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Farm Mechanisation, Agricultural Productivity and Structural Change in India

A State-Level Analysis of Post-Reform Period

by

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Abstract: Agriculture in India is characterised by low productivity, and structural change has been slow and unconventional. Nevertheless, at state-level one can identify different patterns for these process. The attempt in this work has been to understand the linkages between farm mechanisation, agricultural productivity and structural change at the state-level during the post-reform period. The aim was to identify whether mechanisation can contribute to productivity growth and thereby structural change. We made use of the micro-data of India's nationally representative surveys to estimate the three variables of interest. We also relied on a decomposition method to calculate the drivers of labour productivity growth. We find that mechanisation continues to be highly unequal among states, although there was a convergence during the last two & half decades. Not all structurally transformed states were mechanised. But the highly mechanised regions of Punjab & Haryana, are witnessing a sort of conventional pattern of structural with a growth in manufacturing employment. Their experience has important lessons for the low structurally transformed, low mechanised and low productivity regions of central and eastern India. Apart from labour-substitution, mechanisation also offers other demand linkages that directly contributes to the growth of non-farm sectors. It becomes imperative for developing manufacturing sector for exploiting the demographic dividend that these languishing states currently possess.

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1 INTRODUCTION

Indian agriculture has for long been characterised by low productivity, profitability and incomes (Balakrishnan, Golait & Kumar, 2008; Mishra & Reddy, 2011). Agriculture accounts for a disproportionately higher share of the total employment compared to its share in the Gross Domestic Product (GDP) [Ghose, 2021]. The inter-sectoral productivity differences have also sharply widened over the years - productivity growth in agriculture was considerably slower compared to other sectors. For instance, Ghose (2021) finds that there was an improvement in labour productivity growth from 1.4 percent p.a. during 1978-94, to 2.7 percent p.a. during 1994-2010. However, the ratio of manufacturing to agricultural labour productivity has increased from 2.8 times in 1978 to nearly 5 times in 2010. Additionally, evidence also suggests that there are persistent yield gaps in several parts of the country (particularly in Eastern India) where the effects of the green revolution did not percolate (Jha, Palanisamy, Sen & Kumar, 2022). Therefore, it is an immediate and important need to boost the land and labour productivity of this sector, hasten the process of structural change where sustained and decent employment opportunities are created in the non-farm sector for the workers moving out of agriculture. In this regard, the contribution of farm mechanisation to the changes in both productivity and labour use was widely debated in the Indian context (see Raj, 1972; Rao, 1972; Jodha, 1974; Basant, 1987) – these studies however pertain to the period where structural transformation was limited, and the modernisation of the farm sector was in its initial phases. As such, the objective of this study is to analyse how farm mechanisation, agricultural productivity and structural change are inter-linked by focusing on the trends at the state-level in India. We aim to identify the linkages between the three which are crucial for the processes of both agricultural and structural transformations in the economy. Our focus will therefore be on the post-reform phase, during which the pace of structural transformation of agricultural workforce was considerably hastened.

1.1 Research Questions and Objectives

As stated above, the objective of this thesis is to understand the processes of mechanisation, productivity growth and structural change, and the interlinkages that characterise the differential processes across states in India. There is an obvious explanation for focusing the analysis at the state-level in India. States in India are characterised by considerable differences in terms of all the three aspects under consideration (Gulati & Juneja, 2020; Sarkar, 2020; Thomas, 2023). This allows for an exploration of various possibilities in order to understand the linkages between the three. While conventional wisdom might indicate that higher mechanisation would free-up the rural labour that is absorbed by the growing non-farm sector and vice-versa the case of Indian states suggests it need not always be straightforward or a one-way relationship (Vaidyanathan, 1986). For instance, the southern Indian states are marked by relatively lower levels of mechanisation compared to the advanced agricultural regions of the north (such as Punjab)[Sarkar, 2020]. Nonetheless, structural change has been more or less similar for these two sets of states (Thomas, 2023).

It is therefore useful to analyse these relationships based on the existing evidence at the state-level and thereby be able to understand it is a dynamic relationship. This is to understand, if the highly mechanised states are also the ones that structurally transformed with a larger non-farm sector. If not, what is the relationship between the extent of farm mechanisation and the extent of structural change. It could be possible that despite considerable mechanisation, agriculture is accounting for a large portion of the total employment due to the lack of absorptive capacity of the non-farm sector. It could also be the case that certain states are not witnessing a faster mechanisation of farm operations due to the lack of sufficient non-farm jobs suggesting that there could be disguised unemployment. Considering these objectives the research questions can be summarised as follows:

1. What is the difference in the extent of farm mechanisation at the state level in India? How has it changed over the course of nearly three decades of liberalisation reforms?
2. What is the relationship between the extent of farm mechanisation, agricultural productivity, and the growth of the non-farm sector during this period? How did that impact the nature of structural change experienced by Indian states?
3. What were the main drivers (and their contributions to) of labour productivity growth in agriculture across Indian states during the post-reform period in terms of cropping intensity, yields and labour use per unit of land?

The post-reform period is crucial for an understanding of our three main variables of interest. This period witnessed an acceleration of structural transformation process particularly the remarkable rise in the services' contribution to the economy (Papola, 2012). The manufacturing sector, on the other hand, continued to languish and its contribution to both output and employment have stagnated (Thomas, 2012). However, the transformation has largely been confined to shifts in output share – while employment growth in the non-farm sector has been sluggish (Kannan & Raveendran, 2019). Furthermore, the shift away from agriculture has not proceeded in the manner that was conventional. Due to the low returns associated with farming, workers were forced to seek employment in non-farm sectors (Thomas, 2012; Bakshi & Modak, 2017). However, they were not completely 'de-peasantised' - although they engage in wage work (Bakshi & Modak, 2017). A portion of their household income still came from farming - by cultivating on the marginal landholdings (Bakshi & Modak, 2017). This was largely due to the precarity of non-farm employment that, as mentioned before, was increasingly being characterised by low employment elasticity of growth, informalisation and casualisation of work (Mishra, 2020; Basole, 2022). Despite, an overall growth in labour productivity in agriculture (Binswanger & d'Souza, 2012), the liberalisation period was also characterised by a growing agrarian distress – which many have attributed to the increasing withdrawal of the state support to the sector (Ramakumar, 2010; Ramachandran & Rawal, 2010). These processes were also similar to the experiences of a number of developing economies – the relatively slower decline of agricultural employment vis-à-vis its share in output, is a concern that is common to the development experience of a number of economies (Timmer, 2009). The relative dominance of services, and a premature deindustrialisation is another feature of developing economies that has serious impacts on nature of growth and its sustenance (Rodrik, 2014; McMillan, Rodrik, & Sepulveda, 2017). The attempt in this work, therefore, is to identify the explanation for these structural change processes in India – using differences in mechanisation and agricultural productivity of different states.

1.2 Thesis Outline

The subsequent chapters of the thesis are organised as follows. The next chapter provides an overview of the debates surrounding the processes of mechanisation, agricultural productivity and structural change with a particular focus on India. The chapter concludes with a discussion on the theoretical approach that this thesis would follow. The third chapter deals with a description of the methodology that is followed. This chapter outlines the different techniques that were used in estimating the variables from micro-data. The fourth chapter consists of a discussion on the data sources that were used and reviewed for this study. The fifth chapter provides some background and context to the study with a descriptive analysis of the changes in Indian economy pertaining to agriculture and structural change. The sixth chapter presents the results of the empirical analyses. The seventh chapter discusses the findings in the context of relevant theoretical research. The final chapter concludes with a summary of the findings and some limitations and scope of future research.

2 REVIEW OF LITERATURE

2.1 Patterns in Mechanisation

Farm mechanisation is the process by which human and animal labour gets substituted for mechanical sources of energy - such as tractors, harvesters, threshers, diesel & electric pumps etc. These have a direct impact on labour productivity - by freeing up labour to work in the non-farm sector - given that there exists a labour absorbing non-farm sector (Timmer, 2009). Furthermore, mechanisation could contribute to improvements in land productivity, as well, if the necessary socio-economic environment is conducive i.e. there is a synchrony between the introduction of advanced bio-physical inputs (such as high yielding seeds) and farm machinery(Raj, 1972; Kahlon & Grewal, 1972; Jodha, 1974). The necessity of using machines on Indian farms first emerged with the introduction of intensive methods of cultivation that required greater energy use (Kahlon & Grewal, 1972). A major advancement brought about by the new seed varieties was the reduction in cropping period (Jose, 1984). And mechanisation makes possible quick and timely completion of farm operations and thereby increases cropping intensity and output per unit land (Kahlon & Grewal, 1972; Jose, 1984). Additionally, Raj (1972) argues that mechanisation also brings about certain changes such as deeper tillage, through use of tractors for ploughing, that improves yields. Therefore, the importance of mechanisation for boosting productivity cannot be ignored.

Binswanger (1986) presented a generalisation of the trends in farm mechanisation across different regions. It was found that power-intensive farm operations were the first to be mechanised (Binswanger, 1986; Pingali, 2007; Singh, 2015). Even in India the use of tractors, for land preparation, has been predominant - while the spread of mechanisation for other farm operations has been relatively restricted (Bhattarai et al., 2020, pp. 104). Mechanisation in India has been extremely uneven across states, agroclimatic zones and crops (Sarkar, 2020; Bhattarai et al., 2020, pp. 104). Inequality in ownership of farm machinery has been high across the various socio-economic classes (Sarkar, 2013a). However, the use of farm machines has been relatively less unequal compared to ownership (Aryal, Rahut, Thapa & Simtowe, 2021). This could be due to the smaller landholding size of Indian farms as a result, machinery use has been largely through renting and hiring services (Bhattarai et al., 2020, pp. 99; Aryal et al., 2021).

Mechanisation being a component of technical change, its adoption could be explained using the model of induced innovation as propounded by Hayami and Ruttan (1971). This strand privileges the effect of relative factor scarcities, and thereby relative factor prices as the prime causes of adoption of new technology (Hayami & Ruttan, 1971; Binswanger, 1986). According to them, as labour becomes less abundant, it induces innovations that develop more and more labour-saving technologies such as farm machinery. According to the works of Hayami & Ruttan (1971) & Binswanger (1986), Mechanisation in agriculture is a product of workers moving out of this sector – mechanisation is somewhat an effect of labour movement, and not its cause. Labour scarcity induces machine adoption. This is in contrast to the studies on structural change (eg. Timmer, 2009), which argue that modernisation efforts in agriculture free-up farm labour, and can be shifted to other higher productive sectors. Another proximate cause for mechanisation, as developed in the theory of farming systems evolution, is through population pressure – based on the work of Ester Boserup (1965). A growing pressure to feeding the population would create the necessity for intensifying agriculture, which is made possible by increasing the cropping intensity. Cropping frequency in turn determines the kind of implements or technical inputs that are used.

2.2 Mechanisation and Labour-Use

The early literature on farm mechanisation focused on two aspects - adoption patterns and the impacts of such a process. The focus of studies analysing the impacts of mechanisation is confined to the issues of labour-abundant developing economies and whether or not these mechanisation practices displaced the rural labour. On the one hand, studies have documented the labour displacing effect of mechanisation and were largely sceptical of the social benefit arising out of substituting machines for labour on farms in developing economies (Raj, 1972; Mclnerney & Donaldson, 1975; Binswanger, 1978; Singh & Singh, 1980; Jose, 1984). An argument was that if machines are introduced irrespective of the relative factor costs, it would create largescale unemployment and reduce real wages. Furthermore, since large farms are better equipped to exploit the returns to scale from introducing capital intensive machinery, they would benefit disproportionately to small farmers and thereby leading to increasing income and asset inequality (Jose, 1984). Raj (1972) points to the inherent bias towards small farms in capital-intensive mechanisation. While large landholders have lesser capital constraints, small farmers' credit accessibility (particularly in low-income countries) becomes constrained due to their smaller asset size. In cases without formal banking, the issue of accessing credit becomes even more problematic, as credit flow is controlled by the large landholders in the village (Raj, 1972). Another consequence discussed by this strand was the increase in farm size by reduction in leasing out and increase in tenant eviction, by already large holders, due to the possibilities of economies of scale thrown open by machines such as tractors (Mclnerney & Donaldson, 1975; Binswanger, 1978). Landlords have used mechanisation, also as a bargaining instrument, to reduce their dependence on farm workers and suppress their wages (Raj, 1972).

Another strand has argued that these effects are not uniform for all types of farm operations (Rao, 1972; Binswanger, 1986; Pingali, 2007). For instance, Binswanger (1986) and Pingali (2007) claim that, unlike control-intensive operations (such as weeding), mechanisation of power-intensive operations (such as ploughing and tilling) is not dependent on relative factor prices and can take place irrespective of land-labour endowments. Furthermore, it is argued that displacement of labour was not an outcome of mechanising power-intensive operations, but only that of control-intensive ones (Pingali, 2007). Rao (1972) makes the case for selective mechanisation of farm operations - land augmenting mechanisation such as use of tractors. Since land-augmenting machines bring about scale economies, and increase yields and cropping intensity, the overall labour use on the farms increases. On a similar note, Chattopadhyay (1984) finds that although new farm technologies tend to displace labour, the effect gets offsetted by the increase in employment due to changes in cultivation patterns.

On the contrary, studies have also identified that mechanisation leads to efficiency and that there is higher labour use on farms with mechanised sources of power (Sarkar & Prahladachar, 1966; Wills, 1971; Kahlon & Grewal, 1972; Acharya, 1973; Jodha, 1974). Acharya (1973) finds that, although tractors by themselves reduced labour, the tractor operated farms witnessed an increase in labour use - due to the use of these machines in combination with the high yielding seeds. However, he argues that in the long-run this combination would reduce labour use and increase capital intensity. After studying the adoption of machines in Punjab, Kahlon and Grewal (1972) conclude that the overall benefit (increased incomes, greater energy use etc.) from adopting machines led to the displacement of animal labour, while human labour use continued to increase. Machine ownership by farmers also allows for diversifying income sources by providing rental services on other farms or for engaging certain machinery (such as tractors) for non-farm business as well (Jodha, 1974).

The debate on the impact of farm mechanisation on labour displacement continues to be unresolved (Biggs, Justice & Lewis, 2011; Narayanamoorthy, Bhattarai, Suresh & Alli, 2014; Afridi, Bishnu & Mahajan, 2020). Afridi, Bishnu Mahajan (2020) argue that use of tractors in farm operations have a differential impact and displace women's labour more than men's highlighting the gendered nature of farm mechanisation impacts. Bhattarai, Singh, Takeshima & Shekhawat (2018) argue that different machinery have different impacts on labour vs land augmentation. However, the lack of a labour absorbing non-farm sector providing more higher productive jobs remains a concern (Mishra, 2020). Mishra (2020) argues that those leaving agriculture are increasingly moving to the informal sector as petty producers, self-employed and casual wage earners.

2.3 Agriculture and Structural Change

The studies documenting structural change as shifts in sectoral shares can be traced to the works of Chenery (1960) & Kuznets (1973). Kuznets (1973) identifies this process of shift away from agriculture as a characteristic feature of the modern growth process. The strong linkages between the growth in agriculture and other sectors of the economy in the growth process were underscored by several works. The initial focus of the structural change studies were on the labour supplies from agriculture - such as the models of Lewis (1954) and Fei and Rani (1961). Lewis (1954) propounded that the shift away from agriculture in terms of labour movement continues until the excess labour gets absorbed in the industrial sector. Agricultural productivity is intricately linked with the success of a sustained structural transformation and a balanced growth of both the farm and non-farm sectors (Johnston & Mellor, 1961; Mellor, 1998; Timmer, 2009; Diao, McMillan & Wangwe, 2018). In addition to the role in driving industrialisation and structural transformation, agriculture also contributes to sustaining high growth rates, reducing poverty and ensuring food security among other important linkages that it produces (Byerlee, de Janvry & Sadoulet, 2009; Christiaensen, Demery & Kuhl, 2011).

