Assessing Farm Size and Mechanization on Indian Agricultural Yield

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Abstract

This thesis will illustrate the process, and importance of farm mechanization and highlight the potential economic ramifications and benefits to developing nation, in particular the Indian case. Individual states in India present different needs and capabilities working towards the goal of mechanization. National and state level policies and schemes will be assessed as to their level of effectiveness and potential benefits starting with the agriculture sector down to individual farmers.

There is ample literature on the subject of farm mechanization. While it is universally accepted that machinery increases farming output, analytically significant results are sparse. Countries concerned with farm mechanization invariably fall under developing nation status, facing many issues at the national level. India offers a unique opportunity as an emerging economy to provide a blueprint for modernizing their farms, which has potential to be applied to countries on a similar growth path. India, among its developing nations brethren, is in the enviable position of having flourishing sectors of its economy. Comparatively, this allows India greater financial wherewithal, granting them the ability to think in terms of not IF they can modernize and mechanize their agriculture sector, but simply a question of HOW is the best way of going about doing it.

Since the turn of the century the Indian government has recognized the potential of their agriculture sector and has taken on the task of modernization headlong. This study finds that, as expected, there is a positive effect from increased mechanization on agricultural output as a whole. It appears that in the case of India, accounting for other underlying institutional and systematic conditions it is still in the best interests of all Indian states to further promote modernization of their farmers. The benefits of such an effort would have far reaching effects in a country that still relies on its agriculture for a significant portion of its Gross Domestic Product and, in the author's opinion more importantly, the overwhelming portion of the nation's work force that it employs.

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List of Abbreviations

- AACP Agricultural Competitiveness Project
- ACD Agriculture Census Division
- AMPP Agricultural Mechanization Promotion Policy
- ARIASP The Assam Rural Infrastructure and Agricultural Services Project
- CAP Common Agriculture Policy
- CSAM Center for Sustainable Agriculture Mechanization
- DAC Department of Agriculture & Cooperation
- FAO Food and Agriculture Organization
- GDPPC Gross Domestic Product Per Capita
- ICRISAT International Crops Research Institute for the Semi-Arid Tropics
- IFPRI Food Policy Research Institute
- MMA Macro Management of Agriculture
- NCR National Capital Region
- NIC National Informatics Centre
- RKVY Rashtriya Krishi Vikas Yojana
- TFP Total Factor of Productivity
- USDA United States Department of Agriculture
- WTO World Trade Organization

Introduction

"Growing 100 bushels of wheat in 1830 required five acres of land and 300 man hours of labour, same as in biblical times,"

- Howard Dahl, President, Amity Technology

That statement has profound meaning when you think about it. Thousands of years ago, humans had the capabilities to produce as much, and as efficiently as we could as recently as a little less than two hundred years ago. Or from the opposite perspective, until a little less than 200 years ago we were still only as good at farming as humans whose major breakthrough at the time was metal casting. The problem is, for the overwhelming majority of the world's population, agriculture is still a painfully laborious and inefficient process.

The birth of agriculture can be traced back 10,000 to 11,000 years ago, when humankind first stopped being a nomadic peoples and settled down to reliably grow their own food. This could be argued, is the single greatest "invention" for humans ever, comparable with the first tools used and sustaining heavier than air flight. Throughout human history, agriculture advancement has allowed mankind to flourish and overcome adversity. As the saying goes, necessity is the mother of invention, agriculture being no different. No one seeks out progress where none is needed or asked for. Time and time again though, either through famine, growing population, shrinking farmland, mankind has been forced to come through with new and better ways to feed its people.

Agriculture progress can be summarized most easily by three distinct leaps forward. First the invention of agriculture; Second, mechanization which coincided with the European Industrial Revolution¹, which in turn freed up a greater amount of population to pursue other endeavors and allowed cities to flourish and made labor more efficient; Third, what has become known as the "Green Revolution" which has been centered around technological and biological breakthroughs in the plants and animals themselves allowing for greater yields.

While the scope of this thesis is not large enough in scale for the proper consideration into the necessity of agriculture innovation for the continued prosperity and evolution of mankind, it is of the author's opinion that it is a prerequisite for continued growth. Walt Whitman Rostow, an American economist, political theorist, and National Security Advisor during the Lydon Johnson administration theorized about the importance of agriculture to a nations ability to economically develop. He commonly referred to a nations' advancements as "the take-off?" where a nation enters and then continues past industrialization. While other factors can drive progress, agriculture capabilities can be a limiting factor to how far or swiftly they could go¹¹. Other factors, combined with agriculture form a matrix necessary for sustained growth¹¹, Rostow notes that government most likely needed to play an active role in agriculture's piece of the puzzle. Fostering acceptance of innovation from farmers, tempering inability to adjust, either due to stubbornness and unwillingness to adapt or more practical financial reasons which make diffusion of technology difficult was part of a governments obligations to its country. Thus economics and agriculture have given birth to the basic concepts behind this thesis. Globalization and economic policy that may facilitate the growth of developing nations who seek to remove themselves from the middle income trap.

Across the globe, low to medium income countries are seeking ways to modernize their agriculture sector. While much of the developed world is well into and pushing the limits of the Green Revolution, much of the globe is still trying to mechanize their farms. Agricultural institutions, development institutions, national governments, and state and local level governments in lower income countries all acknowledge the need for mechanization. The Food and Agriculture Organization (FAO) of the United Nations, Prime Ministers and Heads of State, down to state and local governments in Asian, African, and South American nations draw attention to their need for catching up in the agriculture sector. To provide their farmers, not only with the tools to adequately feed their people, but, taken a step further, become active on the international markets with their comparative advantages in labor and farm space.

The problems facing developing nations modernizing their agriculture force are not simple ones, and vary widely in complexion and solutions. Certainly western, highly developed nations are far removed from the yield and effort levels illustrated in the opening quote to produce a given amount of food. They are far into the green revolution where the reality is, feeding themselves as nations is hardly the main concern of their individual agriculture sectors. There are inescapable differences between say, United States farms, and Indian farms.

Chapter I: Farms and Mechanization

1.1: World Farming at a Glance

According to an agriculture census of 2012 conducted by the U.S. Department of Agriculture the average American farm size was 434 acres or roughly 175 hectares a farm. Comparatively, India's average farm size is miniscule weighing in at only 1.15 hectares³. Moreover, it is important to point out the trends of these two countries farm sizes, and their country's respective economic order are heading in opposite directions. Farm size in the United States shows no signs of scaling down as more and more farms are being swallowed up by large conglomerates to form super farms. India is indeed trending the other way, with marginal and small size farms making up the lions percentage of farms in the country and more than doubling their number in the last 30 years. Further, if compared to developed nations standards almost all farms in India are "small". The database used in this thesis in fact categorized any farm being over 10 hectares as "large". This might begin to escape from marginal into the "small" category in countries like France, Germany, the U.K. or U.S. as without fail fully developed nations such as those all exhibit a considerably higher average farm size.

