Agriculture in the Process of Development: A Micro-Perspective*

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Abstract

This paper compares national-level data from India with 40 years of household panel data from rural India to track sectoral changes in employment and income as well as examine the hypothesis of induced innovation in agricultural production. In the national data, India appears to be in the midst of a structural transformation. The share of agriculture in GDP and employment has shrunk while agricultural output continues to grow. This productivity growth appears to adhere to the induced innovation hypothesis, as productivity per hectare has increased more rapidly than productivity per worker. Many of the same patterns exist in the household data. Tracking households across time, I observe agricultural output has increased, despite more households engaging in off-farm labor. Household agricultural production is highly specialized and has increased its reliance on improved inputs. However, while agricultural income has grown, industrial and service income has remained stagnant, and the relative income of these households has declined in recent years.

JEL Classification: C11, D81, O12, O13, Q16, Q12

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1 Introduction

The process of economic development is defined by structural transformation, in which the relative role of agriculture in the national economy diminishes as the roles of the industrial and service sectors increase (Lewis, 1954; Kuznets, 1957). In addition to the declining importance of agriculture, the literature on economic development has noticed a number of other empirical regularities or stylized facts (Syrquin, 1988; Timmer, 1988). These include an increase in agricultural output, despite a diminishing agricultural labor force (Johnston and Mellor, 1961; Johnston and Kilby, 1975), factor bias or induced innovation in technological change (Binswanger, 1978; Hayami and Ruttan, 1985), increased specialization (Schultz, 1964; Chavas, 2001), and the convergence of agricultural and non-agricultural earnings (Timmer, 1991; Gardner, 2000). For the most part, both the theoretical and empirical literature has focused on structural transformation as a national or macroeconomic phenomenon. Yet, with the donor community focused on microeconomic interventions, understanding how the process of development manifests at the household-level is key to achieving such transformation.

In this paper, I use the experience of India over the past 40 years to better understand how the conventional wisdom of macroeconomic structural transformation is reflected in the transformation of the rural household experience. To the degree that macroeconomic indicators are aggregates of microeconomic agents, one would expect that a large enough representative sample of households to mirror the national accounts data. Yet, in a country as diverse as India, the experience of the "average household" is unlikely to be informative regarding the lived experience of any given household or set of households. The concern is that the conventional wisdom regarding the process of development relies on national statistics and these data can mask the vast heterogeneity in experience across various states. Using the stories we tell ourselves about the development of nations in order to drive research agendas, which are more and more micro-focused, may lead to misguided policy prescriptions and misallocated resources. Alternatively, we may find that contemporary economies are sufficiently integrated as to allow historically marginalized households to fully participate in the process of development.

To accomplish this task, I compare national-level data from India with household panel data from village India to track sectoral changes in employment and income as well as examine the hypothesis of induced innovation in agricultural production. I am able to make these comparisons because the household data, which was collected by the International Research Institute for the Semi-Arid Tropics (ICRISAT) as part of the Village Level Studies/Village Dynamics Studies in South Asia (VDSA), spans a 40 year period (VDSA, 2015). The first round of data was collected in 1975 with the last round coming in 2014. This allows me to track changes in household-level production, employment, and income over a relatively long time frame, abstracting away from short-term or idiosyncratic shifts in behavior, and observe long-run trends. The six VDSA villages are in no way nationally representative and thus it is an open question regarding the degree to which households in these villages have participated in the national trends. My approach in the paper is statistical, relying on non-parametric regressions, but presented graphically. For clarity all charts are formatted in a consistent manner.

The national-level data comes from the World Bank, the Food and Agricultural Organization (FAO) of the United Nations, and the Reserve Bank of India. I find strong evidence that India as a whole is in the midst of a structural transformation. The share of agriculture in GDP and employment has diminished while agricultural output continues to grow. This productivity growth appears to adhere to the induced innovation hypothesis, as productivity per hectare has increased more rapidly than productivity per worker. However, I find little evidence of increased specialization in Indian agriculture, nor do I find much evidence that the agriculture earnings gap has begun to shrink.

The household-level data tells a similar story to the nation-level data, though key differences do exist. Furthermore, the richness of the VDSA allows me to explore factors in microeconomic structural change. The growth in agricultural production appears due to yield gains in rice, cotton, and wheat, though yields for all the crops that I examine show improvement. For most crops, the increased yields correlate with increases in land productivity, suggesting gains along the intensive margin. Increased land productivity comes with substantial increases in purchased inputs such as fertilizer, pesticide, and mechanization. In fact, the increase in application rates for several inputs have outstripped gains in yields, suggesting households have reached a point of diminishing returns for these inputs. Again, as in the national-level data, there is no evidence of increased specialization in household agricultural production. However, unlike in the national data, there is a positive agricultural earnings gap and agricultural income as a share of total income has actually increased in recent years. Despite this agricultural-led growth, income per capita has failed to keep pace with GDP per capita, meaning that the relative income for households in the VDSA has declined.

These findings contribute to the academic literature on structural transformation, microeconomic research on village and households economies, and the policy debate regarding how best to foster economic development. The literature on structural transformation has largely been theoretical and focused exclusively on macro or sectoral trends (Lewis, 1954; Ranis and Fei, 1961; Ranis and Stewart, 1993; Gollin et al., 2002; Herrendorf et al., 2014). More recently, this research has focused on presenting empirical evidence regarding sets of stylized facts (Hayami and Ruttan, 1985; Syrquin, 1988; Timmer, 1988; Foster and Rosenzweig, 2008; Gollin, 2009; Briones and Felipe, 2013; Collier and Dercon, 2014; Davis et al., 2017; Masters et al., 2018). An exception to this trend is Bustos et al. (2016), who use household census data to investigate agricultural production, factor bias in technology adoption, and structural transformation in Brazil. There is also a wealth of research on village and household economies focused solely on the VDSA, though much of this relies on the pre-2001 data (Antle, 1987; Rosenzweig, 1988; Renkow, 1990; Walker and Ryan, 1990;

Rosenzweig and Binswanger, 1993; Rosenzweig and Wolpin, 1993; Frisvold, 1994; Saha and Stroud, 1994; Townsend, 1994; Jacoby and Skoufias, 1997; Ligon, 1998; Foster and Rosenzweig, 2001). To my knowledge, this is the only paper to use the entire time series from the VDSA. Finally, there is a continuing debate on what works in development (Bauer, 1984; Chang, 2003; Banerjee, 2007; Cohen and Easterly, 2009; World Bank, 2019). While I do not provide evidence for or against specific policies, the findings in the paper raise a number of questions for policymakers to consider as agriculture moves through the process of development.

This paper is most similar to Foster and Rosenzweig (2004), in that it uses data and trends to describe economic development in India over several decades. As Foster and Rosenzweig (2004) note, a key limitation to their study, and other similar studies, is a lack of available data. Additionally, the analysis by Foster and Rosenzweig (2004) is primarily descriptive. By using the VDSA, I am able to provide a more complete picture of structural transformation as it has occurred in village India. Furthermore, by using non-parametric regressions, I can conduct statistical tests for changes over time, instead of simply presenting summary statistics. That said, I make no claims to causal interpretation but rather comment on the trends that I can statistically identify in the data. Though the VDSA villages are not nationally representative, nor are they representative of Indian agriculture as a whole, the similarities and differences between the household-level and the national-level data illuminates the integration of rural communities into the larger economy.

2 Structural Transformation in India

The process of structural transformation in agriculture has been remarkably uniform both across countries and over time. This uniformity has given rise to several stylized facts that describe the transformation, at least at the national-level. While there has long been vigorous debate regarding the policy implications of structural transformation (Prebish, 1950; Lewis, 1954; Johnston and Mellor, 1961; Schultz, 1964; Preobazhensky, 1965; Lipton, 1977; Bates, 1981; Ruttan, 1990), there is a fair degree of consensus regarding agriculture's role in the process (Tomich et al., 1995; Chavas, 2001). In his seminal article, Timmer (1988) describes this consensus and puts forward a set of stylized facts regarding agricultural transformation.

Typical macro-level research on structural transformation takes a cross-country approach, describing and comparing differences in outcomes for countries with different levels of GDP. I instead focus solely on India and compare aggregate national data to household data. India is an interesting test case for several reasons. First, the country has begun a process of rapid industrialization, with GDP growth at well over three percent in nearly every year since 1990. This rapid GDP growth means that good economic data exists throughout the entire process. Second, despite this rapid growth, there are still more people in extreme poverty in India than in any other country. This provides an opportunity to try and understand why some populations may be left out of the growing national wealth. Third, the country is extremely diverse both ethnically and geographically.