However, the debate on the role of agriculture is far from resolved. Despite considerable support in the literature on agriculture-centred development and industrialisation strategies, studies have questioned that it cannot uncritically be applied irrespective of contexts – such as geographical and resource endowments statuses (Dercon & Gollin, 2014). Additionally, there is a strand of literature that argues that 'urban pull' factors play a greater role in rural-urban migration, and in the overall process of structural transformation away from agriculture. These studies emphasise the importance of industrial growth, and the ability of industrial technology to engage a large part of the former agricultural workforce in higher productive activities in the urban areas without compromising on the productivity levels (Jedwab & Vollrath, 2015). However, it was observed that a number of economies, even at the lower income levels, are witnessing an urbanisation without economic growth or without industrialisation – these studies argue that urbanisation and structural change need not be synonymous (Jedwab & Vollrath, 2015; Gollin, Jedwab & Vollrath, 2016). Urbanisation in the absence of industrialisation stems from dependence on natural resource exports and growth of non-tradable urban services – the latter sector emerges as the major employer of the workforce leaving agriculture (Gollin, Jedwab & Vollrath, 2016).

2.4 Theoretical Approach

The earlier sections presented some debates on the impact of mechanisation in labour abundant economies. Although this is relevant for a theoretical understanding of the linkages between mechanisation and employment changes, it has some limitations in terms of replicability for our research objectives. The question of labour displacement has been discussed in the context of (or assuming) a non-existent or small non-farm sector. By and large this was true during the 1970s and 1980s. However, the non-farm sector has grown considerably, and the studies on structural transformation have stressed on the importance of shifting workers from low productive sectors to high productive ones (Diao, McMillan & Rodrik, 2017). Therefore, the question of labour displacement needs to be contextualised in a framework of structural change – wherein sustained increases in per-capita incomes are possible through labour transition to higher productive avenues (Timmer, 2009; Basole, 2022). The approach in this work is to conceptually understand the link between the patterns in farm mechanisation and structural change across Indian states. Such a link is possible through changes in agricultural productivity. Substitution of capital for labour offers a pathway for freeing up farm labour, which then can be absorbed in the non-farm economy. One cannot view the growth of the non-farm sector in isolation from that of the farm economy. Agriculture is both a supplier and a consumer vis-a-vis the industrial sector (Johnston & Mellor, 1961). Agriculture supplies labour and primary commodities, while at the same time demanding industrial inputs, which in turn propels the industrialisation process. The increase in incomes and profitability that accrue from farm productivity growth is essential for generating a robust domestic demand site for industrial goods (Adelman, 1984). Simultaneously, this growing industrial sector is essential for absorbing the labour moving out of agriculture in search of higher productive jobs.

The large gaps in capital intensity in agriculture and labour productivity across different countries could be explained by the extent of adoption of modern technology (Chen, 2020). "Technology, as embodied in fixed or working capital" was found to be a determinant of the wide labour productivity differences that existed between the developed and least developed economies (Hayami & Ruttan, 1970" pp.895). Adoption of mechanised technology helps in boosting the agricultural labour productivity growth and Chen (2020) also finds that accounting for the changes in mechanisation helps explain labour productivity differences by one and half times. Furthermore, it was found that capital intensity in agriculture increased at a faster pace compared to non-agriculture during the 20th century, overlapping the period of agricultural mechanisation. An increase in the use of technical inputs supplied by the modern industrial sectors aids in boosting labour productivity even in the absence of a labour movement, or in other words when the land to worker ratio remains constant (Hayami & Ruttan, 1970). Shift away from a sector is possible when the elasticity of substitution is higher for that sector – agriculture to non-agriculture in the initial stages of development or from manufacturing to services in the latter stages (Alvarez-Cuadrado, Long & Poschke, 2017). Driving structural change through mechanisation also becomes important in light of the evidence that substitutability of labour and capital is higher in agriculture, than in non-agricultural sectors – making labour transition easier (Herrendorf, Herrington & Valentinyi, 2015; Chen, 2020). With large landholders and landlords shifting to machine use, the inverse relationship that was hypothesised between farm size and efficiency is also under question (Ghose, 1979; Fan & Chan-Kang, 2005). As economies grow, and expand the non-farm sector, the efficiency of small farms will disappear, and higher mechanised farms become a necessity to maintain efficiency (Hazell, 2011). In this context, mechanisation is an imperative for the large majority of farmer households in India, who operate on small land parcels, to increase production and reduce family labour input, and thereby allowing for diversification of sources of incomes.

3 DATA

There are three categories of indicators that need to be captured at the state-level for this study. Firstly, the data on farm mechanisation. Secondly, the data on agricultural productivity and land use. Thirdly, the data on structural change and the growth of the non-farm sector. For all the three categories of data we rely on the official statistics released by the Government of India.

3.1 Farm Mechanisation

The National Statistical Office (NSO) conducts large-scale national sample surveys (NSS) and they have been a crucial source for researchers studying various aspects of the Indian economy. NSO has been conducting All India Debt and Investment Surveys (AIDIS) since its 26th round in 1971-72. The origins of this survey can be traced to the Reserve Bank of India's All India Rural Credit Survey in 1951-52. The objective of AIDIS is to collect information on the assets, liabilities, and capital expenditure with the household as the unit of enquiry. For the purpose of our work, we make use of the information collected by AIDIS on the number and value of different farm machinery owned by the household as on 30th June the year preceding the date of survey. The research objective pertains to the post-reform period i.e. from the year 1991 to the present. Therefore, we would be relying on the 48th round conducted between January and December, 1992 and the 77th round conducted between January and December 2019 – these rounds are the closest available ones to our periodisation (NSO, 1998; NSO, 2021). Refer to Appendix A for a description of the different NSS rounds used in this study.

AIDIS is not the only data source that is available to capture different aspects of farm mechanisation. However, each of these data sources have considerable limitations which make them unfavourable compared to AIDIS. Commission for Agricultural Costs and Prices of the Ministry of Agriculture provides information on the different components of costs of cultivation, of which machine cost is one. However, this data is presented for only a few major crops - which are also not uniform across states. Therefore, aggregating the same for one state as a whole will not be possible. For instance, of the data on costs collected for 25 crops during 2017-18, the data for Andhra Pradesh (southern Indian state) is only collected for 12 crops, and does not cover the total crop cultivation in the state.

Input Use survey conducted alongside Agricultural Census, every five-years, by the Ministry of Agriculture, Government of India is another data source that collects information on mechanical inputs. However, the unit-level data is not available for public access. The reports published by this survey contain information on only the proportion of operational holdings (parcel of landing engaged in cultivation) using a particular machine as an input or not. The data for all states is not consistent – the data for all the major Indian states is not available for every round. Even this survey precludes any computation of an aggregate level of mechanisation at the state-level – which is possible when using AIDIS. For these reasons, we prefer to use AIDIS over Cost of Cultivation data and Input Use Survey.

Nonetheless, AIDIS is not without limitations as pointed by several previous works (Jayadev, Motiram & Vakulabharanam, 2007; Subramanian & Jayaraj, 2009; Chavan, 2012; Bharti, 2018). The sampling methodology of AIDIS leads to underestimation of the wealth of the richer households – there is no deliberate attempt to oversample the wealthy to overcome this issue (Jayadev et al., 2007; Subramanian & Jayaraj, 2009). It was also found that there was a decrease in the sample size of the successive rounds of AIDIS which would be another reason for the underestimation of wealth of the upper deciles, and indebtedness of the poorer households (Chavan, 2012). However, since our work is based on inter-state comparisons, all the states are likely to be effected by this underestimation. Therefore, despite these limitations, we proceed to use AIDIS for calculating mechanisation levels.

3.2 Agricultural Output, Land Use and Employment Statistics

For calculating agricultural productivity we make use of value of agricultural output published by the Ministry of Statistics and Programme Implementation (MoSPI), Government of India. We estimate the farm employment from the labour force surveys discussed below. And the data on the extent of land under cultivation (i.e. either Gross Cropped Area or Net Sown Area) is published by the Ministry of Agriculture and available for access from Reserve Bank India's Handbook of Statistics on Indian States (Reserve Bank of India, 2022)

The employment figures at the sectoral level for the states are not available directly. These figures have to be estimated from the labour force surveys of NSO. Until 2011-12, NSO used to conduct sample quinquennial labour force surveys called the Employment-Unemployment Surveys (EUS). However, these labour force surveys were discontinued thereafter, and were replaced with the annual sample surveys from 2017-18 called the Periodic Labour Force Surveys (PLFS). While there were some modifications, the broader objectives of the two surveys remain similar (Jajoria & Jatav, 2020). And the procedure for estimating the sectoral distribution of employment continues to be the same. We make use of EUS pertaining to the 50th round of NSO conducted between July 1993 to June 1994, and PLFS conducted between July 2018 and June 2019 (NSO, 1996; NSO, 2020). These two surveys are the closest available to our periodisation i.e. the post-reform phase. Since the reference period for AIDIS and labour force surveys are not overlapping, we proxy the values. For instance, AIDIS was conducted in 1992, while EUS was conducted during 1993-94. Therefore, we proceed to use the values estimated from AIDIS 1992 as representing the year 1993-94. Similarly AIDIS (2019) and PLFS (2018-19) were used as representing the year 2018-19. The rest of the variables (land use, value of agricultural output) are available on an annual time-series basis, so there is no need for proxying to match the analysis' years.

4 METHODOLOGY

This thesis will primarily be based on descriptive quantitative methods. We will also rely on a multiplicative decomposition method, as developed in Dev (1986 & 1988), to disaggregate labour productivity growth in agriculture into cropping intensity, yields and labour use per unit of land.

4.1 Measuring Farm Mechanisation

The level of farm mechanisation can be measured as the total number or value of machinery in a state. Since values are subject to price fluctuations, we deflate them using the Wholesale Price Index for agricultural machinery (Refer Appendix B for details on splicing). However, a direct comparison of these figures would be incorrect as different states are endowed differently in terms of the extent of agricultural land, size of the farm economy etc (Sarkar, 2013a). Therefore, we need to standardise these measures, by accounting for the extent of land under cultivation (NSA) to ensure their comparability between states.

$$\text{Level of Mechanisation} = \frac{\text{No. of Machinery(or Value of Machinery)}}{\text{Net Sown Area}}$$

4.2 Measuring Productivity and Structural Change

In this thesis, we compute both land and labour productivities. The terms yield and land productivity are used interchangeably, unless otherwise specified. Land productivity can be measured either in value or quantity terms. In quantity terms it can be captured as tonnes of output per hectare. However, one limitation is that it can obscure some changes in cropping pattern. For instance, the quantity yield might be lower for cash crops, but its value could be higher. If we measure in terms of quantity, it will be concluded that yields have fallen, while its value is in fact higher than before. Furthermore, quantity measurement makes it difficult to aggregate different agricultural output – 100 tonnes of food grains and 100 tonnes of fruits cannot be the same. Therefore, in this work, we measure land productivity as value of output per unit of gross cropped area.

Labour productivity is measured as value of agricultural output per worker. As mentioned, number of workers is estimated from the micro-data of the labour force surveys, EUS and PLFS. These surveys collect information on the activity status of the respondents – Usual Status and Currently Weekly Status. Usual status is further subdivided into principal (PS) and subsidiary statuses (SS). For estimating the number of workers in a sector, we have considered both principal and subsidiary statuses (PS+SS). This is the usual procedure followed in the literature while estimating labour force surveys of NSO (Kannan & Raveendran, 2019; Thomas, 2023). Refer to Appendix A for a detailed description of this estimation.

Structural change can be measured either as changes in structure of output or of employment (Timmer, 2009). For the purpose of our work, we confine to the measurement in terms of employment alone. The reason being that shifts in employment are more important for the purpose of raising productivity and thereby living standards (Timmer, 2009). Proxying output shares for structural change will obscure the productivity dynamics. In the Indian case, agricultural output share is very low at 14.6 percent in 2010, while its employment share was nearly 50 percent – this indicates low productivity (Aggarwal, 2018: Tables 3 & 4). In this study, we define structural change as the non-agricultural and allied sector employment share. To avoid generalising all the non-agricultural sectors, we provide discussion of the changes in the employment shares of manufacturing, services and construction as well.

The NSS data pertains only to a sample. And we have estimated the data for the population using the weighting procedure provided by the report of the corresponding round of the survey. The detailed sampling methodology is provided in the respective reports of the survey published by NSO. The procedure followed in this work for estimation of the sample variables is as provided in the documentation of the corresponding survey – which provides the formula for calculating weights/multipliers (i.e. the representativeness of each household). The weights are provided along with the micro-data files for each SSU.

4.3 Decomposition of Labour Productivity Growth

Unlike the non-farm sectors, productivity in agriculture depends on the quality of land, and the intensity with which it is used. Therefore, labour productivity in agriculture is a combined effect of yields, cropping intensity, and land-labour ratio (Dev, 1986). A similar decomposition was performed in Gollin, Lagakos & Waugh (2014).

Firstly, Output per worker can be expressed as a product of land productivity and land-labour ratio:

$$\frac{Y}{L} = \frac{Y}{NSA} \times \frac{NSA}{L} \quad (1)$$

Where,
Y = Farm Output
L = Total Number of Workers

NSA = Net Sown Area

Secondly, Land productivity can be further decomposed into yields (output per unit of gross cropped area) and cropping intensity (gross cropped area over net sown area). And (1) can be re-written as:

$$\frac{Y}{L} = \frac{Y}{GCA} \times \frac{GCA}{NSA} \times \frac{NSA}{L} \quad (2)$$

Where,

GCA = gross cropped area

$\frac{Y}{L}$ = output per worker or labour productivity

$\frac{Y}{GCA}$ = yields

$\frac{GCA}{NSA}$ = cropping intensity

$\frac{NSA}{L}$ = land-labour ratio

Thirdly, we represent each of these components in terms of an index - fraction of two years (t_0 and t_1).

$$LP = Yield \times CP \times LLR \tag{3}$$

Where,

$LP = \dfrac{(Y/L)_{t_1}}{(Y/L)_{t_0}}$ = Labour Productivity Index

$Yield = \dfrac{(Y/GCA)_{t_1}}{(Y/GCA)_{t_0}}$ = Yield Index

$CP = \dfrac{(GCA/NSA)_{t_1}}{(GCA/NSA)_{t_0}}$ = Cropping Intensity Index

$LLR = \dfrac{(NSA/L)_{t_1}}{(NSA/L)_{t_0}}$ = Land-Labour Ratio Index

Fourthly, to calculate the contribution of each of these components to growth in $\left(\frac{Y}{L}\right)$ over two periods (t_0 and t_1), we take the natural logarithm of both sides of (3) and divide it by *'t'* i.e. time between the two periods.

$$\frac{1}{t} log(LP) = \frac{1}{t}[log(Yield) + log(CP) + log(LLR)] \tag{4}$$

Finally, (4) can be simplified in terms of growth rates i.e. growth in output per worker is a summation of growth in yields, cropping intensity and land-labour ratio. *'G'* is the compound annual growth rate.

$$G(LP) = G(Yield) + G(CP) + G(LLR) \tag{5}$$

5 CONTEXT

Before proceeding to our analysis it will help to specify the context within which the above issues are discussed subsequently. So the main aim of this chapter is to provide an overview of the changes in the Indian economy relating to agricultural sector and structural transformation in the post-independence phase i.e. since 1947.