Table 1 Number of Operational Holdings & Average Holding Size in India



Number of Operational Holdings and Average Holding Size in India

Source: Fourth Semi-Annual Medium Term Agricultural Outlook Report, September, 2015, NCAER.

This fact alone presents all sorts of challenges to the ultimate goal of agriculture mechanization. The necessary capital to obtain machinery is primary among these concerns. Smaller farm size means smaller income, especially "disposable" income. For most farmers, who are already cash strapped, coming up with the necessary funds to afford machinery, which ultimately would afford them more financial freedom, is nothing but a pipe dream. According to World Bank Statistics, Indian gross national income per capita has made tremendous strides since 2002, jumping from 470 U.S. 2015 dollars, all the way to \$1,590 in 2015.

That is real progress for the world's second most populous country with limitless potential for growth. Still though let us consider for a moment how much farming equipment costs. At one extreme, if one were to go to John Deere's website, one of the world's largest producers of agriculture equipment of all sizes, right now if you felt so inclined, you could build your very own \$900,119 cotton harvester. It would come equipped with among other things self-driving satellite navigation and a heated enclosure if you still felt the need to actually be present as your machine did the work of what used to take an army of laborers and weeks' worth of time. It would achieve this with the ability to simultaneously do the work of what previously took numerous separate machines and processes in conjunction with vast amounts of man hours. However, it is understandable that particular piece of equipment has no bearing on anything close to a typical farm in India. It merely serves the purpose to illustrate the vast difference, capital and scale wise, between fully developed and developing nation's agriculture sectors. There is such a technological and mechanization gap in farming efficiency it can clearly be illustrated by per hectare yields of both the U.S. and India. According to The World Bank's database, in 2001 the United States per hectare yield for wheat was 5890.8 tons which increased to 7638.1 by 2014. In comparison India's was less than half of that, at 2423.1 tons per hectare in 2001 to 2984.1 in 2014. So not only is there a sizable productivity gap to begin with, America saw an impressive 30% increase in its per hectare output in those 13 years, while India saw a 23% increase in their per hectare productivity. They are not closing the gap, but in fact it is growing. For a country who still obtains nearly 14%⁴ of its GDP from agriculture it quickly becomes apparent why increased efficiency in the agriculture sector would be mightily beneficial for them.

1.2: India's Mechanization and Farming Outlook

India's world agriculture outlook is a hodgepodge of statistics and rankings. As far as natural resources that cater to agriculture, India's outlook is very good. It ranks 8th in the world in agriculture land in square kilometers, 2nd in value added even after the fact that it ranks 84th in cereal yield per hectare. If India could move that needle for yield up even marginally to enter the top 50, it would have a significant impact for its 2nd world ranked amount of farm workers. In India this amounts 261 million working in there agriculture sector as of 2008, which was the year all of these statistics were taken from, provided by the online databases Food and Agriculture Organization of the United Nations¹², Nation Master¹³, and CIA World Factbooks¹⁴.

The goals for Indian agricultural modernization and therefore mechanization are more grounded than purchasing a nearly million dollar piece of equipment for every farmer. Much more modest aspirations as far as machines are being pursued. The FAO shows India ranked 75th in the world in tractors per 1000 hectares of farm land at 2.38. This is despite the fact that they also report India possessing the 2nd most tractors in the world at 2.53 million tractors. With one third of world's tractor production in India⁷ it has become a pure numbers game of tractors versus population for the world's second most populace nation to supply its farmers sufficiently.

If we once again visit John Deere's website and look for more obtainable pieces of machinery we come across their smallest tractor at a mere 22.4 horsepower, compared with the 450 horsepower provided by the 900 thousand dollar piece of equipment highlighted earlier. This tractor can be obtained for pennies on the dollar at only \$12,000. One might think that's a reasonable amount for something that can provide a farm with invaluable increased capabilities, and you would be correct. In a more capitalistic developed society that is would be the case. At 7.5 times the average Indian's salary a loan is almost certainly still required to make such a crucial investment. Therein lies the problem, loan acquirement is not as easily achieved for an Indian farmer as for your typical American who shows a propensity for good farming, walks into a bank and asks for a loan.

Despite the difficulties his country faces the Union Minister of Agriculture in India, Radha Mohan Singh, speaking in June of 2016 at a conference on "Innovations in Agricultural Mechanization - Development of linkage among R&D Institutes - Industry – Farmers" highlighted the fact he wanted his country to become further modernized in agriculture and was constantly working on making machinery available to his farmers. Plans are being explored and implemented to further encourage farmers and manufacturers working together to increase farmer income and yield of the ample land available for farming present in India.² Table 2 Availability of Farm Power Different Resources



Availability of Farm Power different resources 1971-72 to 2012-13 (in percentage)

Source: CR Mehta et al, Project Coordinator, FIM, CIAE, Bhopal, Trends of Agricultural Mechanization in India CSAM Policy Brief, June 2014.

Chapter 2: India, State Wise Conditions

2.1: Geographical and Environmental Conditions

To better understand individual state outcomes from the data it is useful to at minimum be aware of the inherent differences in their agriculture outlook. This will be useful to bear in mind while using a fixed effect model later in this paper. India consists of 29 states and 7 more union territories, the difference being, the union territories are controlled and governed by the central government directly whereas the states have their own central government. For this thesis the author has used the same sources to establish prevailing agriculture conditions from which the variable data was obtained for the best possible reflection of from one to another.



Illustration 1 Map of India Representing Ecological Regions and Production Systems

Agro-ecological regions and production systems. (Source: PME Note 6, ICAR)

In the maps above in illustration 1 the different agricultural environments present in India are illustrated ranging from the hilly and mountainous dominated north-eastern border defined by their proximity to the Himalayan mountains, to the lush, almost tropical settings of the coast line that stretch from Bangladesh all the way around and up to the North-West desert like conditions bordering Pakistan to the Indian interior which is a vast expanse of plains and flat lands mixed with jungle like conditions. One further key condition to note is the presence of irrigation or not which is a telling influential factor for agriculture production. To expand on the illustration on the left, to the right we can see the main production present in each of the environments. They typically reflect what one might expect would be the strength of the local eco system, fruiting type agriculture dominating more tropical wet eco-systems, more resilient grains prospering in the interior where little is needed for their success, and more specialty type outputs representing smaller portions of the overall land that require special growing conditions.

It is fair to assume that the effects and benefits of input variables in agriculture are at the mercy of existing conditions much the same as the true value of a million dollar fishing boat is predicated on whether it is put in a pond in the middle of the desert or put in an ocean teeming with ocean life. In this way it shall be taken into account during this analysis the prevailing ecosystems of each state under question. While some states are dominated by their proximity to the Himalayas, other are defined by their more tropical settings near the coast, and yet others still are completely plain and landlocked, themselves affected by whether or not they have access to irrigation or are rain water fed.