With such diversity there is the potential for national data to provide an overly generic picture of the causes and consequences of economic growth. While the Indian experience is likely to be unique among developing countries, its sheers size in terms of geography and population make it of intrinsic interest to economists seeking to understand the who, how, and why of poverty and growth.

The first stylized fact that I consider characterizes agriculture's initial role in the development process.

Stylized Fact 1 *Agriculture's output share and share of employment decline, in relation to industry and service.*

Lewis (1954) first modeled the reasons for agriculture's declining share in a country's output and labor force, but the process had long been noted in the historical record (Nurske, 1953). As Mosher (1966) describes and Ranis and Fei (1961) show more formally, resources flow out of the agricultural sector through a shift in the terms of trade, allowing resources to be more productively invested in the higher value-added sectors of industry and service. This shift in the inter-sectoral terms of trade has been documented in a wide variety of countries (Johnston and Kilby, 1975).

At the national-level, Stylized Fact 1 clearly describes the Indian experience (see Figure 1). Since 1974, agriculture's share of total GDP has declined. For the fifteen year period 1960-1974, agriculture made up, on average, 42 percent of GDP. By the year 2000, agriculture's share of GDP appeared to have stabilized at around 18 percent. The employment data is not as rich, only going back to 1980. Despite this limitation, a decline similar to that of GDP is evident. In 1980, agriculture's share of the workforce was 70 percent but by 2015 it had fallen to 44 percent. Over the period for which data is available, agriculture's output share has declined by 1.65 percent per annum while the employment share has declined by 1.04 percent per annum. The more rapid reduction in output share compared to employment share appears to be a feature of structural transformation across Asia (Briones and Felipe, 2013). The result is that, in India, agriculture remains the largest employer but no longer the largest contributor to GDP.

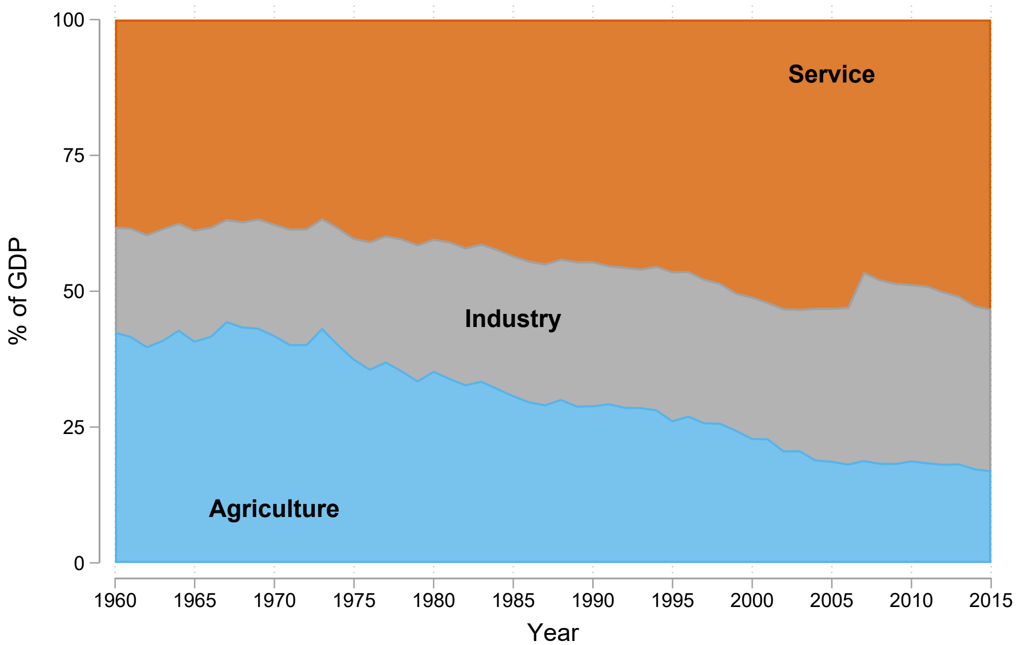
The falling share of agriculture in GDP and employment does not mean that agricultural output is also falling. Rather, the second stylized fact states just the opposite.

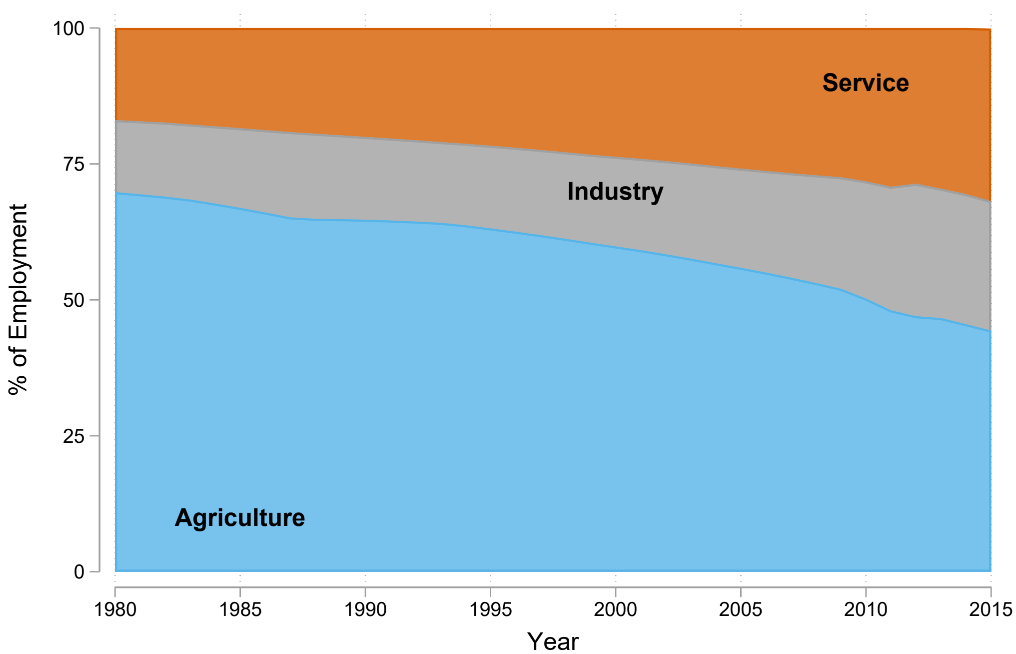
Stylized Fact 2 *Total agricultural output increases.*

In order to feed the growing number of non-agricultural workers, agriculture itself becomes more productive. As Johnston and Mellor (1961) and Mellor (1966) point out, the only way to achieve these productivity gains is through investment in agriculture, as opposed to squeezing investment out of agriculture.

The phenomenal growth in agricultural output on the sub-continent since the introduction of dwarf wheat varieties in the mid-1960s is well known. Figure 2 charts the growth of yields at the

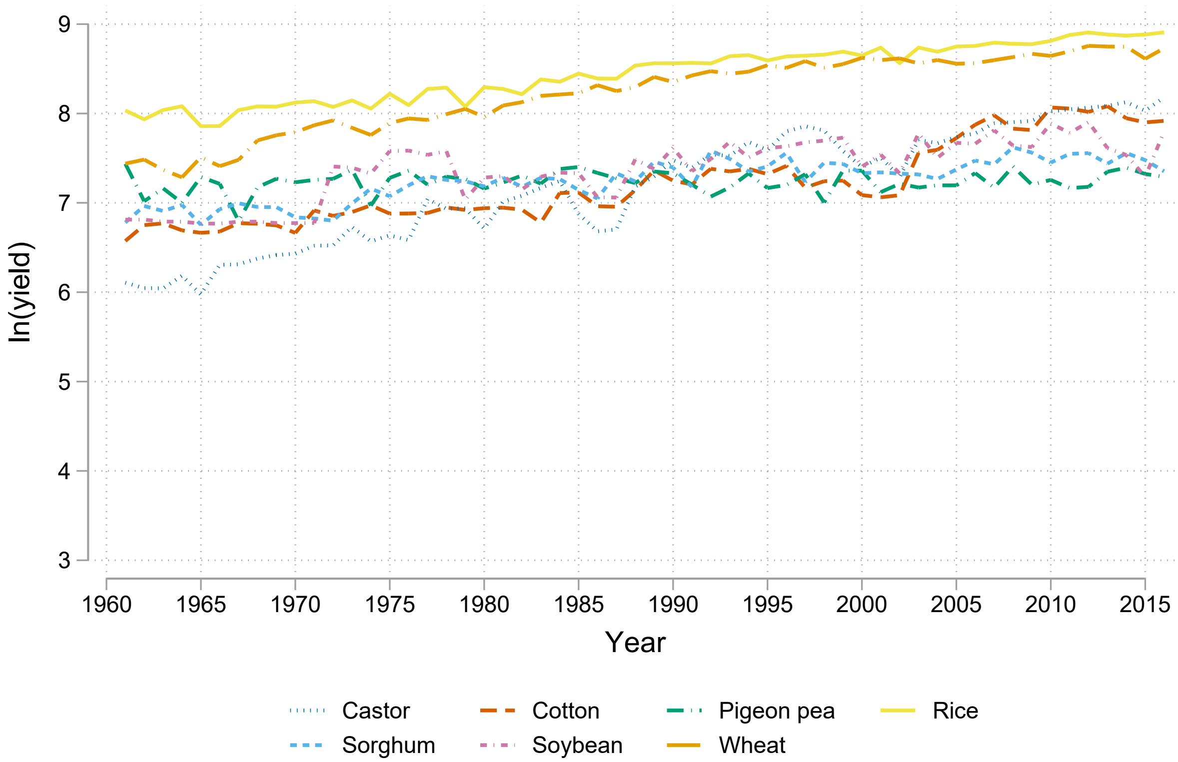
Figure 1: Sectoral changes in GDP and employment