5.1 *Overview of the Agricultural Sector and Structural Change in India*

Immediately after independence, India followed an import-substitution industrialisation and focused on setting up large capital intensive industries (Rao, 1994). There emerged a neglect of agriculture in the planning process with an unfinished agenda of land reforms (Ramakumar, 2010). As a result farm outputs have suffered during the 1950s. With an impending food crisis and an excessive dependence on foreign food aid, the Indian government realised the importance of boosting crop production particularly those concerning the primary food grains of wheat and rice (Rao, 1994). In the 1960s, a package of policy measures, termed as the New Agricultural Strategy (NAS), were introduced with strong state support across different stages of farm production – credit disbursal through priority lending schemes from public sector banks; supply of subsidised bio-physical and mechanical inputs through state agencies; procurement and marketing of food grains at assured minimum support prices; investments in public research and development (R&D); expansion of public irrigation networks (Rao, 1994, pp.132; Posani, 2009; Ramakumar, 2010). These have also come to be known as the green revolution strategies. With the introduction of high yielding variety (HYV) of seeds, the yields have considerably increased (Prahladachar, 1983). However, the impacts varied significantly across regions and classes of farmers – largely due to policy framework that neither resolved the pre-existing agrarian inequalities nor promoted an equitable use of the new farm technologies across different classes of farmers (Prahladachar, 1983; Parayil, 1992). Nonetheless, in regions where it was successful, several field studies have concluded that the green revolution transformed the nature of Indian agriculture by introducing market mechanisms in the erstwhile subsistence setups (Parayil, 1992). The usage of HYV seeds and the resultant increase in yields necessitated a modernisation of the sector, and propelled further changes in technology use – modern machinery for quick and timely completion of farm operations was one such imperative (Kahlon & Grewal, 1972; Binswanger, 1986). Despite these advances, the pre-liberalisation planning period did not witness any fundamental transformation of the agriculture sector i.e. in terms of addressing the rural inequalities in the form of semi-feudal agrarian relations (Rao, 1994, pp.128), nor was labour productivity increasing at a rapid pace.

By 1980s, liberalisation measures were being adopted by Indian planners – who in 1991, triggered by the balance of payment crisis, initiated reforms under the structural adjustment policies of International Monetary Fund (Nagaraj, 2011). The slew of reforms included disinvestment and privatisation of state owned enterprises; removal of trade controls; allowing foreign investments; removal of licensing and production controls for industries; reduction in fiscal deficit and public expenditure (Nagaraj, 2011). The liberalisation reforms had a debilitating impact on the agricultural sector, which was until then being supported by state subsidies for modernisation efforts. The withdrawal of the state and steady reduction in fiscal support posed a considerable challenge for driving agricultural productivity growth (Balakrishnan, Golait & Kumar, 2008). The sharpening of the agrarian distress during this period is reflected in declining profitability of farming and its increasing unviability due to indebtedness, low farm incomes and recurring crop failures (Balakrishnan, Golait & Kumar, 2008; Guha & Das, 2022). Input subsidies were a crucial means through which state agencies directed the adoption of modern farm technologies, including machinery, during the pre-liberalisation period – and with the steady withdrawal of these subsidies under the regime of structural adjustment, the state diminished its role in directing technical change in the sector (Ramakumar, 2010). It was widely believed, that agriculture would be driven by export growth that is possible under free trade. Contrarily, imports have risen, and price volatility has increased putting small farmers at risk (Ramakumar, 2010). The global trade regime has also continued to be skewed against the interests of the developing economies' agriculture (Timmer, 2009).

While this was the case with the agricultural sector during the post-reform period, the pace of structural change has picked up. There was increase in the non-farm employment, and a sectoral movement of workers was evident. Nonetheless, the manufacturing employment had not increased, while services and construction sector absorbed the bulk of the workers. Manufacturing shares of both output and employment have stagnated, and in the post-reform phase even negative employment growth was registered (Thomas, 2012; Kannan & Raveendran, 2019). While agricultural share in output has declined at a faster pace, its share of employment has not been so

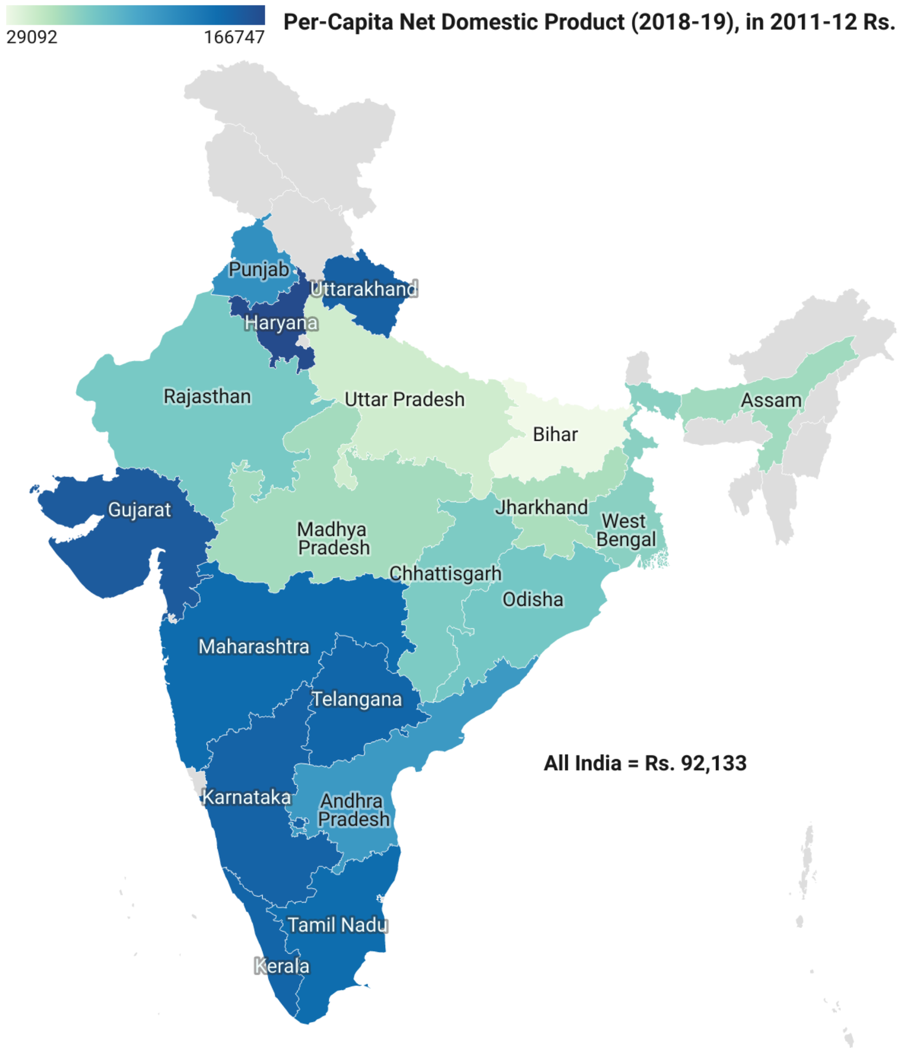
(Ghose, 2021). Even among services, it was the low-productivity and informal service sectors that were the major employers of the workers moving out of agriculture. Studies have also documented that workers did not completely move out of agriculture, owing to the precarity of non-farm jobs and the lack of labour demand in agriculture throughout the year (Bakshi & Modak, 2017; Basole, 2022). Therefore, in both the pre- and post-liberalisation phases, structural change in India has not been in favour of manufacturing, but led to the increase in the share of non-tradable services. This services-led growth, however, has contributed to increase in income inequality, and the welfare gains from the increase in living standards largely benefitted the upper income groups in urban areas (Ghose, 2021; Fan, Peters & Zilibotti, 2021).

5.2 Geographical Scope of the Study

While India currently has 28 states, we limit our analysis to the 15 major ones, in terms of population (National Commission on Population, 2020: Table 1) – Andhra Pradesh (AP), Assam (AS), Bihar (BH), Gujarat (GJ), Haryana (HR), Karnataka (KA), Kerala (KL), Madhya Pradesh (MP), Maharashtra (MH), Odisha (OD), Punjab (PN), Rajasthan (RJ), Tamil Nadu (TN), Uttar Pradesh (UP), and West Bengal (WB). These 15 states together accounted for 97 percent of the total net sown area, and 98 percent of the total gross cropped area in the country in 2018-19 (RBI, 2022: Tables 52 & 53). The state boundaries have been altered during the period of our analysis. While, Telangana was carved out of Andhra Pradesh in 2014 - Jharkhand from Bihar, Chhattisgarh from Madhya Pradesh, and Uttarakhand from Uttar Pradesh, were all formed in 2000. However, to maintain uniformity in our analysis, we consider the state boundaries prior to the division itself. So, for instance, Andhra Pradesh in 2018-19 includes the region of Telangana as well. For Figure 5.1 alone we depict as per the current administered boundaries.

Figure 5.1 depicts the per-capita domestic product of the states and presents the geographical context of the states under study. As we can see, there is a clear gap between the southern, western and northern states (Tamil Nadu, Andhra Pradesh, Gujarat, Maharashtra, Punjab, Haryana etc.) on the one hand, and central and eastern states (Madhya Pradesh, Rajasthan, Uttar Pradesh, Odisha, Bihar, West Bengal etc.) on the other.

Figure: 5.1: Per-Capita Net State Domestic Product (2018-19), in 2011-12 Rupees



Note: Accessed from Reserve Bank of India (2022). Since, the data pertains to only 2018-19, we have considered the state boundaries as they are currently administered

Even the performance of the agricultural sector varied significantly across the states over the years. States of Punjab and Haryana, and western parts of Uttar Pradesh were the first to benefit from the green revolution policies, and have witnessed a boost in the yields of the major food grains of rice and wheat (Gulati, Roy & Hussain, 2021). During 1971-72 to 1985-86, agricultural GDP grew at 5.7 percent p.a. in Punjab, while it was only 2.3 percent at the all-India level (Gulati, Roy & Hussain, 2021). Then it spread to other regions in the south – Andhra Pradesh, It was only by 1990s, that the growth of agricultural output picked up pace in the Eastern Indian states of Assam, Bihar, Odisha, and West Bengal (Dantwala, 1996).

Indian planning focused on irrigation as early as during the first-five year plan (i.e. 1951-56). However, the focus on agriculture was limited to irrigation expansion – even that was ignored in the second-plan that laid greater emphasis on heavy industrialisation (Parayil, 1992; Ramakumar, 2010). Expanding irrigation coverage became an urgent imperative for the success of HYV seeds and the package of green revolution strategies. Or others have argued that green revolution strategies were introduced in areas that were already well-endowed with irrigation facilities (Ramakumar, 2010). So in either case, the extent of irrigation reflects an advancement of agricultural sector. Table 5.1 shows the proportion of area which is irrigated in each state. And we can see that the early green revolution states of Punjab, Haryana and Uttar Pradesh, had considerably higher share of irrigated area in 1993-94 itself. The gap between these three states, and the rest of the country was very stark. While the gap has been closing over the years, not a single state was able to reach the irrigation coverage in 2018-19 that was achieved by the above three states in 1993-94 itself.

Table 5.1: Net Irrigated Area as a Proportion of Net Sown Area (in %)

	1993-94	**2018-19**
Andhra Pradesh	37.5	46.7
Assam	20.6	13.4
Bihar	47.5	51.9
Gujarat	27.0	51.9
Haryana	75.8	90.9
Karnataka	21.6	37.8
Kerala	14.5	19.9
Madhya Pradesh	27.1	64.9
Maharashtra	14.1	18.7
Odisha	33.2	27.3
Punjab	93.2	99.8
Rajasthan	28.3	46.6
Tamil Nadu	47.4	56.0
Uttar Pradesh	67.0	85.6
West Bengal	35.0	59.2
All India	**36.0**	**51.3**

Source: Calculated from Reserve Bank of India (2022)

A trend decline in the public investment in rural infrastructure such as surface irrigation in the aftermath of liberalisation, added to decline in overall decline in investments (both private and public) – private investments were also not forthcoming in the space vacated by the state (Ramachandran & Rawal, 2010). Beyond, the first-five year plan (20% of the plan outlay was dedicated for irrigation), the share allocated towards irrigation expenditure has been low which led to the slow growth of irrigation in a number of regions (Ramakumar, 2010). As there was decline in public investments in expanding the surface irrigation networks, there was an increase in private investments towards groundwater irrigation (Ramakumar, 2010). This seems to be the driving the force for the growth in the irrigated area in the last two and half decades in the states other than Punjab, Haryana and Uttar Pradesh.

6 EMPIRICAL ANALYSIS

6.1 Farm Mechanisation in India

The introduction of machines in farm operations was intricately linked with the introduction of the high-yielding varieties of seeds during the green revolution period in India (Kahlon & Grewal, 1972). Over the years, mechanisation of farm operations in India has been dominated by a heavy concentration of tractors compared to the other countries at similar income levels (Sarkar, 2013b). Furthermore, the shift to tractor use occurred at a lower labour wage rate, dispelling the neoclassical view of relative factor prices determining the adoption of modern inputs (Bhattarai, Joshi, Shekhawat & Takeshima, 2017). The origins of this could be traced back to the 1970s when the debate on the introduction of heavy machinery such as tractors was a prominent one – with the process being dubbed as 'tractorisation'. Over the years, India has also emerged as a major manufacturer and exporter of tractors (Sarkar, 2013b, Bhattarai et al., 2017). Although, India fares better than the neighbhouring South Asian countries in terms of mechanisation, it performs poorly when compared to the developed countries of the west, or even middle income economies such as China and Brazil (Aryal, Rahut, Thapa & Simtowe, 2021). Even among the South Asian countries, there is evidence to suggest that countries such as Bangladesh and Sri Lanka have outperformed India, for instance in terms of the extent of mechanised tilling (Biggs, Justice & Lewis, 2011). While that is the scenario at the national level, one can find that farm mechanisation is severely unequal among the different regions and socio-economic classes of farmers (Sarkar, 2013a; Aryal et al., 2021). The attempt in this section will be to analyse the differences in mechanisation specifically among the major Indian states between two years (1993-94 and 2018-19) in the post-reform period.

As discussed in the methodoloy chapter, mechanisation levels can be captured using both number and values, as proxies. Tables 6.1 and 6.2, depict the trends in mechanisation based on the estimations of number of machinery that were owned by households in the major Indian states. There has been an increase in the ownership of the major farm machinery across all the states under consideration. The prevalence of machines differ based on both the socio-economic and agro-ecological features of the states (Bhattarai et al., 2017 & 2018). For instance, the usage of power tillers is prominent in areas with a dominance of smaller operational holdings – for whom investment in larger land operation machines such as tractors mght be a hindrance (Aryal et al., 2021). Power tillers are relatively less capital and energy intensive (lower horse power compared to tractors), the ownership of which is more common in less agriculturally prosperous regions (Bhattarai et al., 2017). There is a greater use of these power tillers compared to tractors in the eastern states such as Bihar which are less agriculturally prosperous and have greater dominance of small sized holdings (Table 6.1). Nonetheless, it is only in relative terms that these states have higher prevalence of power tillers, i.e. when compared to their ownership of tractors. Among the states, however, the prosperous northern regions of Punjab, Haryana and Uttar Pradesh, have the highest numbers of power tillers.

With the exception of three states (Haryana, Punjab & Uttar Pradesh), number of tractors per thousand hectares were all less than 10 in 1993. Odisha registered the lowest prevalence of tractors with less than one per thousand hectares. Tractor density has increased by four times at the national level. A number of states witnessed a considerable increase in tractor ownership. West Bengal registered the lowest density of tractors, while Punjab had the highest. Mechanisation of farm operations, other than ploughing/tilling, has been limited in India. The ownership of large harvesting machines such as combine harvesters is extremely limited – only a little more than six harvesters were available in India for every thousand hectares. Since, combine harvesters are relatively less prevalent, the dependence of threshers is high. The former performs harvesting and threshing together. On other hand, threshers are smaller equipment and are less capital intensive in nature – hence the greater usage. Binswanger (1986) argues that mechanisation of harvesting operations is delayed for two reasons – *firstly,* for a number of crops harvesting is a very control intensive activity; *secondly,* in a low-wage economy it is not profitable to shift to capital intensive and large machinery such as combine harvesters as it is cheaper to hire labour. And in developing economies' agriculture, harvesting is a major source of farm employment (Binswanger, 1986).

The extent of rural electrification and electricity prices determine the choice of ownership of diesel and electric pumps. The dominance of diesel pumps is evident in the states such as Bihar, West Bengal and Uttar Pradesh, where electrification proceeded slowly compared to the rest of the country (Nhalur, Josey & Mandal, 2018). Nonetheless, at the national level there is an increasing shift towards electric pumps. At the all India level, diesel pump density has increased by 2 percent p.a, while electric pump density has increased by 3 percent p.a., despite having similar initial levels in 1993-94 (Table 6.1 and 6.2).

