Women in Agriculture: Gendered impact of mechanisation on labour demand[1]

Executive summary

There has been an exponential increase in tractor adoption in India since the 1990s. This trend of mechanisation in agriculture has been accompanied by a reduction in farm employment in rural areas, particularly for women. When the production process is sequential and the division of labour across complementary tasks is gendered – as is the case in agriculture – technological change can have a differential impact on women's and men's labour. This study shows that a 1 percentage point increase in mechanisation of tilling operations decreases female labour use per hectare by 0.7%. The decline is driven by a significant fall in labour required for weeding – a complementary, downstream operation that is generally undertaken by women – as a result of improved tilling quality. The observed 32 percentage point increase in mechanisation during 1999-2011 can account for 22% of the total 30% overall decline in in women's rural employment in agriculture.

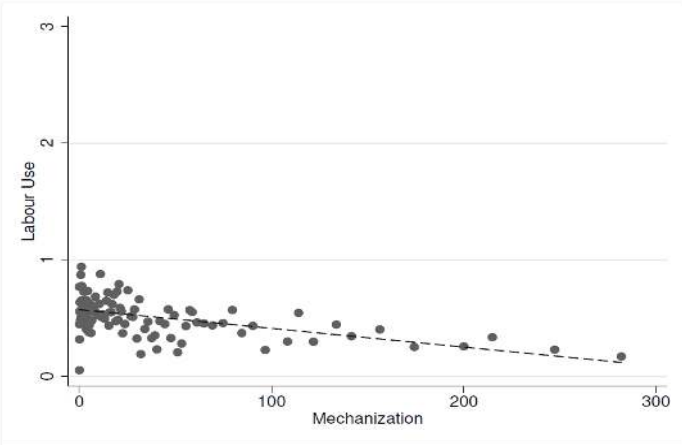
Introduction – context and rationale

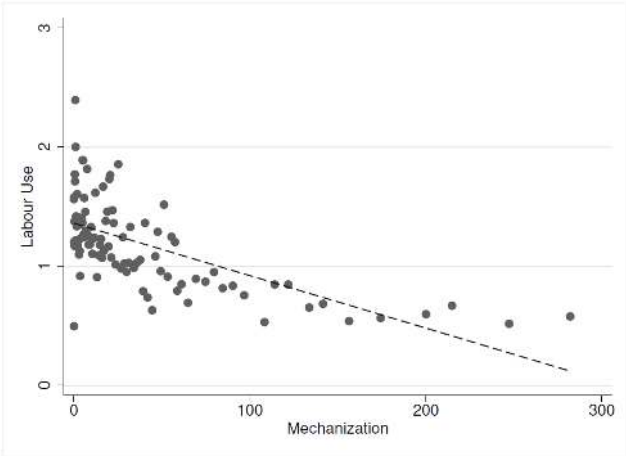
Agricultural technology on Indian farms has undergone a rapid change, with increased machine usage over the last two decades. The adoption of machine tools, often powered by tractors, has been accompanied by a drop in farm employment in rural areas. During 1999-2011, the proportion of working-age adults employed in the rural farm sector has fallen by 11 percentage points (National Sample Survey (NSS), 1999 and 2011). Women have fared worse, with not only a decline in their farm-sector employment but also a steady reduction in their overall labour force participation in rural India over the last three decades (Afridi et al. 2018) – from 49% in 1999 to 41% in 2011 and further to 28% in 2017 (Periodic Labour Force Survey, 2017-18). A large part of this decline has been due to a reduction in women's employment in agriculture, with no commensurate increase in their employment in other sectors in rural India. Around 39% of working-age women were employed in rural farms in 1999 and this fell to 27% in 2011. However, their employment in the construction sector increased from 1% to 5.4% over this period, in the services sector from 3% to 3.5%, while it remained stable at 4% in manufacturing (NSS, 1999 and 2011).

[1] This Policy Brief is based on Afridi et al. (2020), 'Gendering Technological Change: Evidence from Agricultural Mechanisation', Working Paper, August.

Figure 1. Mechanisation and labour use in agriculture

(a) Female labour **(b) Male labour**





There is consensus in the literature that mechanisation in agriculture has often been labour-substituting rather than labour-complementing (Binswanger 1978, De Janvry et al. 1989). However, insights into whether mechanisation affects women's and men's labour differentially, are largely missing. Technological change in general, and mechanisation in particular, in agriculture is unlikely to affect female and male labour equally, since women and men are not only imperfect substitutes but their degree of substitutability with machinery also differs (Boserup 1970, Laufer 1985) in agricultural production. For instance, male labour is more likely to be used for operating machines and also for the residual physically arduous tasks, relative to female labour (Jacoby 1991, Skoufias 1993, Quisumbing 1996). When women perform tasks that require different skills from, and that are complementary to, the tasks typically performed by men, technological change can have disproportionate gender impacts. This study uses data on farm labour and input usage during 1999-2011 in India, to analyse the effect of increase in farm machinery usage on women's and men's labour use in agriculture.