Illustration 2 India State Map

These factors all go a long way to determining a particular states agricultural productivity, efficiency, and efficacy to agriculture in the first place. More importantly and specifically to this thesis the predisposition of a particular state allocating resources (capital and otherwise) to furthering their agriculture sector. A broad picture is offered from illustrations 1 & 2 as to which geographically differing areas might lend themselves better or worse to agricultural development more or less so than others.

Categorization of states will be kept to the five present on the map for simplicity sake and to keep uniform with the numerical analysis that will come later which will be completed for the 17 states that full data was available for the three years under study.

Starting in the North-West and moving clockwise Gujarat and Rajasthan are mostly arid environments whose major production is millet and other fodder type grains that are resilient and easy to grow. Moving east towards the mountains are Himachal Pradesh, Uttar Pradesh, Assam, West Bengal which sees most of their production come in the form of rice, maize or wheat which can usually flourish in the hilly wet conditions present where clouds tend to dump all of their water before they attempt to rise above the Himalayas¹. Andhra Pradesh and Jharkhand both directly benefit from the Himalayas being their neighbors in the form of easy access to the run-off water as a byproduct from the wet conditions. As well, most of the Indian interior is heavily dependent on rain water, with the rainy season determining much of how yearly harvests go as far as output.

¹ Because of this phenomenon, a desert is on the other side of the great mountain range as water is to heavy to make it over.

Illustration 3 India's Regional Mechanization Levels



India relative development of mechanisation Source: State of Indian Agriculture, Department of Agriculture report, 2012-13 ** Based on relative scale of farm power availability as shown in the report

We see a nice line running from Central-North to South-East of what can be summarized as economically prosperous states which in turn leads to greater irrigation in the three states of Haryana, Punjab, and Uttar Pradesh. Not only does most of this region constitute a good financial situations for most, it also sees an abundance of rivers which makes irrigation more viable. Kerala, Karnataka, Orissa, and Tamil Nadu represent the lion's share of agriculture output associated with costal environments. Madhya Pradesh, Chattishgarh and most of Maharashtra, which also extends to the coast constitute India's "bread basket" heart land, forming much of the countries interior.



Figure 1 Proportion of Land in Climate Type & Climate Type by Main Produce

Left: Distribution of area by environment type. Right: Distribution of crop type in each environment.

2.2: Farm Size

As highlighted when comparing the worlds' farms to India's, farm size is quite diminutive in India. Two of the states under study, West Bengal and Kerala, have over 75% of their farm land locked up in farms under 2 hectares. So, despite its 5.3 million hectares of land, and the fact that India has grown into one of the worlds' preeminent manufactures of tractors, it has to distribute those tractors over an inconceivable number of farms. West Bengal and Kerala alone have more than 11 million farms to account for. Given the large number of farms that was calculated it was judiciously deliberated upon whether or not errors had taken place calculating the total number of farms in India, for, as it stands the data shows 342,322,985 farms. To put that into perspective, that's roughly one farm per citizen of the United States, and no it does not appear an error was made, if anything there are most likely MORE farms.





The chart above reflects year over year change of the total farmland area represented by small farms against that state's yearly average yield per hectare. Some insight was sought to try and better gauge whether smaller farms or larger farms see better yields per hectare of farmland. This can be parlayed into whether it is important that governments promote access to mechanization to smaller farms swiftly to further exploit the abundance of small farms in India or to try to consolidate farms into larger ones potentially making them more productive. More data is required to know for a mathematical certainty whether the impact of farm size is significant. From the limited data alone, it appears as though, for many states increased smaller farm percentage did still allow for growth in yield. While this is slightly surprising to the author, if it holds true, it does allow for states to not have to change the infrastructure of their farming systems YET for as it stands positive changes to output would not be facing much hindrance from farm size alone. As shown from the chart, at least half of the states in question exhibited yield growth even with their small farm size percent increasing.





Above is the trend line superimposed upon the previous graph. From this simple trend line we can begin to see how farm sizes might affect the output for a given state. With such a small number of observations this might not be sufficient to make a conclusion though, as the trend line above could easily be swayed one way or another with the inclusion of any number of states that was missing data². If the two outwardly appearing outliers are removed, the trend line sign is reversed to slightly positive. Given so many states were omitted due to lack of sufficient data, it was decided to keep them. As we do not know where the other states would lie, it would be superfluous to remove these two as it stands.

 $^{^{2}}$ The idea was played with to exclude what appeared to be two outlier states in the top left of that graph, but as many states were missing to begin with, those two states could in fact be in an acceptable range of values when the nearly 20 excluded states can be considered.

2.3: Policy and Government Roll

Much like the United States, different states put different emphasis on their agriculture, even though nationally, agriculture is an economic driving force there still are differences present between each states policy and attitude much like you would expect importance of agriculture to be different from Kansas to Louisiana. While the national government has taken a more active role in the last decade or two, much has still been left to be determined at the state level.

Maharashtra, which has the 2nd largest state population in this thesis, at 112 million inhabitants, and subsequently the 2nd highest GDP Per Capita as well, has been a leader in attempting to mechanize its farmers. The Macro Management of Agriculture (MMA) scheme was introduced at the national level in 2000-2001, with Maharashtra quickly adapting the scheme, which among its 17 components, farm mechanization is emphasized. Despite Maharashtra's economic prosperity, it's per hectare output remains quite low, even to Indian standards. Since 2001 for every year under study, they did not post a per-hectare yield in the top 50th percentile of states which seems extraordinary considering their economic outlook. A couple theories persist in explaining this and chief among them is the fact that irrigation levels are quite poor for the state. According to state by state evaluation of the MMA, Maharashtra only had 18% of its crop land irrigated against the national average of 42%¹⁹. While the state put considerable funds into developing its irrigation system it also targeted mechanization as well with the newly appointed national funds. Implementation had humble starting goals when the scheme was introduced in 2001. Of \$344,004 earmarked for farmer's subsidies and mechanization promotion only \$310 which ever made it to farmers. By 2007, goals became loftier, with a target amount of \$1,518,579, which was actually exceeded with close to \$1.55 million being dispersed.

While certainly causality is not being claimed from this one statistic alone, there was a 5 fold increase of machine power available to farmers from the year 2006 to 2011 in Maharashtra. This was accompanied by a 15% increased total of agriculture output, and an even better 17% jump in per hectare production. With the third best improvement over the 2001-11' decade among studied states and compared to the national average per hectare growth of only slightly more than 4% the outlook for Maharashtra is quite healthy moving forward.

Assam represents a conditionally different perspective from Maharashtra, as it has no Mumbai type world market scale city providing it considerable access to capital and wealth. Among the states in this study, Assam represented the 2nd lowest Gross Domestic Product Per Capita (GDP_{PC}) in 2011 at \$578 and in a statistical coincidence it also constituted the 2nd lowest GDP_{PC} growth over the 10 year span of 2001-2011. Assam's farmers mainly consist of subsistence farming, have very little connection with bigger picture markets, have little to no credit options, and are facing very low levels of mechanization, fertilizer usage, and once again irrigation.