Table 6.1: Number of Machinery per Thousand Hectares of Net Sown Area, in 1993-94 & 2018-19

	Tractors		**Power Tillers**		**Combine Harvesters**		**Threshers**		**Diesel Pumps**		**Electric Pumps**	
	1993	2018	1993	2018	1993	2018	1993	2018	1993	2018	1993	2018
Andhra Pradesh	2.8	31.7	0.4	23.1	-	1.5	2.8	10.0	25.5	41.0	99.0	170.5
Assam	-	17.3	1.9	9.2	-	0.0	3.9	22.8	4.2	45.9	0.1	47.1
Bihar	5.9	25.1	0.9	35.6	-	2.2	36.3	36.9	79.5	245.7	14.0	62.3
Gujarat	3.7	46.0	0.0	12.9	-	1.5	4.5	7.4	47.1	45.1	35.2	78.2
Haryana	38.1	65.5	26.9	68.9	-	16.3	28.3	71.4	86.0	67.0	112.3	100.4
Karnataka	3.2	20.2	1.1	24.4	-	1.7	13.5	5.3	5.9	4.7	56.6	72.3
Kerala	-	-	2.2	8.1	-	0.2	0.9	4.7	24.8	20.7	158.1	193.2
Madhya Pradesh	5.7	31.9	0.3	16.3	-	4.4	9.4	10.1	10.7	37.8	38.1	150.8
Maharashtra	2.5	16.1	0.5	39.3	-	5.2	3.5	15.6	41.9	24.0	61.6	155.6
Odisha	0.7	9.7	0.0	15.0	-	1.4	20.9	5.0	7.8	50.1	3.1	33.3
Punjab	51.2	108.3	32.2	91.4	-	31.5	32.8	66.9	111.6	51.3	107.7	185.2
Rajasthan	7.9	41.2	0.3	27.4	-	10.7	2.5	20.0	35.7	63.2	27.9	83.3
Tamil Nadu	5.1	19.7	0.9	11.0	-	0.7	3.4	8.6	61.3	51.2	178.9	171.8
Uttar Pradesh	21.4	68.9	5.1	48.6	-	13.6	47.3	43.7	122.2	240.0	27.4	62.7
West Bengal	3.2	3.9	3.8	12.6	-	7.8	64.8	122.6	80.8	109.5	7.8	44.6
All India	**8.4**	**35.0**	**2.8**	**29.2**	**-**	**6.5**	**17.6**	**24.4**	**47.1**	**76.6**	**50.8**	**107.1**
Coef. Variation	1.3	0.8	1.9	0.8		1.26	1.0	1.0	0.8	1.0	0.9	0.5

Source: Own estimations from unit-level data of AIDIS.
[Note: Data on combine harvesters was not collected separately in the 48^{th} round.]

The prosperous and commericalised agricultural regions of the northern states such as Haryana, Punjab and parts of Uttar Pradesh, are clearly outliers in terms of the number of machinery owned. They outperform other states in the ownership of almost all types of machines. It should be noted that, since the table only reports estimations, blanks do not imply that there was no machine ownership in that state. It only implies that the sample that was surveyed, reported very low levels of ownership. And subsequent to our normalisation, by dividing the number with net sown area, the value might be extremely small – hence they were not presented in the table.

We have observed that there has been general rise in the ownership of farm machinery with a few exceptions. However, the growth has been relatively uneven across the states (Table 6.2). Ownership of power tillers grew at the fastest pace at nearly 10 percent p.a. While threshers only registered a growth of 1.3 percent per annum. A number of states have registered a negative growth in diesel pump ownership – owing to the increased preference towards electric pumps as electrification improved. The states, such as Bihar, Odisha, Gujarat, Karnataka, Maharashtra etc., which started off with lower number of machinery in 1993 (Table 6.1), have registered higher growth rates (Table 6.2). This indicates that there is a convergence of sorts and the erstwhile lowly mechanised regions are slowly catching up with others. This is reflected in the decrease in dispersion across states between the two years, measured as the coefficient of variation [Table 6.1].

This holds for all machinery that were reported except diesel pumps – this is because only a few states continue to rely heavily on them, and they report a very high prevalence of the same. For instance, Bihar continues to account for three times higher diesel pumps compared to the Indian average (Table 6.1). A limitation of capturing mechanisation in terms of the number of machinery is that it precludes an understanding of mechanisation in totality. We can only state whether a region is highly mechanised or not in terms of a particular machine. Therefore, we proxy mechanisation in terms of the value of agricultural machinery and equipment owned by households in different states. Value of machines is also advantageous as it contains information on both the quality and the quantity of machines.

Table 6.2: Compound Annual Growth of Machinery (%) Between 1993-94 and 2018-19

	Tractors	Power Tillers	Threshers	Diesel Pumps	Electric Pumps
Andhra Pradesh	10.2	17.3	5.3	1.9	2.2
Assam	-	6.5	7.3	10.1	28.9
Bihar	6.0	15.8	0.1	4.6	6.2
Gujarat	10.7	-	2.0	-0.2	3.2
Haryana	2.2	3.8	3.8	-1.0	-0.4
Karnataka	7.6	13.3	-3.6	-0.9	1.0
Kerala	-	5.5	6.8	-0.7	0.8
Madhya Pradesh	7.2	18.1	0.3	5.2	5.7
Maharashtra	7.8	19.2	6.2	-2.2	3.8
Odisha	11.2	-	-5.5	7.7	9.9
Punjab	3.0	4.3	2.9	-3.1	2.2
Rajasthan	6.8	19.5	8.7	2.3	4.5
Tamil Nadu	5.6	10.5	3.8	-0.7	-0.2
Uttar Pradesh	4.8	9.5	-0.3	2.7	3.4
West Bengal	0.7	5.0	2.6	1.2	7.2
All India	**5.9**	**9.8**	**1.3**	**2.0**	**3.0**

Source: Own estimations from unit-level data of AIDIS

Table 6.3 presents the value of all agricultural machinery and equipment across the states normalised by the NSA. The value of machinery has increased 2.5 times between 2018-19 and 1993-94 at the national level. Apart from Haryana, Punjab and Uttar Pradesh, all other states have had lower than Rs. 20,000 worth of machinery per hectare in 2018-19. This suggests that the difference between the three highly mechanised states and the others is quite stark. We can divide the states into three broad groups based on relative mechanisation levels in 2018-19: highly mechanised (>20000), medium mechanised (10000-20000) and low mechanised (<10000). Majority of the states (eight) fall under the category of medium level of mechanisation. Four states were low in mechanisation – Karnataka, Kerala, Odisha and West Bengal. These are only arbitrary divisions and can only be interpreted relatively.

The changes between these two years in terms of the relative positions of the states in the mechanisation hierarchy has been limited. The rank correlation coefficient, at 0.73 indicates that there is strong correlation between the rankings of the states in the two years. This implies that the states that were the higher (or lower) in mechanisation levels in 1993-94 continue to be higher (or lower) in 2018-19. However, there are some important exceptions – Andhra Pradesh has moved seven positions during this period and has significantly bettered its mechanisation position compared to other states. At the same time, Tamil Nadu fell behind by seven spots to reach 11th position in terms of machinery value owned in the state.

Table 6.3: Value of All Agricultural Machinery & Equipment per Hectare of Net Sown Area (in 2011-12 prices)

	1993-94		**2018-19**		**Ratio**
	Value per ha (Rs.)	**Rank**	**Value per ha (Rs.)**	**Rank**	**(2018/1993)**
Andhra Pradesh (AP)	3789	12	15142	5	4.0
Assam (AS)	1151	15	10673	12	9.3
Bihar (BH)	5209	7	14565	8	2.8
Gujarat (GJ)	4428	8	14598	7	3.3
Haryana (HR)	27243	1	26672	2	1.0
Karnataka (KA)	4067	9	9683	13	2.4
Kerala (KL)	3487	13	4360	16	1.3
Madhya Pradesh (MP)	3955	10	13133	9	3.3
Maharashtra (MH)	3113	14	12313	10	4.0
Odisha (OD)	971	16	5519	14	5.7
Punjab (PN)	19880	2	40242	1	2.0
Rajasthan (RJ)	5270	6	15508	4	2.9
Tamil Nadu (TN)	7285	4	10940	11	1.5
Uttar Pradesh (UP)	11953	3	24675	3	2.1
West Bengal (WB)	3809	11	4606	15	1.2
All India	**6017**	**5**	**14973**	**6**	**2.5**
Coef. Variation	1.04	-	0.64	-	
Rank Correlation Coef.			0.73		

Source: Own estimations from unit-level data of AIDIS - NSSO 48th and 77th rounds

[*Note*: To make the values from two years comparable, we deflated them using Wholesale Price Index (WPI). The procedure is discussed in detail in methodology & Appendix B]

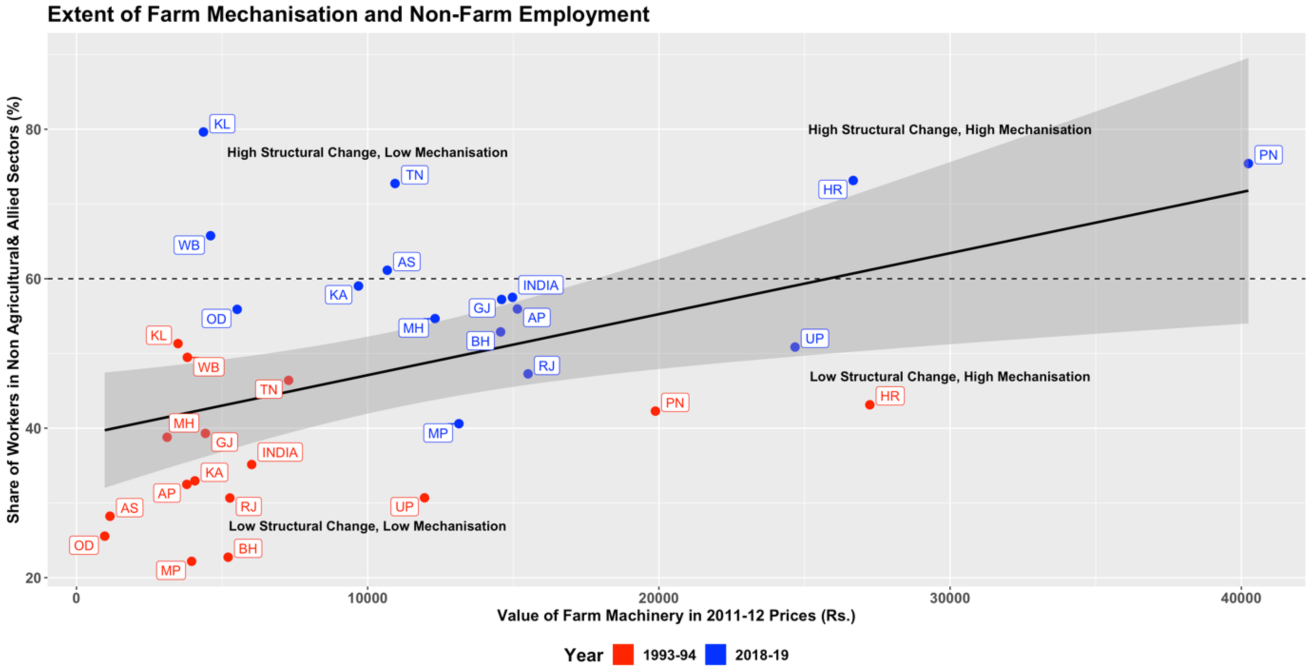
It was clear from the above discussion that there was a growth in mechanisation levels, and literature also supports the view that mechanisation has accelerated in the recent decades. The prospects of earning rental income, and for using some machinery (such as tractors) for non-farm activities like construction and transport, has promoted the ownership of agricultural machines (Bhattarai et al., 2017). Nonetheless, we also could find that there is a growing convergence among the states which is reflected in the lower coefficient of variation in 2018-19 compared to 1993-94. While there is a trend towards convergence in mechanisation, the relative dominance of few states has remained unchanged, as reflected in the high rank correlation. And, despite the increased convergence in mechanisation levels in the last two and half decades, there exists considerable differences between the states. Furthermore, we found that a few states were relatively worse-off in mechanisation in 2018-19 compared to 1993-94, and vice-versa. This could have implications for both the changes in productivity and in the extent of non-farm jobs. Therefore, it is important to understand these differential processes to make sense of the relationship between mechanisation and structural change.

6.2 Farm Mechanisation and Structural Change

The question of whether machine use frees up human labour in farm operations does not have a simplistic answer. The relationship itself, between mechanisation and extent of non-farm employment need not be unidirectional. On the one hand, lack of off-farm employment opportunities could inhibit investments in machinery that could potentially be labour-saving. On the other, lack of mechanisation could prevent labour transition out of agriculture. In this section, the attempt is to understand how mechanisation and structural change are related and how the relationship has evolved in the last two and half decades.

Figure 6.1 summarises the trends in farm mechanisation, proxied by the value of farm machinery per hectare of NSA in a state, and structural change, measured by the workers in non-agricultural and allied sectors measured as a percentage of total employment. The plot could be divided into four sub-regions based on high/low structural change, and high/low mechanisation - to better categorise the states. The divisions are not definitive as there is no accepted standard value for either mechanisation or structural change. Nonetheless it is useful for an illustrative understanding of how states have (or have not) shifted from one sub-region to the other. Between 1993-94 and 2018-19, all states have increased their mechanisation levels and increased their share of the non-farm employment – albeit with varying degrees. Despite the increase in the share of non-farm employment, a large number of states continue to employ less than 60 percent of the workers in these sectors even in 2018-19. Only in six out of fifteen states, are the share of workers in non-agriculture greater than 60 percent in 2018-19 – Kerala, West Bengal, Tamil Nadu, Assam, Haryana and Punjab. In 1993-94, no state was under this category, and the state with the highest proportion of non-farm employment was Kerala at just over 50 percent.

Figure 6.1: Extent of Farm Mechanisation & Non-Farm Employment, in 1993-94 & 2018-19



Note: Own estimations based on AIDIS (1992), EUS (1993-94) and PLFS (2018-19). Check the state abbreviations from Table 6.3.

We can find that most states in 1993-94 were both structurally less transformed and less mechanised. From here, states such as Tamil Nadu, Kerala West Bengal and Assam have shifted vertically upwards by increasing the share of non-farm employment, but without much increase in mechanisation levels. States such as Punjab and Haryana had higher mechanisation levels to begin with, and have continued to increase the same with a commensurate increase in the share of non-farm jobs. It is to be noted that these states were lower than the other higher structural change states of Tamil Nadu and West Bengal in 1993-94. However, Punjab and Haryana witnessed a faster increase in the non-farm employment share to reach 75 percent and 73 percent by 2018-19. While, the same was 73 percent and 46 percent for Tamil Nadu and West Bengal.