Note: GDP is measured in constant 2010 USD. GDP by sector is the net output of the sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. Employment is defined as persons of working age who were engaged in any activity to produce goods or provide services for pay or profit.
Source: World Development Indicators (GDP data) and Reserve Bank of India (employment data).

Figure 2: National level yield data by crop



Note: Yield data are not recorded but obtained by dividing the production data by the data on area harvested. Yields are measured in kg/ha. Logs are taken using the inverse hyperbolic sine.
Source: FAOStat.

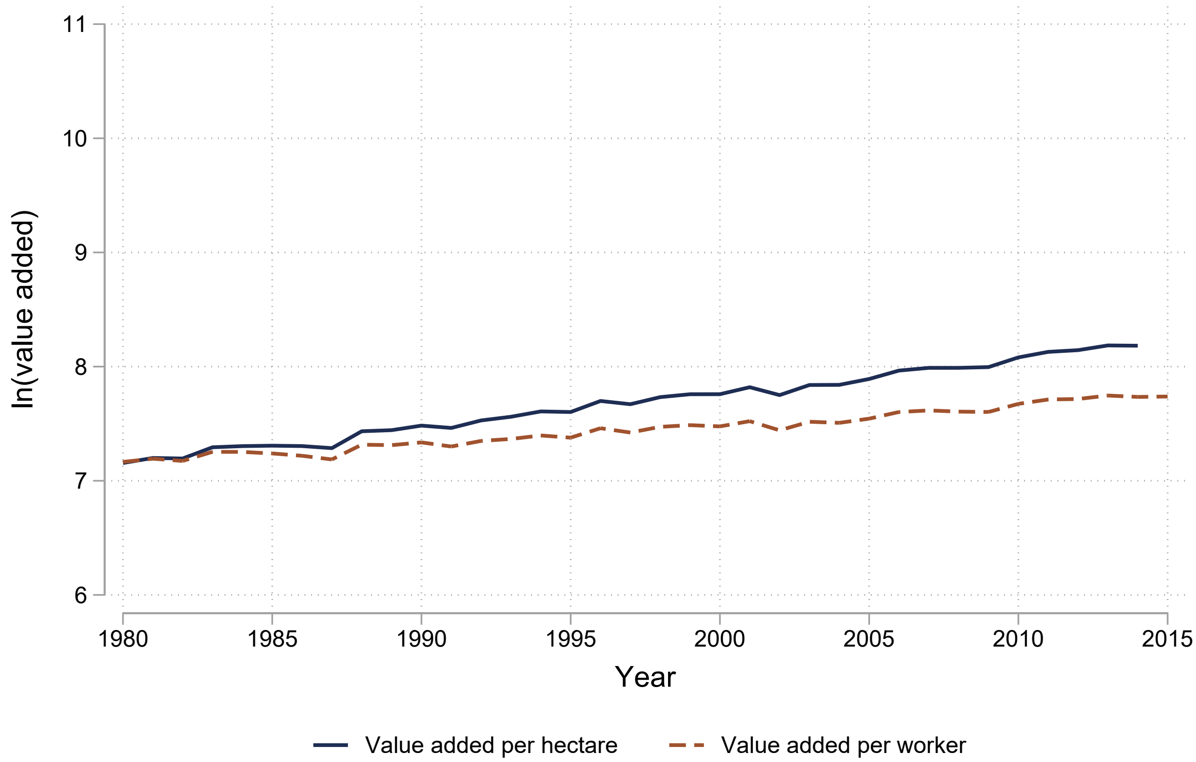
national level for the seven most common crops in the VDSA data set. Overall, crop yields have increased in the last fifty years, though pigeon pea yields appear to have remained stagnant. Most of the growth has come from yield gains in rice and wheat. The increases in these two staples have allowed employment in the industrial and service sector to grow without a return to the famines of the 1960s and 1970s.

The third stylized fact regarding agricultural transformation has to do with how yield gains are achieved.

Stylized Fact 3 *Technical change follows a path of induced innovation.*

Increases to productivity in agriculture come from technical change, which according to Binswanger (1978) and Hayami and Ruttan (1985) is not Hicks-neutral, but biased towards the scarce resource. In countries with abundant land, innovations tend to be made in labor productivity, allow for larger yields per agricultural laborer. Conversely, in countries with abundant labor, innovations tend to be made in land productivity, allowing for larger yields per unit of land (Ruttan and Hayami, 1990).

Figure 3: Value added per hectare and worker



Note: Value added per hectare measures the output of the agricultural sector less the value of intermediate inputs divided by the number of hectares of arable land under permanent crops or under permanent pastures. Value added per worker divides output of the agricultural sector by the number of persons of working age who were employed in the agricultural sector. Value added is in constant 2010 USD. Logs are taken using the inverse hyperbolic sine.
Source: World Development Indicators

In India, value added has increased both in per hectare and per worker terms. In 1980, value added from each input source was virtually equivalent. Since then, the growth in value added per hectare has outstripped the growth in value added per worker. The more rapid growth in land productivity compared to labor productivity is typical throughout Asia (Briones and Felipe, 2013).

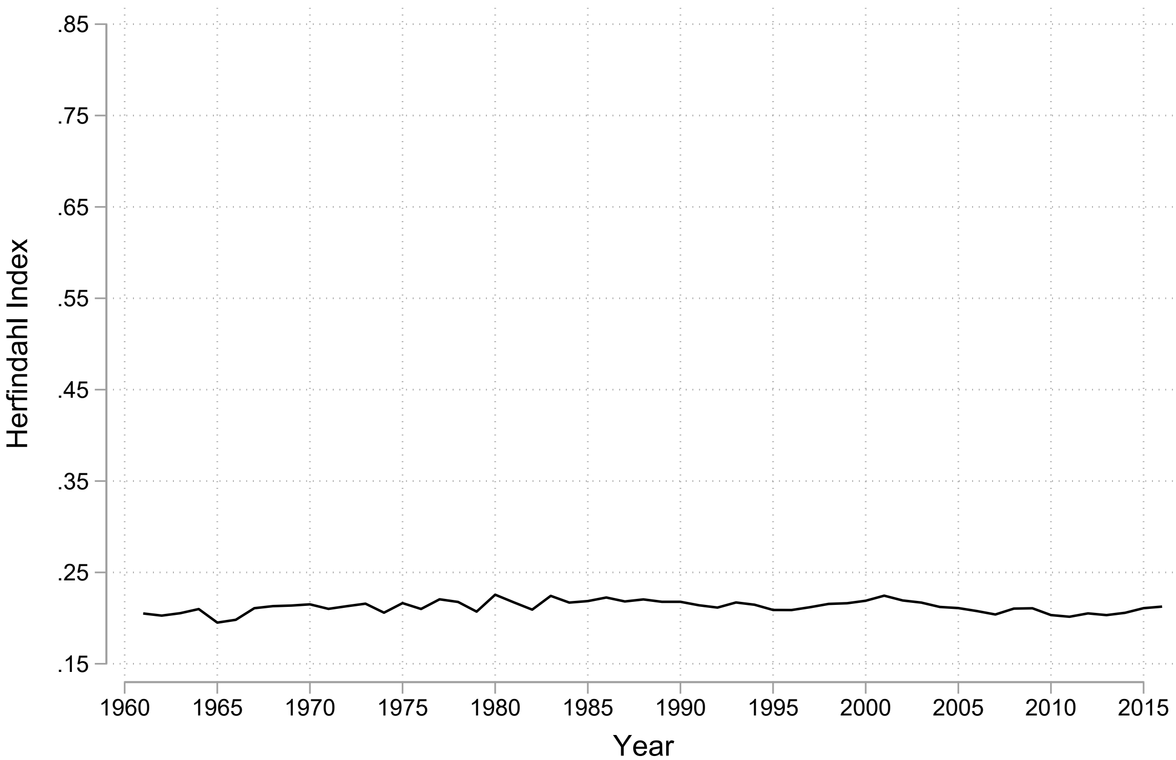
The final two stylized facts describe agriculture in the final phase of its transformation, as it integrates into the industrial economy.

