008	0.011	Chemicals and chemical products
9	30	Fertilizers	0.000	0.000	0.000	0.001	0.001	Fertilizers
10	31	Paints, varnishes and lacquers	0.004	0.005	0.004	0.005	0.006	Paints, varnishes, and lacquers
11	32	Other chemicals and chemical products	0.086	0.088	0.074	0.081	0.076	Chemicals and chemical products
12	33	Cement	0.000	0.000	0.000	0.001	0.001	Cement, lime, and plaster
13	34	Non metallic mineral products except cement	0.084	0.071	0.055	0.042	0.045	Non-metallic mineral products
14	35	Iron and steel industries and foundries	0.014	0.002	0.016	0.037	0.033	Iron and steel
15	36	Other basic metal industries	0.001	0.001	0.002	0.003	0.003	Basic metals and alloys
16	37	Metal products except machinery and transport equpiment	0.068	0.053	0.070	0.064	0.065	Metal products
17	38	Agricultural machinery	0.020	0.017	0.021	0.019	0.019	Non-electrical machinery and parts
18	39	Industrial machinery for food and textiles	0.024	0.020	0.015	0.010	0.010	Food and textile machinery
19	40	Other machinery	0.129	0.123	0.135	0.115	0.108	Electrical machinery
20	41	Electrical machinery, apparatus, and appliances	0.149	0.137	0.160	0.164	0.159	Electrical industrial machinery
21	42	Railway transport equipment	0.007	0.026	0.018	0.020	0.014	Transport equipment and parts
22	43	Other transport equipment	0.118	0.124	0.164	0.123	0.094	Transport equipment and parts
23	44	Miscellaneous manufacturing industries	0.129	0.104	0.081	0.110	0.145	Manufacturing wholesale price index
24	46	Electricity	0.014	0.003	0.023	0.032	0.036	Electricity
25	47	Gas and water supply	0.009	0.021	0.022	0.015	0.021	Electricity, gas and water GDP deflator[1]
		Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	

[1] From www.rbi.org.in

Table A.2. Input Weights in Intermediate Inputs Price Deflator

		Input-Output table					
No.	Commodity description	1973-74	1983-84	1989-90	1993-94	1998-99	**Wholesale price index series**
1	Food (Primary Articles)	0.299	0.168	0.119	0.108	0.128	Food - Primary Articles
2	Eggs, Fish, Meat/Milk	0.031	0.026	0.034	0.024	0.026	Eggs, Fish, Meat
3	Logs and Timber	0.013	0.022	0.037	0.012	0.011	Forestry-GDP Deflator[1]
4	Coal	0.014	0.035	0.002	0.043	0.038	Mining - GDP Deflator[1]
5	Mineral Oils	0.067	0.138	0.104	0.104	0.091	Mineral Oils
6	Sugar/Edible Oil	0.037	0.035	0.011	0.012	0.025	Sugar
7	Beverages and Tobacco	0.005	0.004	0.001	0.001	0.002	Beverages and Tobacco
8	Cotton Textiles	0.069	0.085	0.065	0.052	0.039	Cotton Textiles
9	Wood and Wood products	0.014	0.007	0.000	0.008	0.010	Wood and Wood products
10	Paper and Paper products	0.023	0.024	0.029	0.023	0.022	Paper and Paper products
11	Leather and Leather products	0.008	0.005	0.006	0.006	0.005	Leather and leather products
12	Rubber and Plastic	0.014	0.014	0.013	0.018	0.015	Rubber and Plastic products
13	Chemicals and Chemical products	0.084	0.081	0.126	0.135	0.125	Chemicals and chemical product
14	Non-metallic mineral products	0.009	0.012	0.008	0.005	0.005	Non-metallic mineral products
15	Electricity	0.042	0.079	0.092	0.094	0.106	Electricity
16	Gas and Water Supply	0.001	0.002	0.005	0.002	0.003	Gas/Water Supply GDP Deflator[1]
17	Railway Transportation	0.022	0.024	0.029	0.026	0.023	Rail Transport GDP Deflator[1]
18	Other Transportation	0.030	0.028	0.042	0.088	0.059	Other Transport GDP Deflator[1]
19	Communication	0.000	0.004	0.011	0.009	0.008	Communication GDP Deflator[1]
20	Banking	0.025	0.024	0.038	0.035	0.062	Banking GDP Deflator[1]
21	Insurance	0.003	0.007	0.015	0.010	0.007	Insurance GDP Deflator[1]
	Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	

[1] From www.rbi.org.in

Table A.3. Weight of Services in Intermediate Inputs[1]

1973-1974	1983-1984	1989-1990	1993-1994	1998-1999
8.60%	9.80%	14.70%	17.50%	17%

[1] Services include construction, transportation, communication, banking, insurance, gas and water supply.