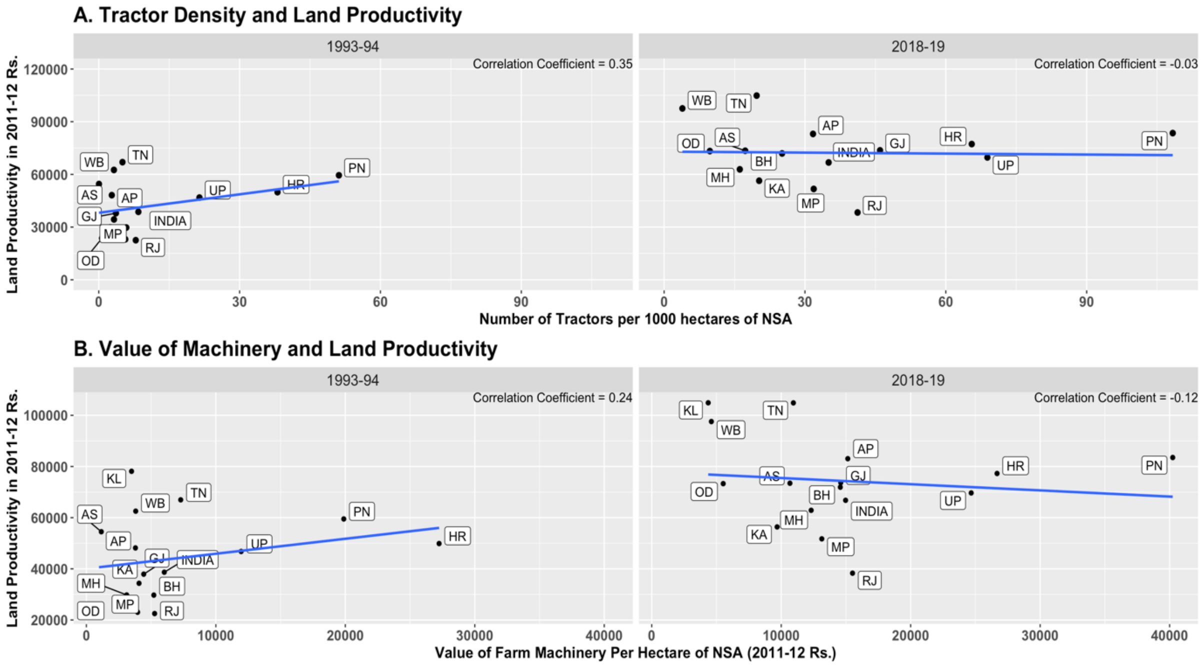
An alarming picture is presented by the large group of states which were not able to move out of the bottom left quadrant of low structural change and low mechanisation – these regions constitute a large section of the rural population in the country, and the low levels of machine use points to the low productive nature of their agriculture. These states, however, witnessed a faster growth in machine use, owing to the lower starting point, if not a quicker structural change (Appendix Table C.1). For instance, Bihar's, Madhya Pradesh's or Odisha's share of non-farm employment, which were at much lower stages in 1993-94 compared to Punjab, still had a lesser decline in agricultural employment. A few states in this low mechanisation, structural change region, are however, moving along the path of the fitted line – such as Andhra Pradesh, Bihar, Rajasthan, Gujarat and Maharashtra. This is a contrasting trend compared to Odisha, Karnataka – the two states have witnessed a bigger vertical shift than a horizontal one. The movement along the line suggests that an increase in mechanisation is associated with an increase in non-farm employment share. Since, the bulk of the states are located within this region, it is of utmost importance to accelerate structural change driven by productivity boosts that are possible through mechanisation.

6.3 Farm Mechanisation and Agricultural Productivity

Productivity in agriculture, unlike other sectors, is crucially dependent on the type of land and the associated agro-ecological features of that region (Binswanger, 1986). Dry land agriculture is generally less productive compared to canal irrigated or fertile regions fed by rivers (Dev, 1986). Therefore land becomes an important input in agricultural production – it is even more prominent in less technologically advanced agricultural regions because of the lower levels of land-saving technologies and also a greater dependence on the forces of nature (Offutt & Shoemaker, 1990). As such, any analysis of productivity in this sector should consider both the land and labour productivity.

In the previous section, we have seen that farm mechanisation and structural change were related. There was a positive association between the two. Mechanisation could be related to structural change via the improved productivity potential it offers. It has been argued that mechanisation of farm operations enhances labour productivity, while increased usage of modern bio-physical inputs such as high yielding seed varieties improve land productivity. The former is labour saving, the latter is land saving. At the same time, there have been studies which concluded that mechanisation has the potential for improving land productivity as it could enhance the quality of an operation – such as tillage (Kahlon & Grewal, 1972; Jodha, 1974). Bhattarai et al. (2018) find that the use of combine harvesters have improved the yields in India. Furthermore, studies have also categorised the differential impacts on land and labour productivity by different agricultural machinery (Bhattarai et al., 2018). It was noted that tractors does not replace humans, as it replaces only the work of draught animals (Rao, 1972, Bhattarai et al., 2018). While, combine harvesters replace human labour at a greater scale – as harvesting is a major source of labour use among farms (Rao, 1972; Bhattarai et al., 2018)). In this section, our attempt is to understand how mechanisation is related to productivity differences across the states. In addition to machinery values, we also make use of tractor density to proxy for mechanisation.

Figure 6.2: Extent of Farm Mechanisation & Land Productivity, in 1993-94 & 2018-19

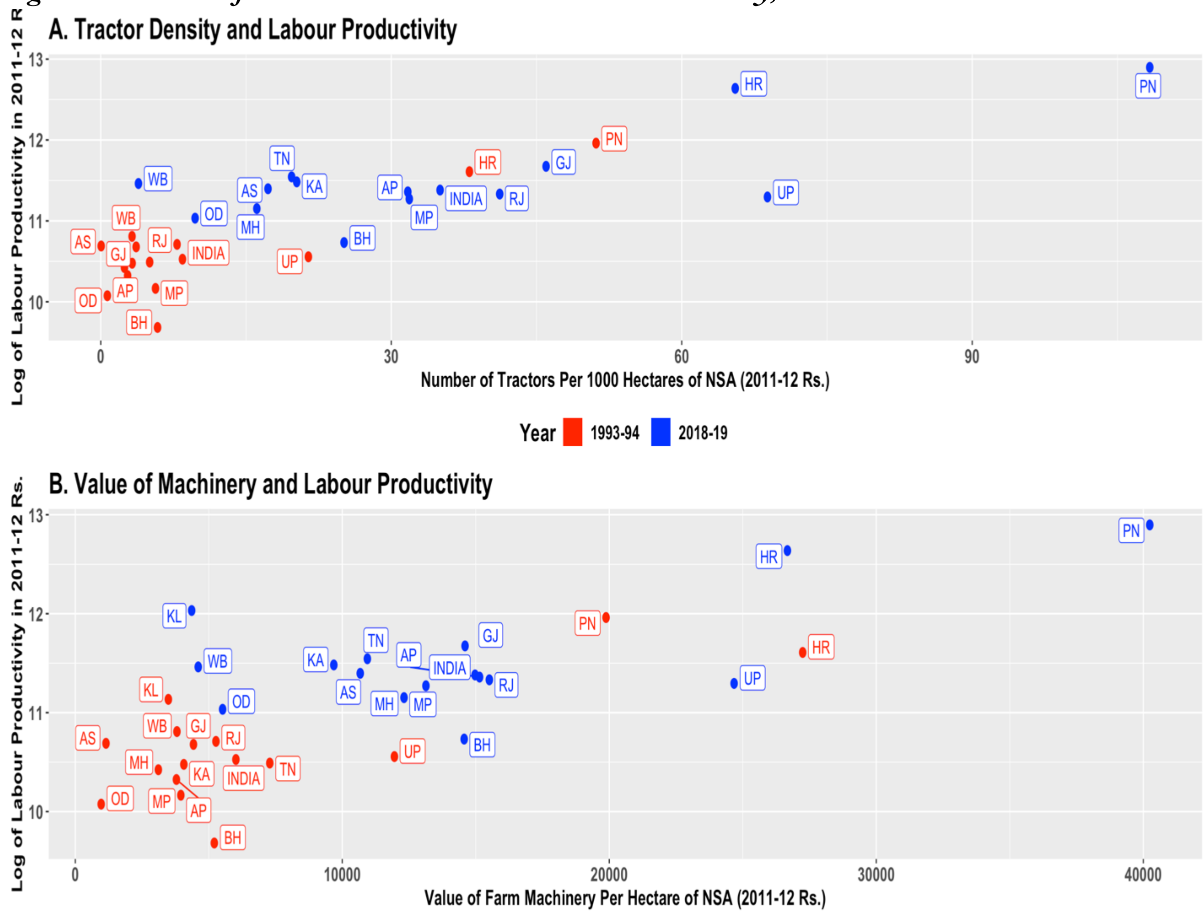


Note: Own estimations based on AIDIS (1992) and Land Use data of the Ministry of Agriculture.

There is a weak correlation between mechanisation and land productivity in both the years as we can see in Figure 6.2. The slope of the fitted line is to a large degree influenced by the outlier states of Uttar Pradesh, Haryana and Punjab in 1993-94. In that year, a large number of states were confined to the region of low land productivity and low mechanisation in the bottom left region.

By 2018-19, there is movement towards an improved land productivity with or without an increase in mechanisation. The weak correlation (at 0.35 and 0.24) in 1993-94 now becomes weaker (at -0.03 and -0.12) and turns negative. This implies that the states with greater mechanisation, have lower land productivities compared to the ones which are considerably lower in mechanisation hierarchy. This could mean that mechanisation is related to land productivity improvement to only a certain threshold level, beyond which its contribution diminishes. Nevertheless, mechanisation and land productivity are weakly correlated. Binswanger (1986) argues that mechanisation is only indirectly related to land productivity and yields. That impact too, is largely contingent on other factor inputs such as fertiliser and seed varieties. It is important to understand why states such as Tamil Nadu, Kerala and West Bengal, feature highly in terms of land productivity, than the green revolution states of Punjab & Haryana – which have witnessed increases in both bio-physical and mechanical inputs. We discuss this in more detail in the later sections.

Figure 6.3: Extent of Farm Mechanisation & Labour Productivity, in 1993-94 & 2018-19



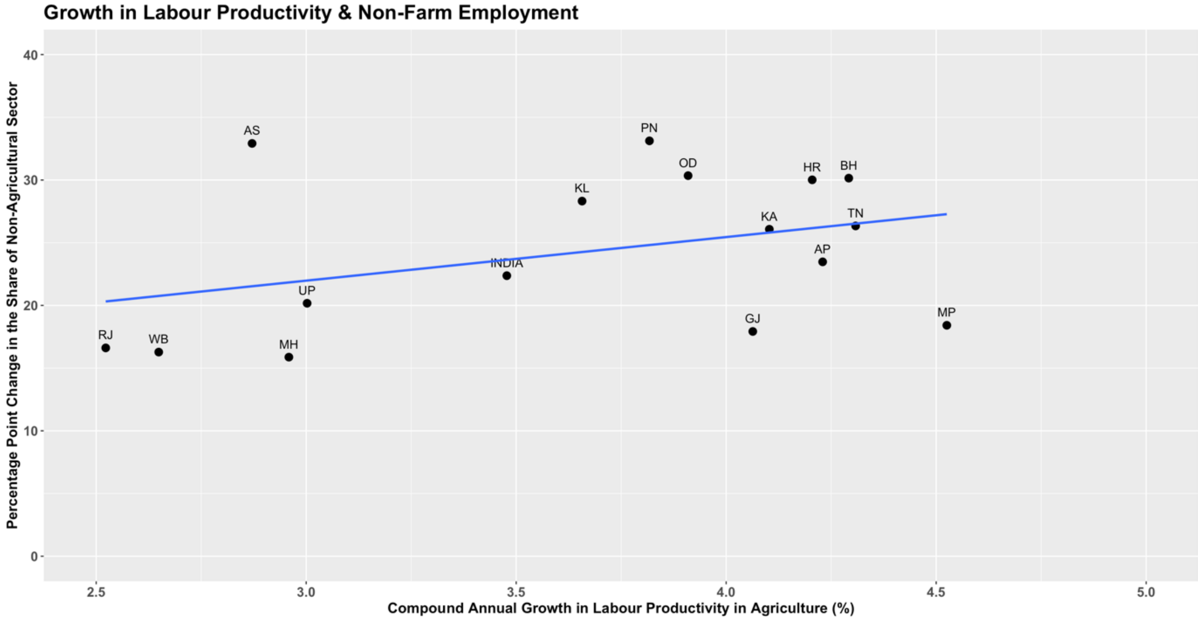
Note: Own estimations based on AIDIS (1992), EUS (1993-94), PLFS (2018-19) and Value of Output data from MoSPI

As proposed by Binswanger (1986) mechanisation influences labour productivity as it replaces human labour. While different machines can effect labour displacement differently, at an aggregate level, the process of mechanisation is labour displacing. Figure 6.3 plots the relationship between mechanisation and logarithmic values of labour productivity. We have used both tractor density and value of machinery as proxies for mechanisation. Tractor density has a clear positive correlation with labour productivity. Majority of the states have shifted along the direction of the 45 degree sloped line, which indicates that mechanisation and labour productivity have both increased. This is unlike the relationship mechanisation had with land productivity where there was a vertical shift that was noticed for several states.

6.4 Labour Productivity in Agriculture and Structural Change

Structural change results when there is a growth in labour productivity in agriculture. Low productive agriculture is characterised by surplus labour and disguised unemployment (Ghose, 2021). So a shift in workforce away from agriculture should not disrupt the absolute production levels – simply because the same output can be achieved by lesser number of workers than is employed under the scenario of a low productive agriculture. Since we are concerned about how the changes in productivity levels are related to the pace of structural change, we calculate compound annual growth for labour productivity and the percentage point change in non-agricultural employment share (Figure 6.4). States which had lower productivity levels in the initial period i.e. Bihar, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Karnataka registered faster growth compared to Punjab or Haryana, which in 1993-94 itself had higher labour productivity than other states in 2018-19. However, despite having faster growth, states like Madhya Pradesh and Gujarat, did not have a greater change in non-agricultural employment than low growth states like Rajasthan, West Bengal and Maharashtra. The lack of non-farm opportunities particularly that of manufacturing could be the major issue. The fitted line being upward sloping suggests that the correlation is positive, as expected.

Figure 6.4: Relationship between Labour Productivity and Non-Farm Employment



Note: Own estimations based on EUS (1993-94), PLFS (2018-19) and Ministry of Agriculture data.

6.5 Decomposition of Labour Productivity Growth in Agriculture

As we have noted, labour productivity growth in agriculture provides the path towards structural change. However, to understand if mechanisation contributes to this growth in labour productivity we make use of a decomposition technique. In the previous sections we have only shown correlations between mechanisation, structural change and agricultural productivity. Through decomposition analysis we aim to provide the degree to which mechanisation could be contributing towards labour productivity. We decompose labour productivity growth into a sum of growth from yield, cropping intensity and land-labour ratio. An increase in the contribution of each component is caused by different factors. Yields can be increased by intensive cultivation – made possible through improved seed varieties, irrigation and appropriate fertiliser use (Dev, 1986). Yields are a direct consequence of bio-physical inputs and much less due to mechanisation, as we have discussed before. Cropping intensity is the number of times cropping is made possible – this is essentially dependent on availability of inputs for multiple seasons. It is difficult to increase cropping intensity in regions dependent primarily on rain-fed agriculture without groundwater or canal irrigation (Dev, 1986). Cropping intensity can also be increased by reducing the duration of cropping - mechanisation, allows for quicker completion of operations and provides potential for multiple cropping (Kahlon & Grewal, 1972 & Jose, 1984). Finally, Land-Labour ratio is improved if cultivation practices are labour-saving i.e. through mechanisation and shifting farm labour to non-farm employment (Dev, 1986). Mechanisation and labour productivity in agriculture are primarily linked through land-labour ratio. And this is our major variable of interest in the decomposition analysis.

Land-Labour ratio can increase either due to an increase in NSA or through a decline in labour input or a combination of the two effects. But the growth of land under cultivation i.e. the net sown area has stagnated. During the period of our analysis, NSA in India has in fact reduced from 1.42 million hectares to 1.39 million hectares i.e. 2 percent decline (Appendix C: Table C.2). Therefore, the contribution of mechanisation towards increasing the land-labour ratio is possible only by freeing up farm labour. And in turn, the contribution of land-labour ratio to the growth in labour productivity is through a reduction in the total number of workers engaged in agriculture, and not by an increase in the area of land under cultivation.

Table 6.4: Contribution of Yield, Cropping Intensity & Land-Labour Ratio to Labour Productivity Growth (%)

	Labour Productivity	Yield		Cropping Intensity		Land-Labour Ratio	
	Growth	Growth	Share	Growth	Share	Growth	Share
Andhra Pradesh	4.1	2.2	52.6	0.0	-0.3	2.0	47.7
Assam	2.8	1.2	42.2	0.2	7.7	1.4	50.1
Bihar	4.2	3.5	84.1	0.3	6.2	0.4	9.7
Gujarat	4.0	2.7	66.7	0.5	13.7	0.8	19.6
Haryana	4.1	1.8	42.5	0.4	10.0	2.0	47.5
Karnataka	4.0	2.0	49.3	0.4	9.7	1.6	41.0
Kerala	3.6	1.2	32.8	-0.3	-8.1	2.7	75.3
Madhya Pradesh	4.4	3.2	73.0	1.0	21.5	0.2	5.4
Maharashtra	2.9	3.0	102.5	-0.1	-4.6	0.1	2.1
Orissa	3.8	4.5	118.1	-1.3	-32.7	0.6	14.6
Punjab	3.7	1.4	36.2	0.2	5.6	2.2	58.2
Rajasthan	2.5	2.1	85.3	0.7	29.3	-0.4	-14.6
Tamil Nadu	4.2	1.8	42.5	0.1	1.9	2.3	55.5
Uttar Pradesh	3.0	1.6	53.8	0.4	12.4	1.0	33.8
West Bengal	2.6	1.8	68.0	0.7	27.1	0.1	4.9
All India	3.4	2.2	63.9	0.3	9.1	0.9	27.0

Source: Own calculations from multiple sources. Labour data from EUS 1993-94 & PLFS 2018-19. Output data from MoSPI. Land use data from Ministry of Agriculture, accessed from Reserve Bank of India's Handbook of Statistics on Indian States.