Stylized Fact 4 *Within agriculture, specialization increases.*

Since Adam Smith, a key feature of industrialization has been specialization. However, Chavas (2001) notes that risk and economies of scope make agriculture a unique sector. Even in the most industrialized countries, farms typically remain multi-product firms.

At the national-level there is little evidence that Indian agriculture has become more specialized over time. I calculate a Herfindahl index for specialization by crop type in each year from

Figure 4: Specialization in Indian agriculture



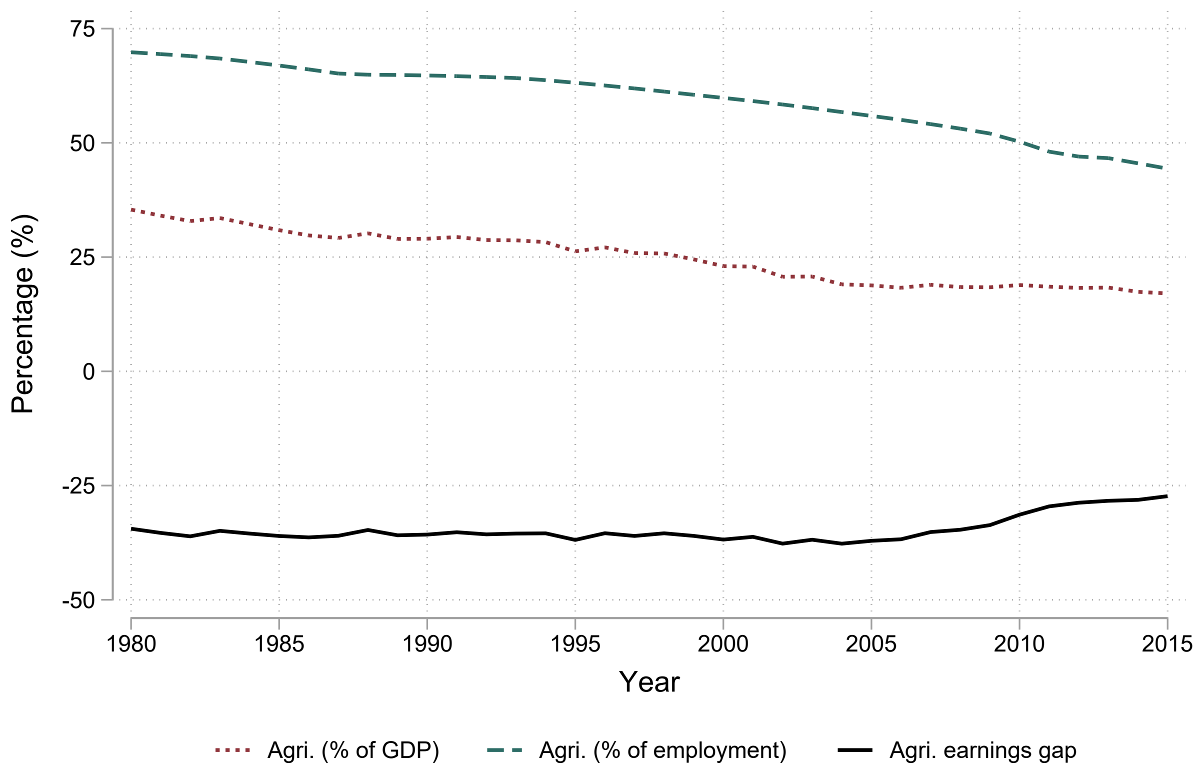
Note: Herfindahl index is calculated as $H = \sum s_i^2$, where i is the product type. I categorize the 104 crops into eight categories: fruits & vegetables, cereals, legumes, livestock, oil crops, spices & sugar & nuts, roots & tubers, and other. Shares are calculated using gross production value in constant 2004-2006 USD.
Source: FAOStat.

1961-2016 based on gross production value (constant 2004-2006 USD). For the entire period, the Herfindahl index only varies between 0.195 and 0.226, always falling within the range of "moderate concentration." To some extent, this is not surprising given the diverse agro-ecology of India. That said, the Herfindahl index for the United States for the same period of time ranged between 0.329 and 0.467, indicating "high concentration." In India, during the period immediately after the introduction of dwarf wheat and other Green Revolution technologies, there appears to be a trend towards specialization, driven by an increased focus on cereal crops. But, since 1985, there has been no further movement to specialize. In fact, the slope of a linear trendline fitted to the data is not statistically different from zero. Increases in the value of livestock and fruit and vegetable production has come at the expense of cereal and legume production, meaning there has been very little change in the Herfindahl index over the last half century.

The fifth stylized fact has to do with the outcome of higher productivity and specialization in agricultural production.

Stylized Fact 5 *Farm income first declines but then increase.*

Figure 5: Agriculture earnings gap



Note: Agriculture's share of GDP and share of employment are calculated in the same was as in Figure 1. The agricultural earnings gap is measured as GDP share minus employment share.
Source: World Development Indicators (GDP data) and Reserve Bank of India (employment data).

Stylized Fact 5 concerns the phenomenon observed in developed countries (and assumed to be true for developing countries), that after a period in which agricultural wages are squeezed, farm income tends to rise above median household income (Gardner, 2000; Timmer, 2007).

The evidence from India is inconclusive, partly because of a lack of data on employment before 1980. Figure 5 could be interpreted as showing the beginnings of convergence in farm and non-farm earnings. Observations only range by ten percentage points, so it is difficult to determine if the process of convergence has begun. However, the slope of a linear trendline fitted to the data is positive and statistically different from zero at the 99 percent level.

Using national data, India appears to be in the midst of structural transformation. The share of agriculture in GDP and employment has shrunk while agricultural output continues to grow. This productivity growth appears to adhere to the induced innovation hypothesis put forward by Binswanger (1978) and Hayami and Ruttan (1985), as productivity per hectare has increased more rapidly than productivity per worker.

There are, however, some anomalies in the process of agricultural development in India. First, while the share of employment in agriculture has fallen, the absolute number of people employed in agriculture continues to rise (Briones and Felipe, 2013). This is a result of continued population growth on the sub-continent so that agriculture is now the smallest sector by value but still the largest employer. Second, there is little evidence that productivity growth has been driven by specialization in agricultural production. While there has been a move away from cereal and legume crops towards livestock and horticulture, farm production in India continues to be multi-crop. Third, India has only begun to start closing the agricultural earnings gap. This is due to a growing agricultural labor force combined with the shrinking importance of agriculture in the economy.

3 The Village Dynamics Studies in South Asia (VDSA)

At the national-level, India adheres to many of the stylized facts in Timmer (1988) and Tomich et al. (1995) regarding structural transformation. The question remains, how is this transformation experienced at the household-level? For the "average household" one would expect to see a transformation in the household economy similar to that in the national economy. But few if any households in India are average. Because of this, I focus on how structural transformation has manifested itself for households in ICRISAT's Village Level Studies/Village Dynamics Studies in South Asia (VDSA). The households in these data are not nationally representative but they have come to be seen as archetypal of life in poor, rural, high-risk environments (Rosenzweig, 1988; Rosenzweig and Binswanger, 1993; Townsend, 1994; Ligon, 1998; Foster and Rosenzweig, 2001). Furthermore, the VDSA is unique in the developing world since it brings a long-term, multi-generational perspective to economic change and provides an extraordinary level of detail on farming activities and the household economy (VDSA, 2015). No other household-level data exists in a long enough time series to examine the process of structural transformation.

Beginning in 1975, ICRISAT collected semi-annual agricultural production data from 40 households in each of six villages in Andhra Pradesh and Maharashtra.[1] Both states contain humid coastal lowlands and semi-arid upland interiors that lay on the Deccan plateau. The VDSA villages are all located in regions that historically rely on monsoon agriculture and cultivate drought tolerant crops such as sorghum, millet, and legumes. All the villages were surveyed from 1975 up though 1979 at which time only half continued to be surveyed until 1984. At that point there was a gap until enumerators returned in 1989. A second, longer gap ensued after 1989 and the panel was not picked up again until 2001. From 2001 until 2008 semi-annual surveys were conducted in

[1] In 2014 the northwest interior region of Andrah Pradesh was seperated out to form the new state of Telangana. As a consequence, both of the VDSA villages that were previously in Andrah Pradesh are now in Telengana. Becasuse this political realignment occurred in the final year of data collection, I still refer to the villages as being in Andrah Pradesh.

the villages. Starting in 2009 data began to be collected every month until 2015, at which point data collection was terminated.