Despite these adverse conditions Assam's government has aggressively pursued advancing its agriculture sector. Two projects were initiated in the hopes of doing just that, first The Assam Rural Infrastructure and Agricultural Services Project (ARIASP) was introduced in 1995 and then in 2004 the Agricultural Competitiveness Project (AACP) which both received heavy funding from the World Bank. The ARIASP's impact on mechanization came in the form of direct machine contributions to the poorest segments of farmers in Assam. 554 tractors, 1500 power tillers, and 300 power threshers were provided²⁰ under the project's name as well as attempts to establish training centers for farmers to come and educate themselves on the most efficient manner in which to utilize the machines.

West Bengal represents the biggest jump in machine power available per hectare of farmland at almost 4 times the availability from 2001 to 2011. Along with Karnataka, and Madhya Pradesh which exhibited machine availability growth upwards of 3 times and to a lesser extent Orissa at 2.5 (though from 01'-06' it was marginal at best and displayed a meteoric rise in the second half of the decade) the lessons of how these states went about increasing their mechanized portion of farming power is of particular curiosity. In 2007 the Rashtriya Krishi Vikas Yojana (RKVY) was launched as a national scheme whose purpose was to significantly improve the productivity of the nation's agriculture sector. Under this umbrella scheme, West Bengal has sought to increase its pre-2007 farm power from 1.2kW/ Ha²¹ to 3.0kW/ Ha by 2020 ³. Nabard Consultancy Services PVT LTD estimates large percentages of cost savings to be had with further mechanization in West Bengal. With their original mechanization levels pretty low from a 2001 starting point, outside the top 50th percentile of states under consideration, to top 3 by 2011. The projected savings between a process done by manual labor versus the same process mechanized amounts are below. These savings extrapolated over West Bengal's 5.3 million farms would be nothing to sneeze at.

Table 3 Potential Savings Value	's Through Mechanized	Vs Indigenous	Farming
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Particulars	Indigenous farming	Mechanized farming	% of Cost Saving	
Land Preparation	1800	675	62.5	
Transplanting of seedling	1700	569	66.5	
Harvesting	1000	665	33.5	
Threshing	750	600	20	
Total	5250	2509	47.8	

West Bengal has been on the leading edge of implementing what they refer to as a "Farm Machinery Hub". Recognizing the fact machine ownership was highly unlikely for the majority of farmers due to their relative size and income as touched on before. These Farm Machinery Hub's function is to act as a rental service for the farmers of each district. West Bengal set up one for each district in its state, 9 of which received 8 Lakh (\$12,400) in 09'-10', 10 receiving 16 Lakh, 6 receiving 24 Lakh and 4 receiving 32 Lakh totaling 232 Lakh or \$348,000²¹. This is a healthy beginning for West Bengal, but such a small monetary commitment stretched out over the number of farmers they have is just that, a beginning. With such savings potential possible it is hard to argue against further investment for a state (and nation) for whom their people rely so

³ Not to be confused with number of machines available which is the primary variable used in this thesis which does not take into consideration power outputs of individual machines, West Bengals measurement here is accounting for differences between tractors sizes based on Horsepower, tillers, combines etc. etc.

heavily on agriculture not only for the primary monetary creator but still very much as the only source of food as their connection to outside markets is limited.

Haryana represents one of the wealthiest states in India according to their GDP_{PC}, ranking 2nd, 1st, and 3rd in the years 2011, 2006, and 2001 respectively. It is also near the bottom of the list of states in size with only 4.4 million hectares of land weighing in at a whopping 1.3%²³ of the country's overall total land area. With its diminutive size it still commits 80% of that land to cultivation, and 84%²³ of that is irrigated. Despite its apparent capital wealth and commitment to agriculture through its high irrigation rates, it does not rank especially high on tractors per hectare indexes, with states Tamil Nadu, and Uttar Pradesh easily outpacing it in that category⁴. Haryana continues its conundrum of statistical combinations, it was the fastest state in India to obtain food self-sufficiency from its inception in 1996 and has since become the second biggest contributor to India's food stocks²³.

Haryana is worried about their declining productivity as they are facing issues with over fertilization which is contributing to a growing soil nutrient deficiency, and water tables being adversely affected as they drill more and more wells to spread irrigation. They have acknowledged these facts and have sought remedies through infrastructure reforms coupled with government assistance on natural resource management. They make note of their ample access to larger markets with their proximity to the National Capital Region (NCR) as additional incentive to increase productivity.

Chapter 3: Literature Review

While not exactly "literature" some personal connections were utilized for insight into modern farming, concerning medium to large⁵ scale farming in the state of North Carolina in the U.S. The owner and founder

⁴ Tamil Nadu did experience an uncharacteristic rise in GDPPC during the timeframe under consideration which could explain some of the discrepancy, but Uttar Pradesh's GDPPC was less than a 3rd of Haryana's and it had nearly double the tractors per hectare as Haryana.

⁵ Medium to large on the developed aka. much larger than Indian scale.

of A New Leaf Landscaping & Nursery explained a piece of equipment called a "grain drill". This relatively simple machine is fed by a hopper full of seed, as the machine goes along, it completes multiple tasks at once; it plows rows equidistance apart to a predetermined depth suited to the seed; it then drops seed into the plowed lane; and as it passes, it then covers up the lane with dirt and the planting process is finished. Efficient, waste reducing and time saving. These machines come in varying degrees of complexity and sophistication capable of tackling small fields to giant machines with air-conditioned cabins that can cover fields as far as the eye can see motoring along at speeds of 6/10mph. Now compare this process to how one might imagine it is done on a typical Chinese farm, as an army of laborers marched, hunched over a patty field with a sack of seeds slung over their back reaching into the water and carefully place one seed at a time or if speed was sought, a device that spun a horizontal wheel and allowed seed to drop down on to it, in the process slinging seed in every which direction⁶. Neither of which are ideal for timeliness or efficient use of agri-inputs. Germination rates for "spreaders" and labor time for hand planted fields are horribly inefficient compared to their mechanized brethren.

From the above illustration, with such capability differences to something so essential to life such as farming one can imagine there is much literature on the topic of agriculture mechanization. With China attributing an estimated 9%⁵ of its 2016 GDP to agriculture, which is upwards of 11 trillion dollars⁵, and as previously mentioned, India attributing 14% of its 2 trillion dollar GDP figure, there is plenty of economic incentive to try and make these sectors as beneficial to their immense populations as possible. The fact that China and India are developing nations, with burgeoning modernization of their respective agricultures sectors foresees a lot of growing pains. The necessity to swiftly and effectively arm their farmers with tools to better do their jobs is paramount.