Brief description of the study

Agricultural mechanisation is defined as a process where the source of power changes from simple hand tools and animal draught power to mechanical power. In order to assess the potential channels through which mechanisation can affect labour use in agriculture, it is

important to understand the organisation of the production process, which consists of multiple operations that are performed sequentially (Skoufias 1993). These operations can be broadly classified into three stages: Stage 1 is land preparation through primary and secondary tilling; Stage 2 is sowing and intercultural operations like weeding; and Stage 3 is harvesting and threshing. Given this sequential nature of the production process, there exist complementarities across operations.

Three characteristics of the production process need to be highlighted, since these carry implications for gender differentiated impacts of mechanisation. First, the extent of physical strength vis-à-vis precision or control required to perform an operation, primarily determines the degree of mechanisation of that operation in agricultural production (Norman et al. 1988). The operation that is the most intensive in 'power' or physical strength is primary (or deep) tillage, followed by secondary (or shallow) tillage. Existing evidence thus indicates that Stage 1 operations are typically more likely (and the first) to be mechanised (Pingali 2007). Mechanisation in Stage 1 is often followed by an increased use of machinery in downstream tasks, particularly for Stage 3 harvesting operations. Since Stage 2 operations require less physical strength and more precision, they are usually less likely (or the last) to be mechanised. This pattern of adoption of mechanical technologies has been observed for both developing as well as developed countries. (Binswanger 1986, Pingali and Hossain 1998).

The second relevant feature is that the extent of machine uptake in tilling depends on the depth of required tillage. The tillage depth in turn is affected by loamy versus clayey content of soil in a region (Müller and Schindler 1999). Loamy soils are more amenable to deep tillage (Wildman 1981, Basant 1987), which requires at least 45 cm of soil to be turned over (Dunker et al. 1994). Increasing clay content in soil only allows for secondary tillage, which is less power or strength intensive. Notably, the total power requirement depends on tillage depth and soil resistance, which are inversely related. Historically, and even in current times, men have always prepared land in both deep and shallow tilling areas (Giuliano 2017). But areas with more loamy soil content are more likely to use tilling/ploughing implements due to greater tilling depth requirement (Carranza 2014). The loamy-clayey content of the soil could then also matter to adoption of power-operated machines, especially in tilling.

In general, adoption of machines can either displace or augment labour, depending on the operation for which they are used and their impact on agricultural productivity. This study specifically looks at mechanisation in Stage 1 of the agricultural operations. In the tilling operation, the ploughing machines are driven either by a tractor or a power tiller. It is also likely that usage of ploughing machines for secondary tilling operations is linked to adoption of ploughing machines in primary tilling operations, since the largest fixed cost of mechanisation involves tractor purchase. Increase uptake of machines in tilling can have direct and indirect effects on labour use. The direct effects can occur if labour use in tilling is substituted with the machine. The indirect effects can occur if improved tilling quality due to machine adoption lowers the demand for labour in downstream tasks like sowing, weeding, and harvesting.