I aggregate income and employment data to the annual-level and cultivation data to the seasonal-level. This results in 25 years of observations (50 seasons) for half the villages and 21 years (42 seasons) for the other half (see Table 1). Over such a long time frame, it makes sense to wonder how long households stay in the panel. Of the $1,054$ unique households in the data, 96 percent are observed for two or more seasons. The average number of seasonal observations per household is eight. However, I observe 396 households for at least ten years and 129 household for 20 years or more.

Table 1: Villages and Years of Data Collection

State	Villages	Years	Time Obs.
Andhra Pradesh	Aurepalle	1975-1984, 1989, 2001-2014	50
	Dokur	1975-1979, 1983, 1989, 2001-2014	42
Maharashtra	Kalman	1975-1979, 1983, 1989, 2001-2014	42
	Kanzara	1975-1984, 1989, 2001-2014	50
	Kinkhed	1975-1979, 1983, 1989, 2001-2014	42
	Shirapur	1975-1984, 1989, 2001-2014	50

Note: All villages were surveyed from 1975-1979, in 1989, and from 2001-2014. Up until 2009 surveys were conducted semi-annually. Starting in 2009 surveys were conducted monthly.

The VDSA has production data on over 81 different crops, much of it household fruit and vegetable production. I focus on the seven most common crops, which in aggregate account for 36 percent of the $38,371$ plot-level observations of crop output. These crops are: castor, cotton, pigeon pea, paddy rice, sorghum, soybean, and wheat. This provides me with $13,862$ plot-level observations from $6,523$ unique plots (see Table 2). Among the seven crops, sorghum is the most common, accounting for 34 percent of observations. Next most common are rice and cotton, accounting for 18 and 17 percent of observations, respectively. Wheat is the fourth most commonly cultivated crop, making up 11 percent of observations. Castor, pigeon pea, and soybean make up the remaining shares with between six and seven percent each. There is a high degree of seasonality in the data. Castor, cotton, pigeon pea, and soybean are all grown exclusively in *Kharif*, with planting at the start of the monsoon in June or July and harvesting post-monsoon in November. Wheat is cultivated exclusively during *Rabi*, with planting in December or January and harvesting in April or May, prior to the start of the monsoon. Rice and sorghum are grown in both *Kharif* and *Rabi*.

Table 3 presents summary statistics by crop. Without accounting for grain density, rice, wheat, and soybean have the largest yields per hectare. Pigeon pea and castor have the lowest yields. Rice and cotton are the most labor intensive crops while pigeon pea, sorghum, and soybean use the least labor. Fertilizer usage is highest for rice and wheat by a large margin while castor, pigeon pea, and sorghum tend to receive much less fertilizer. Unsurprisingly, rice accounts for the vast majority of

Table 2: Crop cultivation by season

	Kharif	*Rabi*	Total
Castor	936	0	936
Cotton	2,310	0	2,310
Rice	1,574	889	2,463
Pigeon pea	915	0	915
Sorghum	994	3,774	4,768
Soybean	898	0	898
Wheat	0	1,572	1,572
Total	7,627	6,235	13,862

Note: Table displays the number of observations of crops for each season.

Table 3: Production descriptive statistics by crop

	Castor	Cotton	Rice	Pigeon pea	Sorghum	Soybean	Wheat
Yield (kg/ha)	328.0	751.1	3,765	290.6	566.2	1,178	1,827
	(246.6)	(699.7)	(1823)	(302.9)	(624.2)	(580.9)	(1035)
Labor (hrs/ha)	476.9	857.5	1,767	284.6	362.3	353.9	605.7
	(219.5)	(391.8)	(868.6)	(223.9)	(315.6)	(168.0)	(570.6)
Fertilizer (Kg/Ha)	42.21	171.2	380.8	18.40	32.85	118.7	255.5
	(50.06)	(157.8)	(253.8)	(50.86)	(69.01)	(47.06)	(156.4)
Irrigation (Hr/Ha)	1.942	12.88	523.3	4.862	7.975	0.819	107.4
	(19.14)	(45.12)	(377.7)	(21.35)	(24.42)	(4.630)	(82.01)
Mechanization (Rs/ha)	2.983	13.99	12.76	2.687	1.696	20.52	9.105
	(4.97)	(17.68)	(18.97)	(5.86)	(3.51)	(12.04)	(7.82)
Pesticide (Rs/ha)	62.81	4,508	549.2	161.5	10.38	9,338	146.7
	(288.9)	(8,883)	(2,130)	(1,196)	(263.6)	(12,552)	(1,085)
Seed (Rs/Ha)	228.0	1,956	677.7	208.0	117.3	2,753	1,652
	(334.6)	(2,740)	(1,012)	(273.3)	(199.8)	(1,753)	(1,761)
Area planted (ha)	1.142	1.242	0.505	0.837	0.980	1.194	0.676
	(0.864)	(0.952)	(0.352)	(0.741)	(0.934)	(0.761)	(0.617)
Number of observations	936	2,310	2,463	915	4,768	898	1,572
Number of plots	599	1,327	1,109	719	2,900	493	1,068
Number of households	179	305	250	265	521	182	293
Number of seasons	24	24	48	24	48	12	24
Number of villages	3	5	6	6	6	4	6

Note: Table displays means of data by crop with standard deviations in parenthesis.

irrigation hours. Since most crops are grown exclusively during the monsoon *Kharif* season, few need much irrigation. Even though sorghum and wheat are cultivated during the dry *Rabi* season, they also receive very little irrigation. Soybean, cotton, and rice require the most mechanization given that they all must be processed prior to sale or consumption. Of all inputs, pesticide use is the most variable. Castor receives on average only 63 Indian rupees, or about 1.40 U.S. dollars at 2010 exchange rates. Conversely, soybean receives on average $9,338$ rupees worth of pesticide, or about 200 dollars. Similarly large variations exist in the cost of seed used for each crop.[2] On average, households use only between 2.50 and five dollars worth of seed per hectare to grow castor, pigeon pea, and sorghum. Improved seed varieties for cotton, soybean, and wheat mean that households spend between 38 and 62 dollars on seed per hectare. Finally, soybean, cotton, and castor have the largest average plot size, with plot areas over one hectare. Rice has the smallest average plot size, reflecting the need for more intensive input use in the cultivation of rice.

In addition to the semi-annual crop production data, I construct annual measures of income and employment. The VDSA contains a rich variety of sources of earnings data for the household. These include rental income from landholding, income from the sale of capital assets like machinery, income from the sale of home produced goods like handicrafts, income from the sale of livestock and livestock products, income from loans, gifts, and remittances, income from crop production, and income from formal and informal employment.[3] Because I am unable to consistently measure the costs to the household of earning income, I calculate gross instead of net income. Because I cannot always tell when crop production is sold versus consumed at home, I treat all crop production as income and value it using data on the unit price of output collected as part of the cultivation schedule of the survey.[4]

The employment schedule of the survey records the total days worked on a given activity by each household member in each year. This results in $290,860$ person-activity observations. The survey divides activities into farm work and non-farm work. If further divides non-farm work in 54 different categories of employment, ranging from carpentry to gold-smithing to driving vehicles to working in a hotel to making alcohol. Importantly, the employment schedule includes labor data on individuals who have migrated and no longer live in the village but are still considered members of the household. Because the VDSA records the type of work being done and the type of good sold

[2] In long-term data like the VDSA one must decide whether to measure seed by weight or by value. The weight of hybrid and non-hybrid seeds may be the same though the yield response will differ between the two. Thus it can be better to measure seed by its price, which would account for the difference in technology. However, households may recycle or exchange seeds, meaning that a value measure may not capture these non-market sources of seed. I have chosen to use value in order to account for changes in seed technology over the last 40 years, though I acknowledge this measure misses seed from non-market sources.

[3] In constructing sectoral measures of income I do not fully account for all sources of income in the VDSA. I exclude passive sources of income (loans, gifts, government transfers, etc.) from my calculations as they do not constitute income earned from employment in the agriculture, industry, or service sectors.

[4] It is frequently unclear if this is the local price of the crop at harvest time or if it is the household's subjective determination of the value of the crop. What is clear is that the price is the procurement price (i.e., the price at which the good could be sold) not the market price for the food product in the market.