⁶ This creates much waste as the seeds are not properly "planted" into the ground and therefore this type of planting can typically expect to see 40-50% of spread seeds wasted.

One of the most common methods used to measure agriculture output will be familiar to economists, Total Factor of Productivity (TFP).

"The substantial literature that decomposes TFP and analyzes its sources (Evenson

[1993] reviewed more than 78 such studies) shows that the TFP, as a residual, cannot be considered to be simple technical or technological change. It is produced by changes in infrastructure, skills, and institutions as well as technology."

- Evenson, Pray, Rosengrant (1999)9

While it would be nice and self-containing for the purposes of studies and research such as this thesis to attribute all changes in TFP to the variable under scrutiny, tractor per hectare, in the real world that does not hold much water. It is good to bear in mind other factors much like any other real world assessment. As far as agriculture output, there is a plethora of mitigating factors other than increased machine usage that can have a negative or positive impact. Agriculture especially is susceptible to varying outside influences, besides common ones such as changes in education, liberalization of markets, capital access etc. you have more basic, fundamental things like the weather, water levels, prevailing local environments that can vastly differ across a nation as large as India.

With some institutions' predictions on global food needs doubling by 2015(GHI 2011), and the added and ever looming issue of sustainability which was not present in previous centuries to the degree it is now, the issue of increasing the world's and individual nations agricultural TFP has once again taken center stage. There is little debate about whether or not machines or mechanical advantages ease the human work load and increase productivity. That is like asking did the wheel allow humans to travel faster, does the computer allow us to tackle infinitely more complex tasks every day.

Figure 4 Total Factor Productivity



Source: Mitchell, C.C, et al. 1996. The Old Rotation, 1896 - 1996. Alabama Agricultural Experiment Station. http://www.aaes.auburn.edu/comm/pubs/specialreports/old_rotation.pdf

The chart above shows the TFP for cotton in the U.S. south. The large jump is clearly visible from 1950 to the early 60's. This directly coincides with a few key historical developments in agriculture. Firstly, WWII had pillaged a lot of the labor force around the globe, specifically 21% of the rural black population went elsewhere between 1940 and 1950¹⁰ much of which historically represented farm labor. Necessity being the mother of invention, this loss of labor spurred on the research and development of tools that might replace such a drop. In the end the labor loss was turned into a large jump in TFP in the realization of the cotton combine. In the span of a decade the U.S. went from 125 man hours needed to produce one acre of cotton to a mere 25 man hours¹⁰. During the same time frame many other plants, fruits, and vegetables saw their processes mechanized, most of which were born of similar necessary circumstances due to labor shortages in the United States rural south, with tobacco and tomato harvesting seeing similar man hour requirements slashed. Farm mechanization increases efficiency in many different aspects, it saves time and labor, cuts costs, reduces losses, and props up total output and farmer income in the long run⁶.

In 2014 the Center for Sustainable Agriculture Mechanization (CSAM) wrote a policy brief on Trends of Agricultural Mechanization in India, they claim a very high correlation between food grain productivity and farm power availability. With r^2 = .986 measuring every decade from 1950 up until 2010, there does indeed appear to be a strong correlation.



Figure 5 Farm Power & Productivity

Trend of farm power and agricultural productivity from 1951 to 2012

Source: CSAM Policy Brief, June 2014

Unfortunately, for this literature it was not clear how they ran their regression as the brief offered no further information as to their methodology. While the chart does appear promising, the mere fact both productivity and available farm power increased over the last 60 years is not conclusive nor does it suggest causality (without further methodology explanation). From the standpoint of lobbying for more machinery, the fact that the farm power line is concave upwards is a good thing and shows promise for the increased availability of machinery across the country moving forward.

An abundance of case studies offer their input on farm mechanization from many African countries trying to better its economic standing. Just as there are differences between India and more developed nations, there exist differences between African country's agriculture outlook and India's. Nonetheless it may prove useful to observe the arguments and results that have been put forth. While the issue of labor marginalization for agriculture workers in India is present, it is much more pronounced in Africa, and for this fact mechanization in Africa has remained a hot button issue. It has been the topic of debate for engineers, economists, agriculturalists, and politicians alike¹⁵. As poor a condition capital obtainment is for the average Indian farmer, it is a practical non-thought for the average African farmer to obtain a loan for a piece of farming equipment. Instead Africa's attempt at raising their TFP has been concentrated more on divisible inputs like fertilizer, seed varieties, and chemicals. One can always buy more or less of seeds or spray, but dividing the cost of a singular physical input like a plow is more difficult.

Still though the African farming situation does allow us some useful mirrors to compare, similar farm sizes, similar capital access problems, these lead to an exaggerated version of Indian conditions. As was discussed previously, it is likely that government will need to play a somewhat active role to promote mechanization. Whereas developed nations had time to mature their mechanical sector, and had comparatively much better economic situations than their developing counterparts, African and Asian developing nations are not afforded the luxury of allowing markets, specifically the private markets, to develop and fill the need in their own due course¹⁵. A key factor in Africa's case is their current inability to manufacture these mechanical inputs themselves, ironically, a large portion of their mechanical inputs are imported from India (and China)¹⁶. It is the simple matter of developing a nation's agriculture sectors sizes have outpaced their ability to mechanize. Population growth is a matter of fact, technological progress faces a multitude of hurdles for developing nations.

A very pointed and specific study was conducted as to the impact on production and employment in Indonesia. A recurring theme that keeps cropping up is that some developing nations while admitting they would like to see their agriculture sectors more productive and prosperous are concerned with employment being negatively affected. This seems to be an especially emphasized topic in this study. They do go on however to point out that on average, mechanized farms in their area of study of West Java were 3 times larger than their non-mechanized counterparts and still required less labor¹⁷. Here the farmers were actually facing labor shortages during peak season, as a result turning to mechanization for the answer. This was usually closely followed by enlarging their farm size due to permanently increased access to working power as the tractors were always available versus seasonal workers. While claiming inconclusive results for the "isolated" effects of mechanization, they were confident enough in their analysis to vehemently say mechanized farms obtained higher yields, with less labor, less pesticides, and were considerably larger. Only to cover their analysis by saying the cause of the increased yield is just as likely to be attributable to any other input as to mechanization.

The International Food Policy Research Institute (IFPRI) wrote a discussion paper December of 2016 on effects of mechanization on small farm holders in Nepal. Their focus was on Terai zone of Nepal which saw custom-hiring of tractors go from 10% 20 years ago to 50% as recently as 2010. Much like most developing nations, Nepal's average farm size was low, around .5 hectares so similar tractor procurement problems were faced by the average farmer here as in India. The study was assessing the different impacts of increased mechanization availability on small verse larger farms. Finding that accounting for previously neglected specialization in off-farm activities for smaller farms, the benefits of mechanization were comparable to those of larger farms.