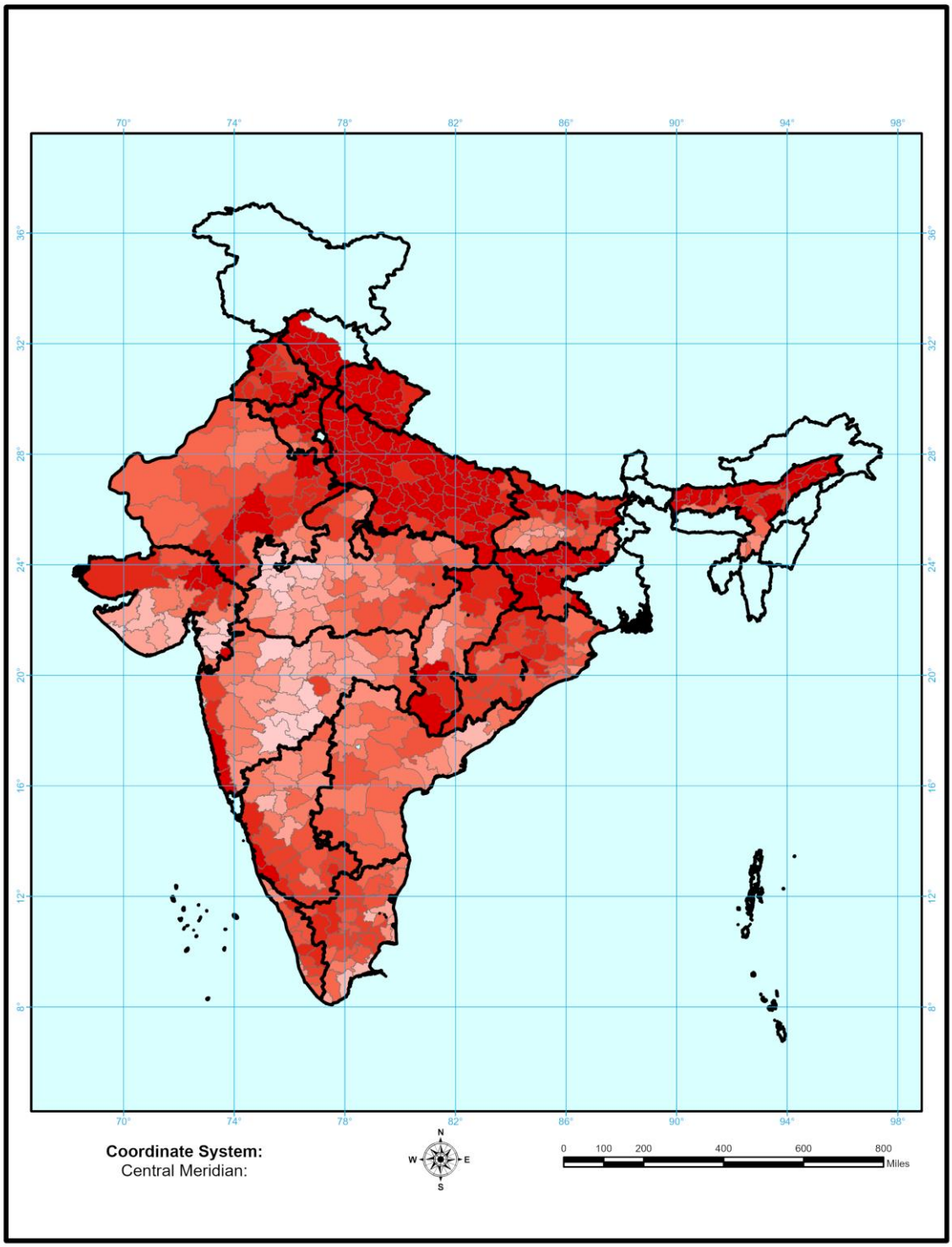
The third and final relevant characteristic is the gendered division of labour in agriculture – women and men perform different but complementary tasks. They are hence, imperfect substitutes. Existing evidence shows that women's labour is less likely to be used in operations that require physical strength, for example, Stage 1 tilling operations, and more likely to be utilised in tasks that require precision, for example, Stage 2 weeding and sowing/transplanting (also in tea cultivation; Qian 2008, Mahajan and Ramaswami 2017). Indeed, operation-level data from NSS show that out of the total labour used in a given task, female labour constituted less than 10% in Stage 1 tilling but over 32% in sowing and weeding in 1999-2011. These data suggest that men are significantly more likely to be used for tilling operations in Indian agriculture, relative to other operations.

The above discussion highlights the potential impact of technology adoption on labour usage, not just in the specific operation that gets mechanised but also in downstream operations due to the complementary nature of production. With greater adoption of power-operated implements in land tilling, a task that requires physical strength and therefore more male vis-à-vis female labour, it is possible that demand for male labour falls. However, to the extent that men's labour is complementary to tillage machines since they are more likely to operate these implements than women, any fall in men's labour usage may be mitigated. On the other hand, if machines improve soil tillage in Stage 1 then less weeding is required in Stage 2, which involves better precision and less physical strength – tasks in which women specialise. It is

therefore, imperative to analyse the impact of technological change on total labour usage as well as by operation.

This study sets up a simple theoretical model to analyse the potential effects of mechanisation on labour usage in agriculture. It uses exogenous variation in the difference between loamy and clayey soil shares in a district, to first show that machine usage in tillage is significantly determined by the extent of soil loaminess (Bigot et al. 1987). It then utilises this predicted, exogenous variation in mechanisation, to analyse its impact on women's and men's labour on the farm.

Figure 2. District-level variation in the difference between loamy and clayey soil shares



Source: Digitised by authors from National Bureau of Soil Survey (1995-1998) maps.