Table 4: Household descriptive statistics by time frame

	1975-1989	2001-2014	Total	MW-test
Income from agriculture (1,000s Rs)	72.20	98.27	91.42	***
	(88.09)	(102.2)	(99.35)	
Income from industry (1,000s Rs)	37.14	62.60	55.90	***
	(43.16)	(63.53)	(59.92)	
Income from service (1,000s Rs)	3.901	27.54	21.33	***
	(12.49)	(47.01)	(42.16)	
Employment in agriculture (days)	103.1	93.49	96.02	**
	(153.7)	(148.5)	(149.9)	
Employment in industry (days)	54.46	45.68	47.99	***
	(99.25)	(120.0)	(115.0)	
Employment in service (days)	11.56	97.53	74.92	***
	(41.62)	(174.4)	(155.94)	
Household size (persons)	6.307	4.958	5.313	***
	(3.198)	(2.261)	(2.609)	
Number of observations	2,323	6,511	8,834	
Number of households	478	760	1,054	

Note: Table displays means of data for the entire data set as well as by survey time frame with standard deviations in parenthesis. Income is measured in constant 2010 Rupees. Employment is measured as the number of days that an individual of working age was employed. Individual-level values are then summed to the household-level. Therefore, the means represent the average number of days that members of the household worked at a given job. Note that while the number of observations in each time period sum to the total number of observations, the number of households do not. This is because many of the same households appear in each survey time frame. The final column presents the results of Mann-Whitney two-sample tests for differences in distribution across survey time frames. Significance of MW-tests are reported in parentheses (*p<0.1; **p<0.05; ***p<0.01).

in any transaction, I can divide both income and employment by sector using the same definitions as are used at the national-level.

Dividing the data into even just two time periods, as in Table 4, presents a number of intriguing patterns. Using the Mann-Whitney statistic, I test if income, employment, and household size in each survey time frame are drawn from the same distribution.[5] In pairwise comparisons I reject the null that sectoral income in each survey time frame comes from the same distribution. Household income coming from the agriculture, industry, and service sectors were all significantly higher for households in the period coming after 2000 compared to the period prior to 1990. This is true even having converting income into constant 2010 Rupees. While household income is higher across all three sectors, where household members are working has changed. Household members spend significantly less time employed in agriculture and industry and significantly more time employed

[5] In this case the Mann-Whitney is preferred to a standard t-test. This is due to the highly skewed, non-normal distribution of input data. Unlike the t-test, the Mann-Whitney test does not require the assumption of a normal distribution and is nearly as efficient as a t-test when the underlying distribution is in fact normal.

in services across the two time frames. The smallest change is in time spent working in agriculture, which is unsurprising since the VDSA surveys rural households. Finally, household size significantly decreased between the survey time frames, falling from over six members to just below five.

4 Agricultural Transformation in the VDSA

I now return to the five stylized facts and use the VDSA data to explore whether they are present at the household- and plot-level.

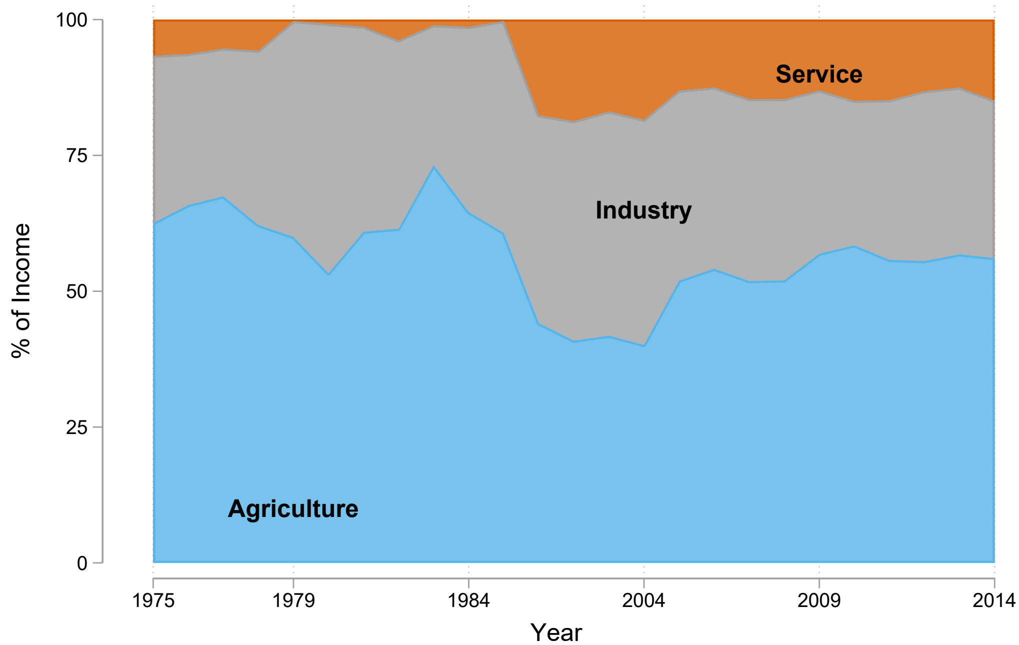
Stylized Fact 1 *Agriculture's output share and share of employment decline, in relation to industry and service.*

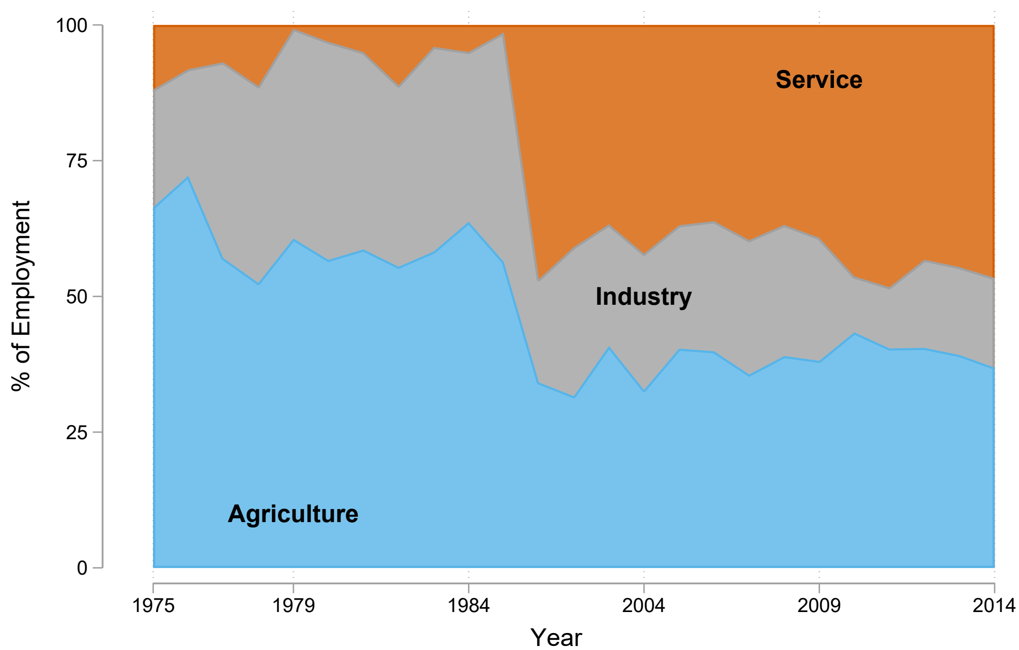
Over the 40 year period that the VDSA covers, both the share of agriculture in income and the share of agriculture in employment have declined (see Figure 6). Prior to 1990, income from agricultural activities consistently accounted for around two thirds of all household income. Though a slight decline is present during this period, the share of agricultural income dropped below 60 percent only once, in 1980. Sometime during the gap in the data (1990-2000), agriculture became a less import factor in household income. This decline mirrors the decline in the national data, though it is less dramatic.

During the years 2000 to 2004 agriculture tended to make up around 40 percent of total income. But starting in 2005 the share of agriculture in income began to rise. This increase corresponds with rising global food prices, however agricultural income in the VDSA villages continued to increase even after the Global Food Price Crisis abated in 2009. Since 2010, agriculture has made up between 55 and 58 percent of household income, well above the earl 2000s level but still below where it was in the 1970s and 1980s. The increase in agricultural income has come at the expense of industrial sector income, which fell from a high of 41 percent in 2004 down to 27 percent in 2010. A similar decline in the industrial sector is not present in the national data. The biggest sectoral shift in the VDSA villages has been the growth of service sector income. In the 1975 to 1989 period, income earned in the service sector accounted for, on average, three percent of total income. Since 2001, service sector income regularly accounts for 14 of total income. The increase in the share of income coming from the service sector is similar to what has occurred in India at the national level, though on a much smaller scale. This is likely an artifact of the VDSA being focused on rural villages.