From 1995 onwards, Nepal introduced a litany of programs and policies to promote agriculture competitiveness, with a few of these specifically targeting mechanization. The Nepalese government appears to have been doing their due diligence to bring their country up to speed, creating agriculture engineering units in the 50's, agriculture research councils that test and develop machinery for Nepal's specific needs, and national training programs have been developed to try and better educate their farmers. A major hindrance Nepal faces for these policies has been lack of adequate funding¹⁸.

With this in mind, the Government of Nepal enacted the Agricultural Mechanization Promotion Policy (AMPP) in 2014 with the stated goals of undertaking research, adopting, developing use, expansion, and promotion of agricultural machinery and equipment for increasing productivity in the agricultural sector and for making the sector sustainable and competitive. Their study revealed some interesting and surprising results. Small farm owners who transitioned from manual cultivation to mechanical cultivation, through custom cultivator renting schemes, saw their per capita income increase by 13%¹⁸. While that is not necessarily surprising, the same regression run for medium size farms saw nearly identical per capita income increases. For study conductors, this was proof enough that it is just as beneficial to promote mechanization to smaller farms as it was larger ones, one result that the author of this thesis hopes to mimic or replicate.

Politics it appears, and bureaucratic red tape are always a concern when trying to develop a nation's strategy and therefore implementing policy changes to positively affect the bottom line. In Africa this rings particularly true for thin skinned politicians who do not appreciate infringements upon their self-perceived worth^{15(page 17)}. So not only do national policies or better yet strategies, that politicians are presented with so that they may form THEIR policies, need to be affective and financially viable, they need to pander to the politicians who hold their potential success or failure in their hands.

The FAO has developed a chronological course of action to create what one would hope will ultimately become a part of a nationally established institution. State objectives, define goals, establish targets, develop policies, initialize a strategy, build the program, and create specific projects. With strategies, programs, and projects usually being left to state level government branches better capable of more catering to localized conditions, the rest being procured at the national level so as to set a common goal.

Chapter 4: Data

3.1: Dependent Variables

The main focus of this thesis is agricultural output per hectare of farmland present in each state of India. An aggregate calculation of all output was made from data sets produced by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) hosted on Village Dynamics in South Asia's website²². These data files gave an in depth every fifth year break down dating back as far as 1966 for some states for their agricultural production profile. These files showed what and how much each state under study was producing, as for this analysis it was not deemed important the individual products as the overall goal is to improve production regardless of the product. These were then mated with statistics on total farmland in hectares which were provided by the Department of Agriculture & Cooperation (DAC), Agriculture Census Division (ACD), in cooperation with the National Informatics Centre (NIC). The resulting dependent variable is then presented in ton of agriculture production per hectare of arable land over the years 2001, 2006, and 2011 for 15 complete state statistics and 2 more partial ones.

3.2: Independent Variables

The independent variables consist of one agri-input and one hypothesized determinant of agricultural output. The first, machine power available to farmers was the summation of the number of power tillers, tractors, and combines regardless of horsepower or size present in each state at the time of the surveys in 01', 06', and 11'. The second was farm size, originally separated into 5 size categories, this was later reduced to small⁷, medium⁸, and large⁹.

⁷ Smaller than two hectares.

⁸ Between two and ten hectares.

⁹ Larger than ten hectares.

Machine power, or tractors_per_hectare, this thesis theorizes, is a key component to developing nations elevating their agriculture sector to compete on the global scale. Without it, these nations are at a distinct disadvantage production capacity wise, it is the attempt of this paper to ascertain, within the nation of India to what degree does mechanization affect productivity. Fortunately there was ample, whole data sets regarding machines available at not only the state level, but it had been sorted into farm size as well.

For developing nations, farm sizes tend to be small compared to developed nations. This directly and materially affects the ability of farmers to acquire machinery, and sparked, the idea of how the spread of machinery across different farm sizes affects efficiency. A question born from this study was, how a governing body makes machinery available to so many small individual holdings. And further down this line of thinking, would it be more prudent for governments to promote larger farms as they appear to be more efficient in their machine usage or can small farms, armed with machinery become as efficient.

Thus, farm size was dissected and taken into account in the regressions run to determine their effect on a state's agriculture output if any. Of particular interest was to seek out and find any trends being projected on output from a state's relative growth or decline of smaller farms and if putting an emphasis on larger farms receiving machinery over smaller farms was a prudent plan moving forward. Number of farms in each size bracket, percent of total number of farms in each size bracket, and percent of farm land represented by each size bracket were taken into account. A state could have vastly differing numbers in each category. Larger farms being present would almost certainly not sway the total number of farms in their favor, but it could drastically reduce the percentage of farmland allocated to smaller farms.

We will take Jharkhand as a prime example, in 2011, small farms made up more than 84% of total number of farms in the state. With the average right around 80% this is a pretty unremarkable statistic, what does stand out though, Jharkhand has the largest difference between percent of total farms that are small, and total farming area that is attributed to small farms. Only 42% of all farmland in Jharkhand is locked up in small

farms, that's easily the biggest discrepancy between those two percentages, at 41%. That's a quarter higher than the national 30% average difference between total farms and farm area in small farms. Unfortunately Jharkhand had only one year of usable data and these noteworthy statistics were not able to be expanded upon much further.

3.3: Control Variables

The control variable that was accounted for was Gross Domestic Product Per Capita (GDPPC). In an attempt to account for underlying differences from one state to another's ability to procure funding for their respective farmers. States individual GDP's and population numbers were taken from India's state census site²³. This is included in the analysis with the thinking being, wealthier states could and should better support their farmers. This in fact should be reflected in the future even further by reinvesting its increased returns and savings back into the agriculture sector.

Chapter 5: Methodology, Limitations, & Results

5.1 Methodology

The quantifiable effects of farm mechanization on agricultural output should be better evaluated, in India's case, as well as the majority of developing countries, it should also be determined whether or not the prevailing small farm sizes will be an obstacle to overcome the goal of more efficient use of inputs resulting in higher output. In order to achieve this Stata was utilized to capture the interactions between the variables previously described from multiple perspectives. A combination of regressions were run between OLS and Fixed-Effect models with varying inclusion or exclusion of variables at the disposal of this thesis. The combination of regressions were run on 17 states, 15 with 3 years, 1 with 2 years, and 1 with 1 years' worth of data.

5.2 Results

First we will take a look at the OLS model. This iteration has output per hectare as the dependent variable against tractors per hectare, percent of tractors in small farms versus medium or large farms, the interaction term between those two, GDPPC, and the percent of total farmland attributed to small farms.