Yield growth appears to be the most prominent contributor for labour productivity growth for a number of states (Table 6.4). Cropping intensity has stagnated during this period, growing at a meagre rate of 0.3 percent p.a. – several states such as Kerala, Maharashtra and Orissa have even registered negative growth of cropping intensity. Growth of land-labour ratio is the major contributor to labour productivity growth in only a few states such as Assam, Haryana, Kerala, Punjab and Tamil Nadu. Haryana and Punjab, have witnessed considerable improvements in yields during the green revolution period, and might now be moving to a phase in which yield growth is getting plateaued. Dev (1986) showed that yield improvements have contributed to almost all of the increase in labour productivity growth in Eastern Haryana and Punjab during the period 1964-65 to 1975-78. Furthermore, these regions have registered a negative growth of land-labour ratio during this period – but during this period most regions have registered negative growth in land-labour ratio owing to the increase in the working age population and the relatively smaller size of the non-farm sector. The negative contribution of land-labour ratio was relatively lower for the high productivity regions of Haryana and Punjab, compared to medium, low and negative productivity growth regions (Dev, 1986).

In the last two and half decades, however, the contribution of land-labour ratio has been positive for all states except – Rajasthan. Growth in land-labour ratio was the highest for Kerala at 2.7 percent, followed by Tamil Nadu at 2.3 percent. These two states have witnessed a sharp reduction in the share of workers in agriculture and allied sectors, although they had a slightly lower share of workers engaged in this sector to begin with i.e. in 1993-94. We have seen that Kerala & Tamil Nadu and Punjab & Haryana have registered a greater contribution of land-labour ratio. However, for the former two states, the growth in land-labour ratio seems to have been accompanied by a significant reduction in the net sown area – it reduced by 22 percent and 9 percent in Tamil Nadu and Kerala respectively (Appendix C: Table C.2). On the other hand, it has increased by 2 percent in Haryana, and reduced by 2 percent in Punjab (Appendix C: Table C.2). We can identify that the increase in land-labour ratio is not of the similar order for these regions. For Tamil Nadu and Kerala, the reduction in the number of workers engaged in agriculture also resulted in the decrease in total land under cultivation. Value of output has also grown modestly at 24 percent and 13 percent. However, for Punjab and Haryana, NSA has remained somewhat similar and value of output has increased by 45 percent and 76 percent respectively. On the other hand, for Kerala and Tamil Nadu, NSA has declined without any concomitant increase in cropping intensity (Table 6.4), and growth in output was also relatively lower (Appendix C: Table C.2). Timmer (2009) argues that structural transformation entails not an absolute decline in output, but only a relative decline - as outputs grow at a much faster pace in the non-agricultural sectors. While Tamil Nadu did not witness an absolute decline in output from agriculture, it's rate of growth however has considerably been slower than other states which have witnessed similar levels of structural change.

There is a relatively lower contribution of land-labour ratio for a number of structurally less transformed states such as Bihar, Gujarat, Madhya Pradesh, Maharashtra, Odisha, Rajasthan and West Bengal. And for these states bridging the yield gaps and improving yields through intensive cultivation seems to be driving productivity growth. However, there is a distinction within these states as well. Bihar, Gujarat, Madhya Pradesh and Odisha have all registered higher growth in labour productivity with contributions from yield ranging between 67 percent in Gujarat to 118 percent in Odisha. Contrarily, Maharashtra, Rajasthan and West Bengal registered very low productivity growth rates of 2.9 percent, 2.5 percent and 2.6 percent respectively.

6.6 Nature of Structural Change in Indian States

The evidence from the previous sections suggest that there has been a trend towards increasing non-farm employment, however the pace and pattern of this structural change is varied across the states and needs closer examination. Furthermore, we find that labour productivity growth has improved compared to the period between 1964 and 1976 (Dev, 1986). However, an indicator for structural transformation, as identified by Timmer (2009) is the shrinking gap between agricultural and non-agricultural labour productivities. In this section, we analyse the changes in productivity gap and relate it to the nature of structural change that the states were undergoing by disaggregating the non-farm employment into manufacturing, services and construction sectors.

Studies have already identified that at the national level, the productivity gap has been widening between agriculture and other sectors with adverse consequences to aggregate process of structural transformation, and the nature of income distribution between rural and urban sectors (Binswanger, 2013; Ghose, 2021). Nonetheless, this widening gap could be expected in the initial stages of transformation, before convergence begins – although studies have tried to provide a generalisation, the exact turning point towards convergence varies for countries (Timmer, 2009;

Binswanger & d'Souza, 2012). The productivity differences have sharpened in the reform period, when the growth of non-farm sector employment has hastened. Table 6.5 depicts the productivity gap between the agricultural and non-agricultural sectors between in the two years. While the non-agricultural productivity in India was around four times that of the farm sector in 1993-94, it has increased sharply to being seven times. The growing productivity gap, at a time of a considerable shift in labour between the two sector indicates that labour is being driven out more due to the 'push' factors – such as low returns, profitability and yields. The productivity gap has widened for all but one state – Madhya Pradesh. But Madhya Pradesh remains as a low structurally transformed state in which only about 40 percent of its workforce is engaged in non-agricultural sectors. The share of manufacturing in the state's total workforce is also consistently lower than other states (Figure 6.5). So the narrowing of the productivity gap was less on account of the growth in agriculture, and more due to the lack of growth in the non-farm sector.

Table 6.5: Ratio of Non-Agricultural to Agricultural Labour Productivity

	1993-94	2018-19
Andhra Pradesh	4.2	6.3
Assam	4.3	3.9
Bihar	6.0	8.0
Gujarat	5.4	7.1
Haryana	1.3	2.7
Karnataka	3.6	9.8
Kerala	2.1	3.6
Madhya Pradesh	6.2	5.7
Maharashtra	6.7	12.7
Odisha	4.9	8.7
Punjab	1.2	1.3
Rajasthan	3.6	6.0
Tamil Nadu	3.6	6.2
Uttar Pradesh	3.4	5.8
West Bengal	2.3	3.4
India	**4.1**	**7.1**

Source: Own calculations based on National Account Statistics accessed from RBI's Handbook of Statistics on Indian States

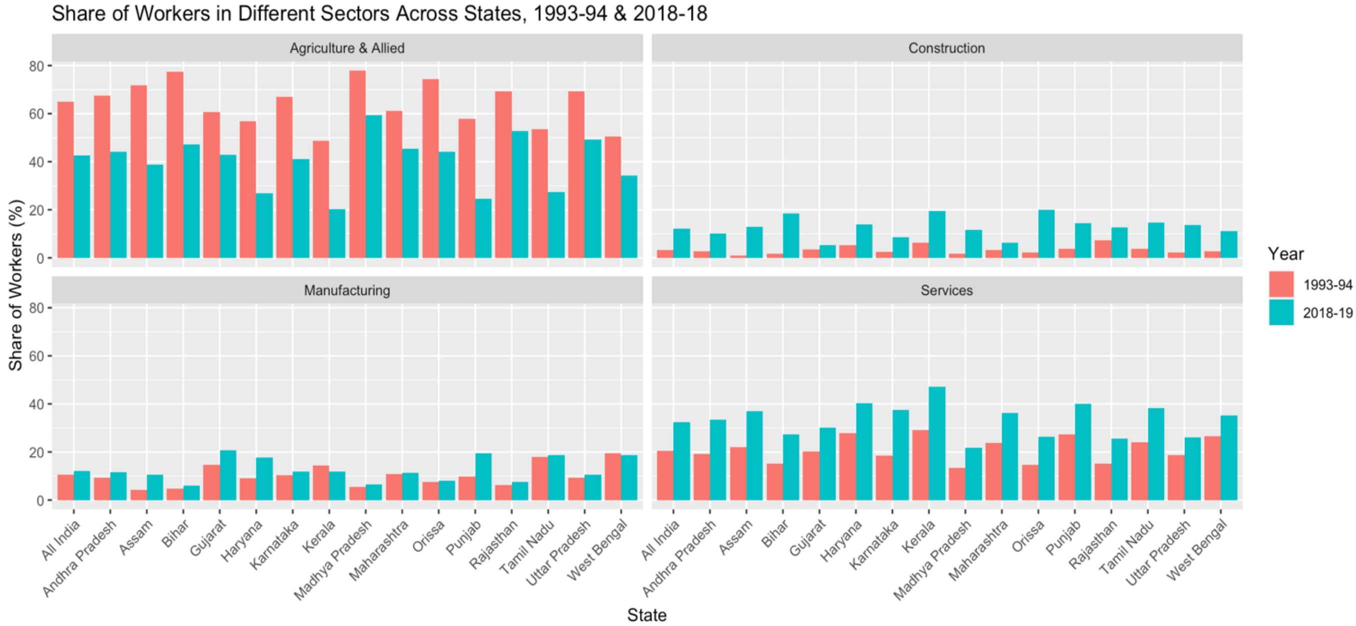
[Note: Here agricultural labour productivity pertains only to the crop sector and not allied sectors such as fishing & forestry]

Although Punjab, Haryana, Kerala, West Bengal and Assam have increased the gap between the sectors, the overall gap is still lower than the other states – particularly for Punjab and Haryana. As we have seen in the preceding sections, these states feature very high on agricultural productivity indicators. And the gap has remained lower compared to the other states as they moved along the path of structural change. Maharashtra, which had the largest productivity gap in 1993-94 at nearly 7 times, witnessed an increase to around 13 times. The other states with very high productivity gap are Gujarat, Karnataka, Odisha and Bihar. Therefore, the increasing gap suggests that structural change is far from complete for a number of states. With the exception of Punjab, all the states have witnessed a widening productivity gap. The widening gap is due to the higher output growth in non-agricultural sector during the reform period accompanied by a slower growth in agriculture (Binswanger & d'Souza, 2012).

So far our analysis of structural change was captured only by the extent of non-farm employment. Figure 6.5 disaggregates the non-farm sector into construction, manufacturing and services sectors, and shows the changes in the respective sectoral shares between 1993-94 and 2018-19. The rationale for such a disaggregation is that non-agricultural sectors are varied in terms of productivity levels and as Gupta, More and Gupta (2018) find, a mere shift away from agriculture is not a sufficient condition for poverty reduction as it is also important to take note of the productivity of sectors which are ultimately absorbing the relocated labour. Non-agricultural sectors offer varied productivity dynamics, and studies have already established the primacy of increasing the manufacturing share of employment for achieving a sustained growth and transformation (Rodrik, 2014).

The striking aspect of this process of structural change across Indian states is the lacklustre growth of employment in the manufacturing sector (Figure 6.5). At the national level, manufacturing share has only increased very marginally i.e. by less than two percent points in the last two and half decades. A similar trend could be discerned for most states. Few states of Punjab, Tamil Nadu, Haryana, Gujarat and West Bengal have more than 15 percent of its workforce engaged in manufacturing sector. Of these, Punjab and Haryana had lower share compared to the other three states in 1993-94, but have steadily caught up with the rest by 2018-19. Only Punjab, Haryana, Kerala and Tamil Nadu, did not have agriculture as the sector with the most number of workers in – it was services – rest all states had agriculture accounting for the highest share (Figure 6.5). West Bengal too had a lower agriculture share than services, but the difference is only a percent point.

Figure 6.5: Share of Workers in Different Sectors Across States, in 1993-94 & 2018-19, in percent



Note: Own estimations based on EUS (1993-94) and PLFS (2018-19)

We have also calculated the extent to which potential agricultural workers[1] moved to non-agricultural sectors and the extent to which different non-agricultural sectors absorbed the workers moving out of agriculture, based on the work of Ghose (2021) [Figure 6.6]. Calculating the extent of absorption is straightforward – taking the proportion of percentage point change in non-agricultural sectors, over the percentage point change in agricultural sector share. It can be read as – 34 percent of the potential agricultural workers were reallocated to non-agricultural sectors in India between 1993-94 and 20181-19 (Figure 6.6, Panel A). 7 percent of the reallocated labour was absorbed in manufacturing, 53 percent in services and 40 percent in construction (Panel B). Here again, Punjab and Haryana performed better compared to the other states. These two states have both reduced a larger share of agricultural workforce – 57 and 53 percent of the potential workers were moved from agriculture respectively – and manufacturing share absorbed a higher share of agricultural workers at 29 and 28 percent respectively (Figure 6.6). The other state which had a larger manufacturing absorption was Gujarat.

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[1] The calculation for the share of potential agricultural workers who moved out of agriculture is as follows (Ghose, 2021):

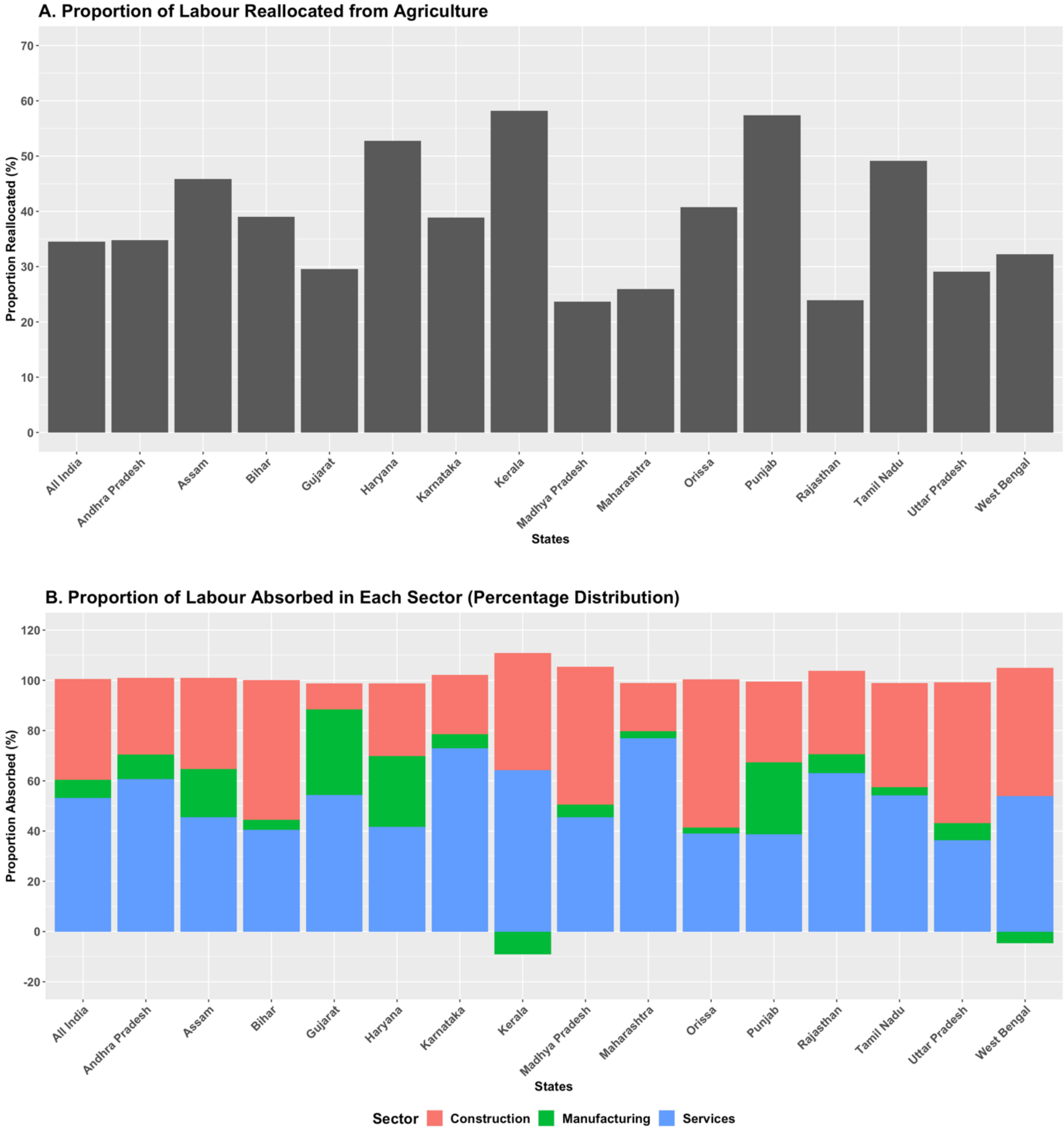
$$\frac{e_{2018-19} - e_{1993-94}}{e_{1993-94}} \times 100$$

(where, '*e*' is the employment share in agriculture).