The percentage of days a household spends working in the agricultural sector declined precipitously over the period 1975 to 2004. Where once a household spent 72 percent of its time in agriculture, by the mid-2000s this number was around 38 percent. This decline in agricultural labor appears to have taken place in two distinct periods. In the first period, roughly 1975 to 1980, agriculture declined at the expense of expanding industrial employment. After this initial decline,

Figure 6: Sectoral changes in income and employment





Note: Income is the sum of wages, crop and livestock production, and business transactions (i.e., selling of home produced goods and services). These are calculated at the individual- or household-level and then summed over all households by year. Employment is measured at the individual level as the total number of days an individual worked in each sector. This is then summed over households by year.
Source: VDSA (2015).

and throughout the 1980s, the division of labor between agriculture, industry, and service remained fairly stable. This period is also characterized by very low employment in the service sector. The second period occurred during the gap in data collection from 1990 to 2000. When data collection re-started in 2001, agriculture's and industry's shares had declined from their 1989 levels by 40 and 55 percent, respectively. Conversely, the service sector's share had increased by 840 percent from its 1989 level.[6] Throughout the 2000s, as was the case in the 1980s, the division of labor remained fairly consistent, though industrial sector employment continued to shrink.

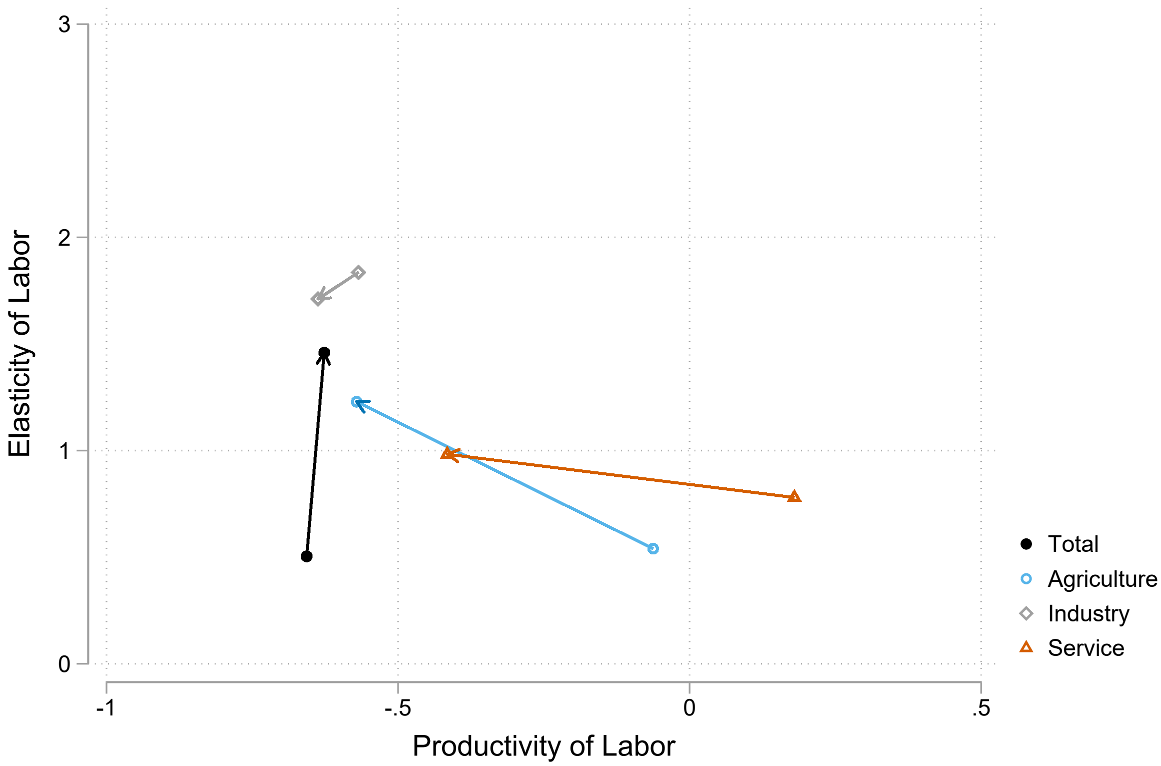
While there is an obvious correlation between sectoral income and employment, this correlation has begun to break down for agriculture. Prior to 2005, the correlation coefficient for agriculture's share of employment and its share of income was 0.87. But, since 2005 agriculture's share of income has been rising while the employment share has remained stagnant. The correlation coefficient since 2005 is 0.56, still highly correlated but much lower than the correlation between income and employment in industry during the same period (0.85) or in the service sector (0.95).

One explanation for the different trajectories that sectoral income and employment took is the differences between the elasticity of labor and the productivity of labor. Following Timmer (1991), I calculate the change in the elasticity of labor as the absolute value of the ratio of the growth rate in employment to the growth rate in income. I do this by sector for each household so that the growth rates measure the percentage change in employment and income within a household from one year to the next. Again following Timmer (1991), I calculate the annual rate of growth in the productivity of labor as the growth rate in income minus the growth rate in employment. The intuition is that if income and employment grow at the same rate then there would be no gains in labor productivity, while if income growth outstrips employment growth, the increase is due to improvements in the productivity of labor. These calculations are done by sector for each household. In order to understand how the value of these variables have changed over time, I take the average value for each of the two survey periods (1975-1989 and 2001-2014) and plot them against each other. Figure 7 graphs these empirical relationships.

Changes in elasticity of labor and productivity of labor differ across sectors. In agriculture, productivity growth of labor was negative in both time frames, meaning the household-level growth rate for employment in agriculture has tended to outstrip the household-level growth rate for income from agriculture. An alternative way to say the same things is that for households in the VDSA, income from agriculture has fallen at a more rapid rate than employment in agriculture. Similarly, both the industrial and service sector have experienced declines in the productivity of labor over the two survey periods, meaning that the household-level growth rate in employment has outstripped

[6] It is possible that some of the dramatic increase in both service sector employment and income is an artifact of improvements to the data collection process. While there has been no change in the employment or income schedule used to collect data pre- and post-2000, there is much more frequent occurrence of self-employment data (stitching clothing, selling vegetables, etc.) post-2000. I suspect that enumerators post-2000 did a better job of recording data on self-employment and income coming from self-employment, though there is nothing about the early employment and income schedules that would exclude self-employment data from being recorded.

Figure 7: Change in the elasticity and productivity of labor



Note: The figure compares the elasticity of labor from income growth with growth in the productivity of labor. Data points that are the average of values from 1975-1989 are connected by arrows to points that are the average of values from 2001-2014. Elasticity of labor is calculated as the absolute value of the ratio of the growth rate in employment to the growth rate in income. Growth in the productivity of labor is calculate as the growth rate in income minus the growth rate in employment.
Source: VDSA (2015).

the household-level growth rate in income by sector. Yet the total productivity of labor has barely changed from the earlier to later survey periods. The elasticity of labor may explain some of this apparent paradox. The elasticity of labor in both the agricultural and service sectors increased, moving from inelastic to elastic for agriculture and near unit elastic for service. The elasticity of labor in industry decreased slight but still remained well above unity. The implication is that the great elasticity of labor is due to households more frequent movement of labor from one sector to another, resulting in large sectoral changes in employment while sectoral income has remained relatively static. This gives the impression of falling productivity of labor in each sector while total labor productivity has remained constant.

Summarizing the sectoral changes in income and employment, the patterns present in the national data are partially born out in the VDSA. The share of agriculture in income and employment has declined while the share of service sector income and employment has increased. However, there are some noteworthy differences. First, there is more volatility and variety in the VDSA trends relative to the national trends. Some of this is due to averaging over hundreds of households instead of millions. But, as Figure 7 shows, some of these differences are likely due to the changing relationship between sectoral elasticity and productivity of labor. Second, agriculture as a share of income has actually increased in recent years. The reason for the initial rise in agricultural income seems to be the rising food prices in the late 2000s. Why agricultural income did not fall of once food prices collapsed is not readily obvious and deserves more investigation.

Stylized Fact 2 *Total agricultural output increases.*

In order to determine the average agricultural output in the VDSA, I estimate the mean and variance of yield for each crop in each season using local polynomial regressions that make no assumptions about functional form (Henderson and Parmeter, 2015). I present these results graphically, with a 95 percent confidence interval representing the variance. Confidence intervals that do not overlap, or that do not encompass the same values from year to year, represent statistically significant differences in the data. This affords me a convenient way to visualize the microeconomic evidence and compare it to the macroeconomic trends. For clarity, charts relying on household-level data are formatted in a consistent manner to those using national- or plot-level data.