Table A.4. Type of Investment by ASI Industries[1,2]

(Ratio)

	Machinery and equipment	Structures
1974-75	0.57	0.43
1975-76	0.60	0.40
1976-77	0.45	0.55
1977-78	0.48	0.52
1978-79	0.42	0.58
1979-80	0.51	0.49
1980-81	0.57	0.43
1981-82	0.55	0.45
1982-83	0.61	0.39
1983-84	0.60	0.40
1984-85	0.56	0.44
1985-86	0.62	0.38
1986-87	0.60	0.40
1987-88	0.58	0.42
1988-89	0.69	0.31
1989-90	0.66	0.34
1990-91	0.58	0.42
1991-92	0.70	0.30
1992-93	0.63	0.37
1993-94	0.72	0.28
1994-95	0.74	0.26
1995-96	0.63	0.37
1996-97	0.85	0.15
1997-98	0.70	0.30
Average	0.6	0.4

[1] *Estimates based on National Accounts Statistics (NAS) data on All-India investment by public, private corporate, and household sector in these 2 categories, applied*

[2] *Figures from 1970-1973, and 1998-2003 were set equal to average over 1974-1997*

Table A.5. Index Numbers of Output and Inputs - All-India Aggregates[1]

	Output	Intermediate	Labour	Capital
1973	26.7	27.0	66.9	16.8
1974	26.6	28.3	70.2	16.1
1975	28.4	32.2	74.0	17.8
1976	32.5	36.0	76.9	17.6
1977	35.5	39.3	81.5	18.3
1978	39.1	42.6	83.2	20.1
1979	39.6	45.0	88.1	23.0
1980	40.4	46.5	89.6	26.1
1981	43.8	48.8	90.3	30.7
1982	49.0	53.2	92.9	34.6
1983	49.8	51.0	90.0	40.0
1984	53.7	55.7	89.2	44.5
1985	56.2	58.5	85.7	49.2
1986	58.3	61.2	84.8	52.9
1987	64.3	66.3	88.6	57.7
1988	71.0	73.5	89.2	61.9
1989	82.1	86.4	92.6	67.2
1990	89.6	92.9	93.4	74.2
1991	87.1	91.2	94.1	81.2
1992	95.2	99.3	100.2	90.1
1993	100.0	100.0	100.0	100.0
1994	113.5	110.1	103.6	115.5
1995	134.3	131.2	114.4	132.4
1996	135.1	126.8	111.9	147.8
1997	155.4	145.3	112.4	158.9
1998	161.9	145.3	108.3	174.5
1999	181.1	160.4	103.1	180.7
2000	174.8	156.3	100.7	186.1
2001	174.8	155.9	97.6	197.2
2002	202.2	177.2	100.1	199.6
2003	223.9	190.2	99.2	206.0

[1] Sum of 2-digit ASI data from 1973 onwards

Table A.6. Indices of Output and Intermediate Input Prices
(1993-94 = 100)

	Intermediate inputs[1]	Output (ASI industries)[1]	Output (overall manufacturing)[2]
1970-71	13.1	14.9	15.2
1971-72	13.7	15.8	16.6
1972-73	14.8	16.7	18.5
1973-74	17.5	18.5	21.2
1974-75	22.6	24.9	25.7
1975-76	23.2	26.5	26.0
1976-77	23.5	26.2	26.6
1977-78	24.9	27.4	27.2
1978-79	25.8	28.2	27.3
1979-80	29.2	33.0	32.8
1980-81	33.2	37.6	39.1
1981-82	38.2	41.4	41.1
1982-83	41.1	43.3	42.6
1983-84	44.2	45.4	45.2
1984-85	46.7	48.0	48.3
1985-86	50.9	52.3	51.2
1986-97	53.5	54.8	53.1
1987-88	56.9	57.6	57.0
1988-89	61.9	63.1	62.3
1989-90	66.1	68.2	69.3
1990-91	72.1	73.4	75.2
1991-92	81.1	83.0	83.6
1992-93	90.4	92.6	92.8
1993-94	100.0	100.0	100.0
1994-95	111.4	108.4	112.3
1995-96	120.8	118.0	122.0
1996-97	128.8	121.6	124.4
1997-98	137.4	125.2	128.1
1998-99	144.9	128.9	133.6
1999-00	152.6	132.1	137.2
2000-01	165.3	141.2	141.7
2001-02	171.8	145.9	144.3
2002-03	178.4	149.0	148.1
2003-04	188.7	153.1	156.5