Notes: The districts are clubbed into deciles of differences in share loamy and clayey soil. Darker shades of red denote higher share of loamy soil as compared to clayey soil. The soil maps for West Bengal, the North-Eastern states, and Jammu & Kashmir are unavailable. Some districts of Himachal Pradesh with many missing soil attributes have been dropped from the analysis.

Information over time (1999, 2007, and 2011) and from multiple sources, on farm employment, agriculture inputs, climate and socioeconomic characteristics at the district level in India, is compiled to create a database with 1,083 district-year observations for the analysis.

Major findings

- *The effect of technological change in agriculture production in India is gendered:* A 1 percentage point increase in mechanisation decreases female labour used per hectare by 0.7%. Men's labour also falls by 0.1% per hectare, but insignificantly. Thus, the observed 32 percentage point increase in mechanisation during 1999-2011 led to a 22% reduction in women's labour in agriculture, other things being equal. This accounts for a major proportion of the 30% decline in women's rural employment in agriculture in the country. The *results are robust to a host of controls* for agricultural, demographic, and economic characteristics of a district, including pre-existing labour force participation of women, district-specific trends in employment, and state-level secular trends.
- *The observed decline in women's labour on farms is driven by a significant fall in labour used for weeding*, a complementary operation that follows tilling of land in the agricultural production process. A one unit increase in the intensity of tillage machinery leads to a reduction in women's labour use in weeding by 1%.
- The effect of mechanisation on male labour in tilling is positive relative to weeding, suggesting that *male labour is likely complementary to machines in Stage 1*, while the direction of the impact of machinery on labour use of women in Stage 1 tilling is negative.
- *Higher family incomes due to mechanisation are not driving the reduced use of women's labour:* The analysis by operation suggests that 'income effects', if any, are unlikely to explain the fact that the decline in women's labour is primarily in weeding. Hired labour is not substituting family labour of women, as would be expected when incomes increase. Besides, in line with the existing literature, the research finds mostly

insignificant increases in yields and cropping intensity, weakening any potential income effects due to mechanisation that could be driving the results.

- *Reallocation of female labour across operations due to any improvements in crop productivity cannot explain decline in female labour usage in weeding:* In principle, the total labour use in agriculture may not fall as much if farmers are able to undertake multiple cropping due to increased timeliness of operations after machine uptake or if crop productivity increases due to mechanisation. For instance, if crop productivity increases, labour could be reallocated towards harvesting in Stage 3 from Stages 1 and 2 without any change in overall labour usage. However, it is seen that increased machine uptake increased total male labour by 0.8% but total female labour fell by 2.8%.
- *Technological change can influence income inequality between women and men:* Farm daily wage rates increased for both women and men by around 0.6% for a 1 percentage point increase in mechanisation. Thus, the adoption of machinery, reduced labour use but positively impacted the productivity of hired labour. The rise in wage rates led to a significant increase in male earnings by 3.6%, but for women there was no significant change in wage earnings due to the decline in their labour use or intensity of work. While the earnings impact is only marginally significant, this provides suggestive evidence that the observed fall in labour use of women may have exacerbated extant gender differences in wage earnings.

Policy recommendations

- This study broadens our understanding of the potential reasons for the decline in women's workforce participation in India, a topic of fierce debate but limited consensus, in recent years.
- The Sub-Mission on Agricultural Mechanisation, under the National Mission on Agricultural Extension and Technology, was launched in 2014-15, to promote inclusive growth of farm mechanisation. The budget allocation for the year 2020-21 is Rs. 1,033 crore, of which Rs. 553 crore has been released to state governments, as of August 2020. The findings of the study point towards the need to strengthen the provisions

for women farmers under the Mission, in terms of training in the use of farm machinery.

- There is an increasing trend of female farm-managers in Indian agriculture, and farms managed by women are seen to have lower production and profits, on average, as compared with farms managed by men. Support should be provided to female farm-managers – in the form of finance, information, and logistics – in the adoption of the latest technologies in farming.
- Given the nature of the ongoing Covid-19 pandemic, there is a broad shift towards automation and use of technology, in various sectors of the economy. Accordingly, there may be a push towards greater mechanisation in agriculture. This may particularly be the case in the relatively well-off states such as Punjab and Haryana, which are also facing an overall reduction in labour supply due to the return of migrant workers to their home states. Policy stakeholders ought to be cognizant of the potential gendered impacts that such technological change might have on the use of labour in agriculture, as well as the wage earnings of women vis-à-vis men.

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Within the initiative, four projects are being led by Prof. Farzana Afridi at the Indian Statistical Institute. This research has been conducted under one of the projects.