While manufacturing share has stagnated for a majority of the states, construction and services sectors emerged as the absorbers for the workers moving out of agriculture. The share of construction has increased significantly for all the states under consideration (Figure 6.5). At the all India level, the share of construction has jumped nearly four times during this period, and it is as high as twelve times for Bihar. Services sector has always been a major employer and its share has only continued to increase steadily across the states. Structural change away from manufacturing has been identified as a process that is 'stunted' (Binswanger, 2013) – non-manufacturing sectors do not offer the kind of productivity dynamics that manufacturing provides especially for developing economies which has an overall lower levels of education and skills in the economy (Rodrik, 2014).

Few states that were able to employ a larger fraction of the workforce in manufacturing have had strong productivity growth in agriculture – Punjab and Haryana. States such as Gujarat and Tamil Nadu have witnessed an increase in manufacturing share without an adequate transformation of the agricultural sector compared to the former two states. However, it is the states which were low in overall non-agricultural employment and a lower manufacturing sector share that present a challenge to the policymaking. These states still have a large fraction of the population engaged in agriculture with low productivity levels. These states of Bihar, Odisha, Madhya Pradesh, Maharashtra, Rajasthan etc. all have lower levels of labour productivity in agriculture in 2018-19 than Punjab and Haryana in 1993-94. The gap is still very striking for these languishing states. It is the pattern of structural change and productivity gaps that is exhibited by these languishing states that is being emulated at the all India level as well.

Figure 6.6: Labour Reallocation from Agriculture & Proportion of Reallocated Labour Absorbed in Other Sectors (1993-94 to 2018-19), in percent



Note: Own calculations based on the estimations from EUS (1993-94) & PLFS (2018-19). [The sum of the proportions of the absorbing sectors might not equal zero, as we have not included Mining and Utilities sector. We have excluded this because this sector employs a miniscule share of the total employment]

7 DISCUSSION

7.1 Explanation of the State-Level Trends

We were able to identify three main categories of states based on the relationship between mechanisation and structural change. These are high structural change and high mechanisation (Punjab & Haryana); high structural change and low mechanisation (Tamil Nadu, Kerala, West Bengal); and low structural change and low mechanisation (Madhya Pradesh, Rajasthan, Bihar, Odisha, Karnataka, Andhra Pradesh etc.). We abbreviate these groups as HS-HM, HS-LM and LS-LM respectively. We did not include the category of high mechanisation and low structural change, as there is only one state, UP, that is close to this category. Among these three groups, the states which are low in both structural change and mechanisation are the majority. These states are also lower in terms of land & labour productivities, manufacturing share of employment and the absorptive capacity of manufacturing sector (Section 6.7; Figure 6.5; Figure 6.6). It is essential to shift these states towards more mechanisation and more structural change.

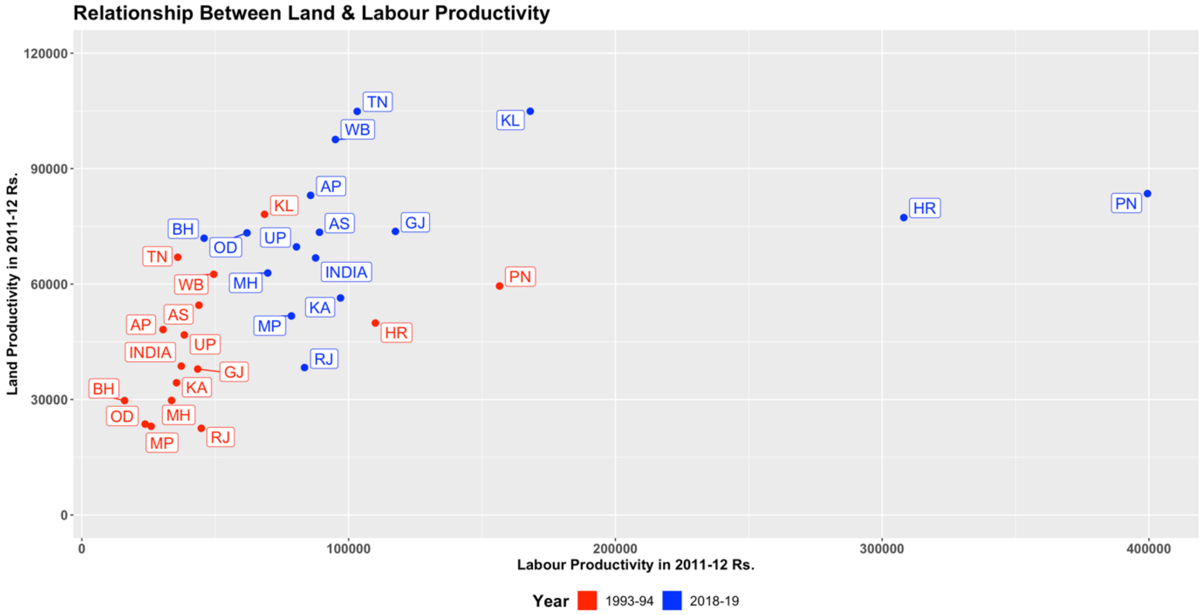
One possible way to conceptualise is to think of the states in LS-LM category as being on an earlier stage of transformation process that is seen in HS-HM or HS-LM categories. That is, with an improvement in modernisation of agriculture, these states can converge to the ranks of Punjab and Haryana. The states in LS-LM have a high share of contribution from yield and cropping intensity improvement to labour productivity growth during the last two and half decades (Table 6.4). This was achieved by Punjab and Haryana, at an earlier stage i.e. since the 1970s, in the aftermath of introducing green revolution strategies in these states (Dev, 1986). It can be argued that LS-LM states are still relying on yield and cropping intensity increases, for which mechanisation could play a role. Nonetheless, we find that even in these states there is some movement out of agriculture), albeit slow and stunted. This is reflected in the low, but non-negative land-worker contribution in most of these states (Table 6.4). This labour transition is probably due to low remuneration and profitability associated with farming, and also due to the presence of informal and casual work opportunities available in the non-farm sector (Thomas, 2012; Bakshi & Modak, 2017; Basole, 2022). As a result the productivity gaps between agriculture and non-agriculture are also higher for these states compared to HS-HM group (Table 6.5).

The HS-HM states, during their intensification phase, witnessed a negative land-worker ratio and an increase in farm employment that was made possible as cropping intensity increased and more land was cultivated (Dev, 1986). And as productivity has increased considerably, and with the structural movement of workers picking up pace, the productivity gap in these states, although has increased, has been lower compared to other states. It was found that the green revolution, during the 1970s, slowed down structural transformation during those years, as it promoted specialisation in agricultural production (Mascona, 2019 cited in Deininger, Jin & Ma, 2022). However, from what we have observed, the benefits in the longer-run were in favour of more advanced structural change for these states with a growth in manufacturing employment as well. Nonetheless, it can be expected that, in LS-LM states, agricultural intensification and boosting mechanisation through the introduction of green revolution style policies, might not hinder structural transformation. As there are already opportunities that exist in non-farm economy both within their states and in more economically advanced states. The movement of workers out of agriculture, conforms to what Gollin, Jedwab & Vollrath (2016) argue, an urbanisation and structural change in the absence of industrialisation – structural change for these states has been mostly through employment in non-tradable services.

It could also be possible that the lack of extensive non-farm jobs might be hindering the adoption of machines particularly on farms using family labour i.e. small and medium sized farms in LS-LM states. Binswanger and d'Souza (2012, pp.196) identifies that the rural non-farm sector is emerging as a major absorber of workers in India, with most households relying on a "part-time farming model" with diversified income sources. This suggests that labour continues to be engaged in farming, but since farm work is not available throughout the year, workers seeks casual and informal jobs during off-farm seasons. Since, they are not completely 'depeasantised' due to the low availability of secure and high income non-farm jobs (such as those available with manufacturing or high-end services), substitution of labour by machines is also probably slow.

Another explanation that is unresolved thus far, has been the distinction between the HS-LM and HS-HM states – if states of Tamil Nadu & Kerala were able to structurally transform (implied by the extent of non-farm employment) at lower levels of mechanisation, is mechanisation even essential for labour productivity growth, and eventually structural change? As we found in the decomposition analysis, both HS-LM (Tamil Nadu & Kerala) and HS-HM (Punjab & Haryana) states, have a higher contribution of land-labour ratio to labour productivity growth. Similarly, we have also identified Tamil Nadu and Kerala have registered higher land productivity at much lower mechanisation levels compared to Punjab or Haryana (Figure 6.2). We can think of two competing interpretations for this: *Firstly,* as we can see in Table C.2 (Appendix C), the former two states registered a negative growth in GCA. On the other hand, the latter states have increased the GCA. This could be the reason for why yields are higher – not because of a significant improvement in production, but because of a decline in land cultivated. *Secondly*, it could also be interpreted that Tamil Nadu and Kerala are able to maintain a level of output even as GCA declined – indicating that their yields have improved due modern application of farm inputs such as HYV seeds. These two states are also highly urbanised - Tamil Nadu is the most urbanised of the big states in India (Bhagat, 2011). So it could be expected that GCA and NSA decline giving way to non-farm activities in the countryside. And if that manifests without a decline in the absolute level of output, it is a positive sign of structural change.

Figure 7.1: Relationship Between Land & Labour Productivity, 1993-94 and 2018-19



Note: Own estimations from EUS (1993-94), PLFS (2018-19) & Value of Output data from MoSPI

Land productivity is higher for HS-LM states, than for HS-HM states, and labour productivity is higher for HS-HM than for HS-LM states (Figure 7.1). This that labour substitution is higher in the latter, while land substitution is higher in the former. It implies that HS-LM states, particularly Tamil Nadu and Kerala, were primarily being driven by urbanisation, while HS-HM states were primarily being driven by non-farm employment. It is also important to note that these two sets of states are not easily comparable. It is widely recognised that Kerala, and to a slightly lesser degree Tamil Nadu too, perform significantly better in terms of human development indicators, and the states have invested significantly on improving education and health outcomes (Parayil, 1996; Véron, 2001; Vijayabaskar et al., 2004; Drèze & Sen, 2013). They are therefore conducive for skill- or capital-intensive industries'-led growth, and not necessarily labour-intensive manufacturing. Noting "Kerala's comparative advantage in knowledge generation and human resources development", Subrahmanian and Azeez (2000, pp.34) suggest that the state could emerge as a "value-added service provider in a globally competitive environment". Tamil Nadu had a higher share of employment in manufacturing to begin with – but not much increase during this period. This is not the case with a number of other Indian states, and it is crucial to take note of these distinctions between the states.

From the above discussion it is evident that Indian states present varied paths of structural change – while India as whole has been exhibiting a troubling picture of a transformation of its economic base (or lack thereof). Both HS-HM and HS-LM states offer important lessons for the states which are neither highly mechanised, nor structurally transformed, nor are particularly high in terms of land/labour productivities. It is beyond the scope of this work to identify which of these two pathways is better for LS-LM states to emulate. Nonetheless, improving mechanisation is essential for LS-LM states for boosting productivities, and for substituting labour to be transferred to higher productive activities. These states are also highly populous and to exploit the demographic dividend of high working age population, these states ought to grow the manufacturing sector that can absorb the substituted labour (Thomas, 2023). As we will see below, apart from substituting labour, mechanisation also offers other linkages that are crucial for the growth of non-farm sectors. The discussions on the features of structural change in HS-HM & HS-LM states are summarised in Table 7.1

Table 7.1: Features of Structural Change Among the High Structurally Transformed States

	High Structural Change High Mechanisation (HS-HM)	**High Structural Change Low Mechanisation (HS-LM)**
States	Punjab, Haryana	Tamil Nadu, Kerala
Land/Labour Substitution	More labour-saving	More land-saving
Absorption by Manufacturing	High	Low
Productivity Gap	Low	High
Prospects for Industrialisation	Labour-absorbing sectors	Capital & skill-intensive industries and services
Lessons for other states	Labour-substituting technical change, and modernisation of agricultural sector to aid structural change	Land-substituting technical change for increasing urbanisation; Investments in human development and scope for capital & skill-intensive sectors

Source: Own elaborations based on the analysis. Interpretations are only relative to the other group.

7.2 *Importance of Rural Demand for Structural Change*

While labour reallocation away from agriculture is important, it is not a sustainable option to focus on merely increasing the non-agricultural employment without improving productivity in agriculture. This increase in productivity is to be derived through boosts in yield and output, and cannot just be an outcome of reduced labour while output remains the same – this was the case of Tamil Nadu where labour productivity increase in agriculture was accompanied by a slow output growth, and a faster shift of workers. The eastern Indian states (Bihar, Odisha and West Bengal) which feature low in mechanisation, productivity and structural change were found to have persistent yield gaps (Jha, Palanisamy, Sen & Kumar, 2022). Without improvements in agricultural outputs and yields, the impact on rural poverty would also be miniscule, and would only hasten a distressed based movement of workers out of agriculture. The Indian experience has shown that this movement does not entail a complete shift of workers. The reallocated workers continue to cultivate land – but as the incomes from crop production are extremely low, they are forced to rely on non-agricultural incomes as well. Basole (2022, pp: 316) argues that this two-way mechanism i.e. "declining viability of subsistence production (in particular agriculture) and precarious employment in the modern sector" is resulting in the reliance on subsistence production itself and is dampening the process of a sustained structural change. Basole (2022) provides a framework linking petty agricultural production with slow structural transformation – the prime cause of this being "weak broad-based demand" emanating from this petty production sector which is characterised by low incomes and low productivity (pp.316). The growth in the higher productive sectors, therefore, is being driven primarily from a demand base which is small – mostly concentrated in the upper section and in urban areas. This demand, however, favours capital-intensive and imported commodities leading to underdevelopment of labour-absorbing industries. Therefore, as Basole (2022) argues, it is essential to improve the productivity and incomes of the petty production sector – vast majority of which are engaged in some form or other in agriculture – to not only hasten structural change, but also drive the growth of labour-absorbing manufacturing. As we will discuss in the next sub-section, mechanisation offers some pathways for generating a 'broad-based demand' in the rural sector.

7.3 Policy Potential for Improving Mechanisation

We have identified that mechanisation varies significantly across states in India. Mechanisation continues to be concentrated in power-intensive operations such as ploughing. Mechanisation is most prevalent for food grains such as rice and wheat. Therefore, it is essential to expand the scope and coverage of mechanisation in India. Ownership of machinery is also highly unequal across different farm size categories (Sarkar, 2020). We find that the Gini-coefficient of the total value of farm machinery and equipment is extremely high at 0.90 for cultivator households in India in 2019 (Appendix C: Table C.3). Inequality has increased for a number of states. Machine ownership is expected to be highly unequal when there is a dominance of small land sizes, and in a historical context of unequal land holding, ownership of heavy machinery is dominated by the large landholders. Studies have also pointed out that use of machines is more widespread than ownership (Sarkar, 2013a; Narayanamoorthy, Bhattarai, Suresh & Alli, 2014). Therefore, there is potential to improve mechanisation via two fronts: promoting custom-hiring services & enabling the development and adoption of machinery appropriate for the small-size holdings. Since ownership requires large investments, policies can be focused on developing suitable terms for hiring services to avoid predatory rental services (Sarkar, 2020). To avoid leaving the small-farmers at the expense of large-landholders who own machines and also resort to renting, government can initiate custom hiring, cooperative ownership, cheap credit and subsidies (Sarkar, 2020). It is argued that machine ownership on small-scale farms is not remunerative due to low returns to scale. Evidence suggests that using custom-hiring services, by those who do not own machinery, contributes to increasing the returns to scale (Takeshima, 2017). There is already considerable demand for these hiring services from small farmers, and it is essential to generate more incentives for a successful expansion of these facilities (Singh, 2017).