[1] *Divisia index; author's estimate*

[2] *Official manufacturing sector price index*

Table A.7. State-wise Time-Series Estimates of Total Productivity Levels

	Andhra Pradesh	Assam	Bihar	Gujarat	Haryana	Himachal Pradesh	Jammu & Kashmir	Kerala	Karnataka	Maharashtra	Madhya Pradesh	Orissa	Punjab	Rajasthan	Tamil Nadu	Uttar Pradesh	West Bengal
1970	0.990	0.952	0.996	1.097	1.040	1.036	0.756	1.022	0.992	1.140	0.987	0.853	1.054	0.928	1.021	0.970	1.025
1971	0.975	0.927	0.990	1.058	1.062	1.248	0.815	1.023	1.026	1.137	0.974	0.829	1.028	0.931	1.008	0.949	1.030
1972	1.034	0.999	1.015	1.100	1.056	0.960	0.886	0.992	1.018	1.161	1.035	0.869	1.046	0.958	1.049	0.981	1.065
1973	1.102	1.098	1.053	1.156	1.072	0.841	0.949	0.996	1.026	1.201	1.102	0.909	1.091	0.993	1.103	1.027	1.114
1974	1.005	1.126	1.052	1.092	1.034	0.726	0.950	0.950	0.949	1.132	1.034	0.818	1.039	0.926	1.058	0.963	1.062
1975	0.995	0.977	0.969	1.013	1.008	0.917	0.817	0.902	0.917	1.076	0.957	0.747	1.015	0.893	0.990	0.988	1.028
1976	1.014	1.062	0.937	1.060	1.058	1.000	0.816	0.933	0.949	1.106	1.015	0.859	1.048	0.930	1.048	1.029	1.059
1977	1.011	1.118	0.925	1.083	1.080	1.058	0.880	0.963	0.955	1.120	0.996	0.844	1.059	0.928	1.066	0.935	1.060
1978	1.022	1.063	0.960	1.074	1.104	1.019	0.982	0.983	1.045	1.145	0.989	0.865	1.088	0.966	1.090	0.956	1.086
1979	0.973	0.993	0.913	1.029	1.034	1.047	0.992	0.964	0.942	1.082	0.966	0.838	1.063	0.941	1.033	0.915	1.033
1980	0.957	0.911	0.866	1.016	1.020	0.975	0.922	0.961	0.911	1.063	0.966	0.785	1.059	0.898	1.025	0.883	1.032
1981	0.991	0.948	0.977	1.047	1.082	1.051	0.982	0.986	0.938	1.092	1.006	0.790	1.081	0.918	1.053	1.041	1.050
1982	1.066	0.987	1.020	1.079	1.114	1.753	1.054	1.016	0.974	1.113	1.038	0.795	1.097	0.922	1.095	1.043	1.080
1983	1.139	1.113	1.120	1.164	1.188	1.635	1.069	1.044	1.054	1.169	1.056	0.850	1.127	1.034	1.126	1.030	1.100
1984	1.140	1.187	1.031	1.130	1.107	1.278	1.128	1.097	1.010	1.172	1.035	0.800	1.125	0.977	1.149	1.027	1.106
1985	1.096	1.208	1.031	1.123	1.105	1.246	1.082	1.069	1.011	1.199	1.075	0.839	1.140	0.982	1.133	1.017	1.110
1986	1.093	1.175	1.027	1.137	1.114	1.199	1.059	1.068	1.021	1.186	1.017	0.868	1.136	1.025	1.138	1.103	1.112
1987	1.076	1.157	1.095	1.159	1.127	1.078	1.105	1.113	1.033	1.190	1.085	0.859	1.172	0.998	1.147	1.128	1.175
1988	1.110	1.090	1.149	1.159	1.140	1.223	1.004	1.103	1.041	1.221	1.086	0.964	1.147	1.008	1.169	1.125	1.110
1989	1.093	1.208	1.126	1.137	1.131	1.096	1.047	1.159	1.073	1.229	1.103	0.978	1.235	1.018	1.180	1.171	1.095
1990	1.144	1.179	1.119	1.160	1.184	1.225	1.110	1.095	1.117	1.256	1.146	0.961	1.196	1.069	1.201	1.177	1.147
1991	1.121	1.137	1.123	1.110	1.158	1.174	1.080	1.135	1.127	1.187	1.082	0.936	1.182	1.041	1.166	1.186	1.129
1992	1.136	1.122	1.107	1.217	1.120	1.126	1.101	1.107	1.129	1.240	1.126	0.927	1.216	1.068	1.163	1.165	1.122
1993	1.159	1.117	1.307	1.236	1.160	1.317	1.278	1.100	1.113	1.296	1.169	0.928	1.219	1.109	1.203	1.195	1.167
1994	1.239	1.148	1.125	1.295	1.233	1.245	1.123	1.139	1.186	1.323	1.188	0.956	1.266	1.188	1.221	1.246	1.175
1995	1.285	1.171	1.163	1.310	1.280	1.231	1.165	1.188	1.168	1.350	1.264	0.978	1.244	1.189	1.220	1.221	1.181
1996	1.251	1.117	1.265	1.316	1.329	1.318	1.169	1.201	1.234	1.333	1.231	0.937	1.318	1.174	1.243	1.283	1.266
1997	1.363	1.176	1.417	1.272	1.331	1.336	1.216	1.238	1.222	1.383	1.281	1.081	1.332	1.287	1.255	1.317	1.342
1998	1.300	1.248	1.380	1.335	1.344	1.335	1.278	1.326	1.219	1.374	1.280	0.974	1.383	1.218	1.278	1.267	1.277
1999	1.347	1.296	1.422	1.367	1.418	1.410	1.358	1.315	1.199	1.443	1.331	1.048	1.444	1.342	1.325	1.297	1.308
2000	1.346	1.191	1.250	1.344	1.388	1.446	1.329	1.316	1.198	1.415	1.343	1.033	1.388	1.324	1.342	1.300	1.318
2001	1.384	1.139	1.239	1.327	1.420	1.465	1.344	1.312	1.240	1.406	1.339	1.022	1.439	1.312	1.319	1.312	1.355
2002	1.416	1.423	1.420	1.399	1.460	1.529	1.380	1.354	1.300	1.464	1.371	1.081	1.460	1.325	1.341	1.363	1.408
2003	1.489	1.500	1.500	1.465	1.485	1.581	1.407	1.396	1.364	1.535	1.447	1.167	1.488	1.370	1.410	1.410	1.469