Figure 6 OLS Output / Trac	ctors
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F(7, 39) =	4.98
Model 3014642.01 7 430663.145 Prob > F =	0.0004
Residual 3374484.06 39 86525.2324 R-squared =	0.4718
Adj R-squared =	0.3770
Total 6389126.08 46 138894.045 Root MSE =	294.15

output_per_hec	Coef.	Std. Err.	t	₽> t	[95% Conf.	Interval]
tractors_per_hec	3325.798	863.4483	3.85	0.000	1579.309	5072.287
percent_trac_in_small	-657.9209	565.6967	-1.16	0.252	-1802.15	486.3085
int_tr_per_h_pc_trac_in_small	-3321.102	1067.574	-3.11	0.003	-5480.474	-1161.73
gdppc	.0240398	.1531872	0.16	0.876	2858106	.3338902
percent_area_small	943.4004	428.7749	2.20	0.034	76.12123	1810.68
year						
2006	12.44266	115.2744	0.11	0.915	-220.7219	245.6072
2011	-84.03265	155.7367	-0.54	0.593	-399.0399	230.9746
_cons	328.0519	295.9773	1.11	0.274	-270.6187	926.7224

Some key take aways from the OLS model above. The two variables offering good significance is a welcome sight, even with limited observations we can count on those two for some trustworthy accuracy. The first three variables should also be viewed and analyzed as an interacting group. To determine their true meaning some calculation were needed. Beginning with tractors_per_hectare, we would like to isolate its effects by taking its derivative thus we have:

tractorsperhec - inttrperhpctracinsmall * average value of percenttracinsmall

3325 - 3321 * .66

= 1134

This is interpreted in such a way, that if the proportion of tractors in small farms to medium/large farms is kept constant, and we increased the number of tractors per hectare by 1 we would expect to see an increased vield of 1,134 tons per hectare. This is an extreme case, for as it stands our "best" tractor per hectare

rating is not quite 1.1, adding 1 would double our best case state, and multiply our worst case state's tractor availability by a factor of 9.

Adding 1 tractor per hectare would be a monumental undertaking for a country with such a large amount of farm land. Instead let us transform those numbers to something more reasonable, a potential target for policy makers perhaps. Keeping to more realistic figures, the average difference for the 17 states, from 1 five year period to the next came out to a positive growth rate of .13 tractors added per hectare. Keeping to that figure and as the idea is to grow more than has been exhibited, let us hope for .15 tractor growth per hectare. This scenario would return an expected 170 additional tons per hectare in agricultural output.

Now the flipside of this regression is as follows. If instead we are interested in determining the effects of keeping the number of total of tractors the same, but moving them from medium/large to small or small to medium/large we would use the same technique but instead isolate this time for percent_trac_in_small. The same principle is applied, $-657 - (3321^*.31^{10}) = -1,686$.

So hypothetically, if the total number of tractors in the state in question remains the same, and you start with every tractor in the state on large farms then take every tractor and put them on small farms, you could expect that states per hectare agricultural yield to decrease by 1,686 tons¹¹.

A more realistic scenario, you have a certain percentage of tractors on large and small farms. You then increase the percent of tractors on small farms by 10% (thereby removing them from large farms, as number of total tractors has to remain the same). In this 10% tractor relocation scenario we would expect to see a 168 ton per hectare yield reduction. Conversely and of more applicable use, if you moved tractors from small farms to medium/large ones you can expect to see reflectively similar <u>increases</u> of output.

¹⁰.31 being the average value of tractor per hectare

¹¹ In this case changing "1" is an all or nothing case as this is a percent as opposed to the trac_per_hectare which is a numeric value

Figure 7 FE Output / Tractors

Fixed-effects (within) regression	Number of obs	=	47
Group variable: stateid	Number of groups		17
R-sq: within = 0.0367	Obs per group: min	=	1
between = 0.0107	avg	=	2.8
overall = 0.0136	max	=	3
corr(u_i, Xb) = 0.0135	F(6,24)	=	0.15
	Prob > F	=	0.9867

output_per_hec	Coef.	Std. Err.	t	₽≻ t	[95% Conf.	Interval]
tractors_per_hec	547.2027	1157.537	0.47	0.641	-1841.835	2936.241
percent_trac_in_small	330.964	433.198	0.76	0.452	-563.1127	1225.041
int_tr_per_h_pc_trac_in_small	-645.1805	1223.727	-0.53	0.603	-3170.83	1880.469
gdppc	0360386	.1127319	-0.32	0.752	2687058	.1966286
year						
2006	6.472551	61.13258	0.11	0.917	-119.6989	132.644
2011	3.44416	113.0716	0.03	0.976	-229.9241	236.8125
_cons	381.9163	280.3849	1.36	0.186	-196.7697	960.6023

Above is the same regression run as the previous, only this time with Fixed-Effects (FE Model). It is immediately apparent that taking fixed affects into account, the coefficients become narrower in their scope as the idea behind running a fixed effect model is to account for inherent underlying differences that go mostly unchanged from time period to time period between states¹². This will "level the playing field" as it were, to account for persistent differences between states output¹³.

Although the numbers appear drastically different at first the important thing to keep in mind is the way you interpret the coefficients for the same variables is the same, and in doing so reveals very similar results. We interpret and manipulate this graph the same as the first, 330 - 645 * .31 = 130. Once again this is the

¹² For this particular thesis, as has been touched on previously, fixed effect differences in agriculture are many and variable. If one state has 1/3 of the entire countries rivers run through it we can expect their total outputs to be universally higher than an otherwise identical state. Permanent political difference supporting agriculture, annually higher rain amounts, perpetually better soil conditions etc. etc. can all fall under this category.

¹³ If year over year, one states output is 1300-1600 tons per hectare, and another's is 400-600, it is most likely safe to assume there are underlying unaccounted for differences, those talked about in the previous footnote, that are comprising the large differences and will therefore have a skewing effect on the inputs that we are running out regressions for.

resulting difference we would expect if we kept total number of tractors constant and moved all tractors from large to small. Somewhat surprising to see a positive number there, this is where the weak confidence intervals actually play in our favor as this is most likely not the case, and at +130 it is close enough to allow reasonable doubt to sneak in. Also keep in mind, if the average tractor per hectare value of .31 keeps increasing, which is the hope of this thesis, then the coefficient will continue to approach zero and pass into the negatives.

Keeping big – small tractor allocation constant we get, 547 - 645 * .66 = 122. As well for tractor efficiency, the lower the percentage of tractors going towards small farms, the better resulting yields you can expect when additional tractors are added. From the results, the numbers show us tentatively that small farm size, and specifically sending available tractor to smaller sized farms rather than bigger ones will be an issue. If you are adding tractors, as expected we see a positive coefficient impact on output. If where the tractors are being sent is not taken into consideration though, the expected benefits can be negated simply by the fact that the tractors will not be used efficiently across smaller farms. This makes sense from a practical standpoint, much like budget airlines are very concise of how long their plans are on the tarmac rather than going on flights¹⁴. Farmers will face an overall negative impact if they purchase a capital intensive input and then realize their farm is not big enough to benefit from the increased working power they now possess¹⁵.