In addition to custom hiring, policy should also focus on enhancing R&D for machinery that are suitable for local farm conditions. The growth of power tillers in areas with a greater dominance of small sized farms was a testament to this adaptation. There is a great potential for similar innovations based on different cropping patterns, and agro-climatic conditions across different regions in the country.

From the foregoing findings, it is clear that mechanisation is linked closely with productivity and the growth of non-farm sector. States that were featuring high in terms of mechanisation and agricultural productivity have had a greater share of workers moving out of agriculture and into manufacturing. We have also identified in the previous sub-section that the lack of adequate demand from rural areas is a major constraint to a sustained process of structural transformation. Mechanisation could also contribute to the growth of non-farm sector (particularly manufacturing) – in addition to the labour-saving and labour productivity effects - as it increases demand. It increases demand for machines, and through income improvements also increases the overall level of rural demand. It provides an opportunity for domestically manufacturing these machines. We have identified two avenues for boosting machine use – custom-hiring services & development of machinery appropriate of the small-size holdings. Both these have direct implications for growth in non-farm sector. The former, albeit marginal, could contribute to growth in service jobs related to hiring and renting. The latter, being dependent crucially on the local conditions, generates a natural advantage for domestic manufacturing of these machines. Such demand linkages are crucial, as Adelman (1984) argues, for building a resilient domestic demand for manufactured goods.

The success of tractor manufacturing and its adaptation in the Indian context case of is a useful example in this regard. India is currently a major manufacturer and exporter of tractors (Sarkar, 2013b; Bhattarai et al., 2017). The growth of domestic tractor industry could be traced to the pre-liberalisation period when there were trade controls (Singh, 2015). Nonetheless, by 1980s India emerged as an exporter of tractors – which only until a decade earlier i.e. 1970 had few manufacturing units and was importing tractors as per government's approved quotas (Singh, 2015). The growth in tractors in India, complemented manufacturing of farm implements that are driven by tractors (Singh, 2015). State supported research on agricultural engineering was a driving force for farm mechanisation in the country – the engineering units attached to the state agricultural universities contributed to developing mechanical innovations and to identifying and resolving the needs of mechanical energy based on local conditions (Singh, 2015). Government's role in promoting R&D related to farm machinery, and building associated infrastructure in the rural areas for greater machine use (such as education and skill training for use of new machines) cannot be underscored (Diao, Silver & Takeshima, 2016). The already existing network of government research and extension systems can be effectively channelled towards this end.

At the same time, if mechanisation can lead to improvements in rural incomes then there would be a growth in the demand for non-agricultural goods and services – thereby directly contributing to the growth of the non-agricultural sectors as well. Apart from influencing crop outputs, mechanisation can become an additional income source in the rural areas through the establishment of custom-hiring services – contributing to incomes for not just cultivators, but also others involved in these avenues in the rural areas. Furthermore, farm machinery such as tractors and pump sets, can be used in non-farm activities as well. Small and medium farmers who invest in such machinery would resort to renting, to activities such as rural construction, particularly during the periods when they are not being used for farm activities. This generates diversified income sources for these farmer households, and reduces the precarity associated with solely relying on farm incomes.

8 CONCLUSION

8.1 Summary

Mechanisation has increased over the last two and half decades – the backward regions have improved, and convergence has increased over time. However, the advanced agricultural states of Punjab & Haryana, far outperform the other states – the states which were ahead in mechanisation in 1993-94, continue to be in 2018-19 as well. This position is not likely to change any time soon. Of the three highly mechanised states (Punjab, Haryana & Uttar Pradesh), Uttar Pradesh had a greater share of workers engaged in agriculture compared to other sectors. This is probably because mechanisation has largely been concentrated in the western regions. Uttar Pradesh being a very large state, has severe intra-state inequalities.

From the decomposition exercise, it was evident that for most states during the post-reform phase, labour productivity growth was driven by growth in yields, and not due to increase in land-labour ratio – these states were also structurally less transformed. On the other hand, the states which witnessed greater shift of labour from agriculture, had a higher contribution to labour productivity from land-labour ratio. Cropping intensity seems to have peaked for almost all Indian states, and henceforth has not been a major contributor to productivity growth. Mechanisation contributes to the increases in land-labour ratio. And higher contribution of land-labour ratio towards productivity, in the high structurally transformed states (Punjab & Haryana) indicates that improvements in mechanisation contributed to labour productivity – which in turn effected the shift of labour away from agriculture.

Only in four states – Punjab, Haryana, Kerala and Tamil Nadu – agriculture does not account for the highest share of workers. Of these structurally transformed states, not all were highly mechanised. Punjab & Haryana are witnessing a conventional pattern of structural change – labour productivity improvements in agriculture leading to the growth of manufacturing sector employment. Productivity growth was being driven by increase in land-labour ratio i.e. mechanisation is contributing considerably to productivity in agriculture. In Kerala, manufacturing employment has declined, and the state is moving towards service-based economy with a strong consumption base, and high standard of living enabled by investments in human development. Tamil Nadu, though similar to Kerala with respect to human development, and skill-levels, differs in terms of the manufacturing. Tamil Nadu has a strong manufacturing base, however, during the last two and half decades, its share in employment has increased only very little – could be possible that its share of manufacturing has peaked. Therefore, both Kerala and Tamil Nadu have scope for improving capital- and skill-intensive sectors. These states have also a high urbanisation rates, as such productivity growth has been land-saving in these two compared to Punjab & Haryana, for which labour-saving productivity growth was dominant.

Although some states achieved structural change even in the absence of high mechanisation, it can be argued that improvements in mechanisation is essential for the low structurally transformed states (Bihar, Madhya Pradesh, Rajasthan, Maharashtra, Andhra Pradesh, Odisha etc) – which are low in both land and labour productivity. The increase in mechanisation, and the shift towards higher productivity in the last two and half decades indicates a positive development. Most of these states also have a growing working age population presenting a demographic dividend that can be taken advantage of with a growth in manufacturing – if not it is going to be demographic challenge to productively engage this growing workforce. In addition to freeing-up labour, we have also discussed how mechanisation offers other linkages – demand for farm machines and an overall increase in demand in rural areas. This domestic demand in the rural can potentially contribute to the growth of non-farm sectors.

8.2 Limitations and Scope for Future Research

This study has some important limitations which provide scope for future explorations in this field. *Firstly,* our estimations of labour productivity in agriculture could be either an underestimate or an overestimated. This is because we use number of workers engaged instead of number of labour-hours or labour-days. We do so because of lack of data on days or hours. The limitation of using number of workers, as discussed above, in agriculture is that a worker is more than not is 'pluriactive' – engaging in more than one economic activity (Bakshi & Modak, 2017). And based on our estimation procedure from the labour force surveys, we can arrive at an incorrect estimate of productivity – for instance, a worker works for a majority of the time in a year in agriculture, and the remaining period in a non-farm activity. Based on the labour force estimations, we account that worker as being engaged in agriculture alone. It would be an overestimate, if a worker works majority of the time off-farm, and remaining period on farm. So, it is important to capture labour-days that are spent in agriculture. While it might be difficult to capture these in nationally representative sample surveys of NSS, it provides scope for small scale studies based on a few villages – to calculate the productivity levels, and then link them with the extent of non-farm work that is available within that village(s). Such an exercise would provide more precise estimations of productivity.

Secondly, we were able to broadly identify three different patterns of structural change at the state-level in India – of which two groups of states (Punjab & Haryana on the one hand, Tamil Nadu & Kerala on the other) were able to achieve high structural change, but with different pathways. However, we were only able to hint at some implications based on a preliminary descriptive analysis. It is important to further study these two categories, on how and why they differ to better understand their implications for the rest of the states. It is to be seen how industrialisation is achieved in these states – whether Kerala and Tamil Nadu being more advanced in terms of human capital – can offer more potential for services and capital-intensive industries.

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APPENDIX A: DATA DESCRIPTION

This section provides a description of the NSS data that we used for our analysis.

All India Debt and Investment Survey

As mentioned above for our period of analysis, we chose the surveys that closely correspond to the starting year and the current year of the reform period. Since, reforms were initiated in 1991, the closest available AIDIS survey is the one conducted during January and December 1991. The closest available round for the current year is the AIDIS conducted during January and December 2019. However, there were two other rounds, conducted in 2003 and 2013, that we did not use for the analysis. This is primarily because we are concerned with the changes that took place within this period, and we are not particularly interested in sub-periods of this post-reform phase. One of the major limitations of using NSS surveys over time is that information collected on certain items could be different across different rounds. This constrains the use of all the available rounds of the survey. This is another reason why we could not use the 2013 round of the survey, as the information it collected on the number of machines owned in 2013 round cannot be compared across other rounds – as it only collected information on whether a household owner a particular machine or not, and not the quantity of the owned machines. AIDIS is conducted over two visits – however data on agricultural machinery is collected in the first visit alone. The surveys were conducted in a two-stage stratified sampling method – with the census villages and urban blocks being the first stage units, and households being the second stage units.

AIDIS 1992 (48^{th} round of NSS): Village selection is based on 1981 Census of India, and is done with probability proportional to population. From each village a total of nine households were surveyed. The sample size consists of central and state samples – central sample is canvassed by NSO, and the state samples by state statistical units. A total of 36,425 households in rural areas, and 20,606 in urban areas were surveyed as part of the central sample. A detailed description of the sampling methodology can be found in NSO (1998).

AIDIS 2019 (77^{th} round of NSS): The selection of the first stage units was done using simple random sampling technique without replacement. A total of 5,940 villages and 3,995 urban blocks were surveyed – corresponding to a total of 69,455 households in rural areas and 47,006 urban households during the first visit. A detailed description can be found in NSO (2021).

Labour Force Surveys

We estimated the micro-data from the labour force surveys of NSO to calculate the number of workers engaged in different sectors. These surveys collect information on the activity status of the respondents – Usual Status and Currently Weekly Status. Usual status is the work status of the respondent during the preceding 365 days. The latter is the work status in the preceding one week of the date of survey. Usual status is further subdivided into principal and subsidiary statuses. Principal status (PS) is the activity in which the respondent spent the most amount of time (>183 days). Subsidiary status (SS) is the activity that the respondent pursues, for more than 30 days in the preceding 365 days, in addition to the principal activity. For estimating the number of workers in a particular we have considered both principal and subsidiary statuses (PS+SS). For instance, if a respondent is working in two different sectors for principal and subsidiary statuses, then the sector corresponding to the principal status was considered. And if a respondent reports only subsidiary activity and not principal activity i.e. if the respondent works in a sector for more than 30 but less than 183 days, then sector corresponding to this activity status was also considered. This is the usual procedure followed in the literature while estimating labour force surveys of NSO (Kannan & Raveendran, 2019; Thomas, 2023). The sampling procedure is two-stage stratified sampling, and is similar to AIDIS.

Employment-Unemployment Survey (EUS) 1993-94 (50th round of NSS): 10 households were sampled from each village or urban block. A total of 6983 villages and 4670 urban blocks were surveyed corresponding to 356,351 and 208,389 individuals in the rural and urban sector respectively. EUS surveys are quinquennial, and were discontinued since 2011-12. They were since replaced with PLFS surveys, which were conducted annually since 2017-18.

Periodic Labour Force Survey (PLFS) 2018-19: A total of 6983 villages and 5737 urban blocks were surveyed corresponding to 239,817 individuals in rural areas, and 180,940 in urban areas

APPENDIX B: SPLICING

To control for the changes in the general price level of agricultural machinery, we deflate the value of machinery using the Wholesale Price Index (WPI) for agricultural machinery and implements. WPI is compiled by the Ministry of Commerce and Industry, and has the index disaggregated for a range of commodities. For deflating the value of machinery calculated as per AIDIS (1992), we need to use the WPI for 1982-83 series. And for AIDIS (2019), we used WPI for 2011-12 series. Since, the indices are from different series, we followed the splicing technique to obtain the index values of 1982-83 series in 2011-12 series, based on the ratio of the values for the overlapping years. Similarly, we followed splicing technique to bring the value of agricultural output in 1993-94 (which is available in 1993-94 prices) into 2011-12 prices. The values of output for 2018-19 is available in 2011-12 prices. The simple splicing technique, that we used, can be summarised as follows (Ministry of Commerce & Industry, n.d):

$$X_{1i} = \frac{X_{1j}}{X_{0j}} \times X_{0i}$$

Where,

'X' represents any variable that we are splicing – either WPI or value of output.
'j' is the overlapping year for the two series.
'i' is the year for which which we would like to splice the values.
'0' and '1' represent the old series and new series respectively.

APPENDIX C

Table C.1: Changes in Mechanisation & Non-Farm Employment between 1993-94 & 2018-19

	CAGR of Machinery Values	**Change in Non-Farm Employment Share**
	(in percent)	(in percent points)
Andhra Pradesh (AP)	5.7	23
Assam (AS)	9.3	33
Bihar (BH)	4.2	30
Gujarat (GJ)	4.9	18
Haryana (HR)	-0.1	30
Karnataka (KA)	3.5	26
Kerala (KL)	0.9	28
Madhya Pradesh (MP)	4.9	18
Maharashtra (MH)	5.7	16
Odisha (OD)	7.2	30
Punjab (PN)	2.9	33
Rajasthan (RJ)	4.4	17
Tamil Nadu (TN)	1.6	26
Uttar Pradesh (UP)	2.9	20
West Bengal (WB)	0.8	16
India	**3.7**	**22**

Source: Own estimations from AIDIS (1992 & 2019), EUS (1993-94) & PLFS (2018-19)

Table C.2: Growth (%) in Agricultural Output (2011-12 Prices), Workers & NSA between 1993-94 & 2018-19

	Value of Output	**Number of Workers**	**NSA**	**GCA**
Andhra Pradesh	78	-37	3	3.0
Assam	40	-31	-2	3.5
Bihar	129	-20	-11	-5.3
Gujarat	123	-18	0	14.6
Haryana	76	-37	2	13.6
Karnataka	79	-35	-1	9.0
Kerala	13	-54	-9	-15.5
Madhya Pradesh	187	-5	1	27.8
Maharashtra	89	-9	-8	-10.6
Orissa	44	-45	-36	-53.6
Punjab	45	-43	-2	3.0
Rajasthan	124	20	10	31.5
Tamil Nadu	24	-57	-22	-20.8
Uttar Pradesh	63	-22	0	9.2
West Bengal	79	-7	-4	14.7
All India	**83**	**-22**	**-2**	5.7

Source: Same as Table 6.5

Table C.3: Gini Coefficient of the Value of Agricultural Machinery & Equipment Owned by Cultivator Households

	AIDIS (1992)	**AIDIS (2019)**
Andhra Pradesh	0.83	0.90
Assam	0.53	0.91
Bihar	0.84	0.88
Gujarat	0.82	0.88
Haryana	0.76	0.81
Karnataka	0.87	0.91
Kerala	0.80	0.74
Madhya Pradesh	0.90	0.88
Maharashtra	0.84	0.86
Orissa	0.77	0.87
Punjab	0.74	0.76
Rajasthan	0.87	0.86
Tamil Nadu	0.83	0.86
Uttar Pradesh	0.85	0.90
West Bengal	0.84	0.81
All India	**0.88**	**0.90**

Source: Own calculations from unit-level data of AIDIS 1992 & 2019

[Note: Cultivator household is defined as one which operated >= 0.002 hectares of land during the preceding 365 days from the survey date]