Table A.8. TFP and TP Growth Rates Under Different Deflation Methods

	Single deflation[1]	Double deflation[1]	Divisia deflator[2]	Divisia deflator[3]	Current
1970	…	…	…	…	…
1971	-4.3	-21.0	…	…	…
1972	1.1	-2.8	…	…	…
1973	-7.1	17.2	…	…	…
1974	3.9	17.2	16.8	5.8	-3.6
1975	-3.4	-8.2	-14.6	-4.5	-5.1
1976	3.8	12.3	19.2	6.6	4.9
1977	1.3	8.6	10.9	6.5	1.1
1978	10.7	16.3	18.9	7.0	1.8
1979	-10.8	-4.2	-4.1	-7.7	-5.1
1980	-11.3	-11.0	-13.9	-4.4	-2.3
1981	6.4	15.6	24.0	9.2	2.5
1982	9.2	14.5	22.3	9.1	2.7
1983	7.0	-4.4	-2.4	-6.6	3.4
1984	-2.2	-1.1	2.0	0.4	-0.4
1985	2.6	-4.4	-14.2	4.7	-0.4
1986	-4.2	-7.6	-9.1	3.4	-0.5
1987	0.8	-1.0	4.7	1.5	1.9
1988	6.9	4.1	5.7	7.2	0.9
1989	…	…	-6.4	5.3	0.4
1990	…	…	6.5	-1.1	1.6
1991	…	…	-6.0	-11.4	-2.6
1992	…	…	-19.5	5.9	0.3
1993	…	…	…	…	2.8
1994	…	…	…	…	2.7
1995	…	…	…	…	0.5
1996	…	…	…	…	1.5
1997	…	…	…	…	2.3
1998	…	…	…	…	2.9
1999	…	…	…	…	3.2
2000	…	…	…	…	-1.7
2001	…	…	…	…	-0.4
2002	…	…	…	…	4.0
2003	…	…	…	…	4.2

[1] *Based on Balakrishnan and Pushpangadan (EPW 1994)*

[2] *Based on Rao (EPW 1996)*

[3] *Based on Hulten, Bennathan and Srinivasan (WBER 2006)*

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