5.3 Limitations

There were limitations that were born from the data that produced a less than desired number of observations. Originally data was sought for all of India's 36 states and Union territories, but it was quickly apparent that no singular source could provide such a data set. Rather than try and piece together fragments

¹⁴ Budget airlines are aware down to the minute how long their airplanes are sitting versus when they are in the air as it costs them money every second their planes are not in flight, hence the very quick turnaround times for carriers like Wizz and RyanAir

¹⁵ To clarify if not emphasized enough already, work power differential between a few laborers and even the most modest tractors is monumental. It certainly could catch many a farm owners by surprise when they realize they are getting what might have taken a few weeks done now in just a few days. Then this nice shiny new expensive piece of equipment is sitting gathering dust with nothing to do.

of data with differing sources, the most complete singular source was used. The most complete dataset offered statistics only at a 5 year interval at best and this only ran as far back as 2001 before even more states regularly started missing pertinent information. From 36 states usable data was narrowed down to 17 over 3 years. Although not centrally important to this analysis, it would have been desirable to put more weight behind the amount of money lent out to farmers. As it stood the available data regarding this was not very clear for the most part and therefore not as heavily emphasized as was anticipated going into the research.

All in all data appears to be getting better organized and more complete as the issue of mechanization takes a more central stage. This research could certainly use another analysis in the coming years when data sets become more filled in as the concept is rather simply evaluated given enough information.

Conclusion & Policy Recommendations

It is just about universally accepted that farm mechanization is the correct direction for agriculture in developing worlds. From an output perspective the numbers are uncontestable, higher yield, better efficiency in both manpower and inputs, long term savings, and less waste. In the end these things all mean greater income for the farmer, and a healthier agriculture sector of the nations' economy. The only negative that can be construed is displacement of labor from heavy employment rates in farming. The absolute necessity of more food for a growing population will quickly outweigh this small contention. Historically, countries seeing a leap forward into a mechanized agriculture see urbanization with the displaced labor finding gainful employment elsewhere or in many cases labor leaves first and mechanization is the answer to labor shortages.

Large scale implementation of machinery has the potential to allow less developed countries explore their comparative advantages in the agriculture international trade market. India has displayed just this capability in the last 15 years or so. According to the United States Department of Agriculture (USDA) India's total agriculture exports have soared since 2001, going from 5 billion US dollars to nearly 40 billion²⁴. This comfortably positions them as the world's leader in terms of export growth in that period at 21%, securely ahead of Indonesia and Brazil between 15-18% and easily pacing China who saw an export growth rate of 11.8% during that span²⁴.

As has been mentioned, India has the benefit of seeing other sectors of their economy flourishing, namely its service sector²⁵, which has attracted a lot of foreign direct investment as its growth potential has become apparent. Credit to India's rise in exports can certainly be passed around to different causes but the USDA makes a point of mentioning increased "power" support, among irrigation and fertilizer support. Subsidies have been applied directly to support their farmers¹⁶ much like many nations, but this is not to take away from the fact that greater overall investment in machinery is yielding positive long term results.

With a continued, and ideally, increased government attitude of a hands on approach, India can expect to see greater returns from its mechanical investments in agriculture. Direct export subsidies as a whole are not a long term solution for agriculture, and in fact the world market through the World Trade Organization (WTO) has deemed them counterproductive and have moved to ban them. As of the 10th Ministerial Conference the WTO has moved to outright abolish export subsidies for agriculture in fully developed nations. Furthermore the same thing is expected of developing nations by the end of 2018²⁶. India is currently in a position that the EU was in around the turn of the century, as their agriculture sector was being propped up by the Common Agriculture Policy (CAP). Their goods were being exported to poorer countries, those countries markets were being suppressed and yet the EU's farmers were still complaining. This is quite an important issue to India as they have filled a niche that was once held by more developed nations exporting their agriculture to developing nations, with only the United States receiving more Indian agriculture exports than countries like China, Malaysia, Pakistan, and the UAE²⁴.

¹⁶ Until 2014 India had not let the international world know of its agriculture subsidies since 2003-2004 which was drawing the ire of many richer nations complaining of skirting WTO regulations.

The massive amount of money poured into supporting farmers year to year in the form of subsidies, can be put into infantile projects and schemes that are already in place to promote innovation rather than hindering quantifiable progress through handouts. Seeing past month, and even 1-3 year horizons should be emphasized in order to prioritize more long term gains. Machine loan credit lines, direct machinery subsidies rather than output based subsides, communal machine loan centers are all promising viable options. In an ideal world personal machine ownership would be even further prioritized among these possible options as it has been shown to more effective than loan systems¹⁷

Fortunately it can be projected that machine loan systems or "custom hiring" can still have quite a positive affect for the users of such programs. In Nepal's case the results were promising concerning custom hiring institutions when they saw a jump in usage with outputs predictably higher¹⁸. These kinds of programs have the added benefit of a sort of built in education method regarding the machinery. It self creates a community of people knowledgeable on the machinery being used. This is another hurdle that India faces as it moves to mechanization, the lack of knowhow, even if you give fighter jets to a crop duster¹⁸ it doesn't mean they know how to use them. Much the same as generations of farmers in India and other developing nations, if you just hand them tractors they will need time to get the most out of them, developing an educational platform for mechanical inputs will be just as paramount moving forward. India has begun this process, with many states chartering instructional hubs that allow farmers to come educate themselves on just how they can advance their farms potential through machine usage. They combined this with state and national sponsored machine testing centers so that the government may make educated suggestions on which pieces of machinery will perform best depending on the individual farmers' situation.

¹⁷ The inherent timeliness that come with owning your own piece of equipment rather than being at the mercy of a communal loaning center directly lends itself to higher returns on the initial investment of such a piece of equipment. Like most such inputs, the more it is running versus sitting for any amount of time, the more valuable it becomes.
¹⁸ Old school, usually propeller, plane that will fly over a cultivated field to mass spread out fertilizer or pesticide in a spray form allowing farmers to coast their entire fields in the matter of a few hours after a couple of passes.

While data available for this analysis left the author desiring more, it did allow for some promising results nonetheless. The significance levels and confidence intervals were not as tight as the author would have wished for but the numbers produced do point in a direction policy makers could start planning their country's future needs. As a policy maker in developing nations, it would be in the interests of your nation to keep promoting mechanization, and on a more long term horizon, develop plans to promote farm consolidation into bigger farms to get the most out of the machinery once it is in the hands of farmers. Machine loan systems are promising, they can alleviate times where tractors do not have work due to their not being enough of it on a small farm as the next farmer can come and use it with no down time. Problems arise during peak labor times, when all farms in region are harvesting, or planting, and loan centers not having enough machinery to go around. Therefore pointing once again to individual ownership on bigger farms.

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Appendix – Figures & Tables



Figure 8 Export Growth Rates

https://www.fas.usda.gov/data/india-s-agricultural-exports-climb-record-high



India's Agricultural Exports Focused to Developing Countries

Figure 9 Recipients of India's Agricultural Exports

https://www.fas.usda.gov/data/india-s-agricultural-exports-climb-record-high