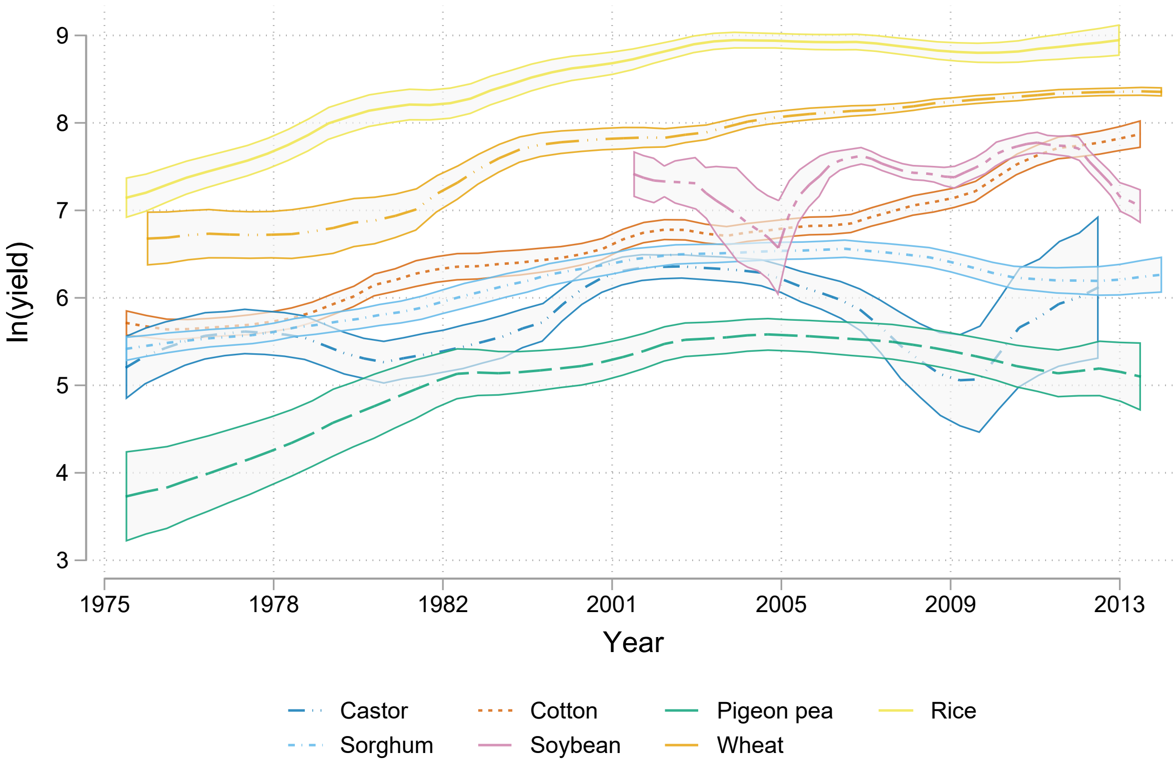
Trends in yields within the VDSA villages have been positive over the 40 year study period (see Figure 8). Similar to the national data, the levels of both rice and wheat yields and their growth rates tend to be greater than the other primary crops. Rice and wheat yields in both sources of data range between $2,500$ and $4,000$ kilograms per hectare, similar to yields reported in the national data.

Yet, the VDSA villages, because of their location in the semi-arid tropics, demonstrate several differences with the aggregate data. First, in the national data, yields for crops other than rice and wheat are all greater than 700 kilograms per hectare. In the VDSA only soy yields are at a similar level. The remainder of the crops (castor, cotton, pigeon pea, and sorghum) all lag behind the average yields at the national-level. Second, the VDSA clearly shows the rapid growth of soybean production at the expense of castor. Both crops are oil seed, though genetic improvements to soybean in the 1990s has resulted in greater disease resistance and higher yields relative to castor (Agarwal et al., 2013). Finally, maize is notably absent from the VDSA. After rice and wheat, maize is one of the most important crops in India. Maize is cultivated in the VDSA villages but their location in the semi-arid region of the country means that the crop is not one of the seven most commonly cultivated by households. Thus, while the overall trend of increased agricultural output is present in the VDSA, how those trends play out for individual crops is unique to these villages and the region where they are located.

I turn to the next stylized fact in order to further explore the reasons for differences in yield between crops within the VDSA and differences in yields between the VDSA and national data.

Stylized Fact 3 *Technical change follows a path of induced innovation.*

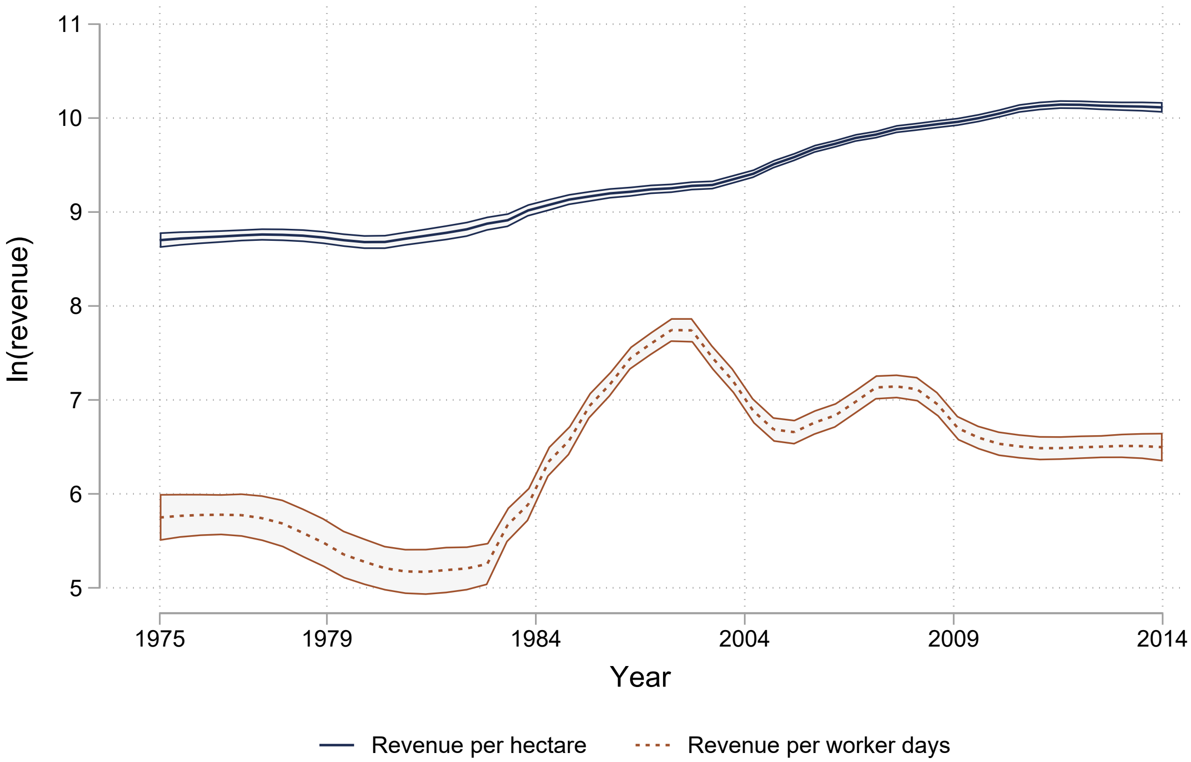
Figure 8: Mean seasonal yield by crop



Note: Yields are measured at the plot-level in kg/ha. Each line is the mean and 95% confidence interval for that crop's yield, estimated in each year using a local polynomial regression. Logs are taken using the inverse hyperbolic sine.
Source: VDSA (2015).

At the national-level, there is clear evidence of the induced innovation hypothesis. Consistent with the "Asian experience" (Timmer, 1988), productivity per unit of land has increased faster than productivity per unit of labor, in order to cope with small farm size. In the VDSA, I estimate the change in revenue over time using local polynomial regressions. Figure 9 shows that a trend similar to that in the national data is present in the household data. While productivity per worker in the VDSA has lagged behind the national average, revenue per unit of land has run well ahead of the national average. As in the national data, productivity per worker grew during the study period but at a slower rate than productivity per hectare. One exception in the VDSA to the slow growth of revenue per worker was the period 1980-1989, which saw a rapid increase in labor productivity. This coincides with the period of declining agricultural employment, and stable agricultural income, in Figure 6. The increase in productivity per worker may have pushed labor out of agriculture or the increasing elasticity of labor may have pulled labor to new sectors, requiring increases in agricultural productivity in order to maintain output levels. While I am unable to ascribe causation or directionality of effects, what is clear is that, similar to the nation

Figure 9: Revenue per hectare and worker



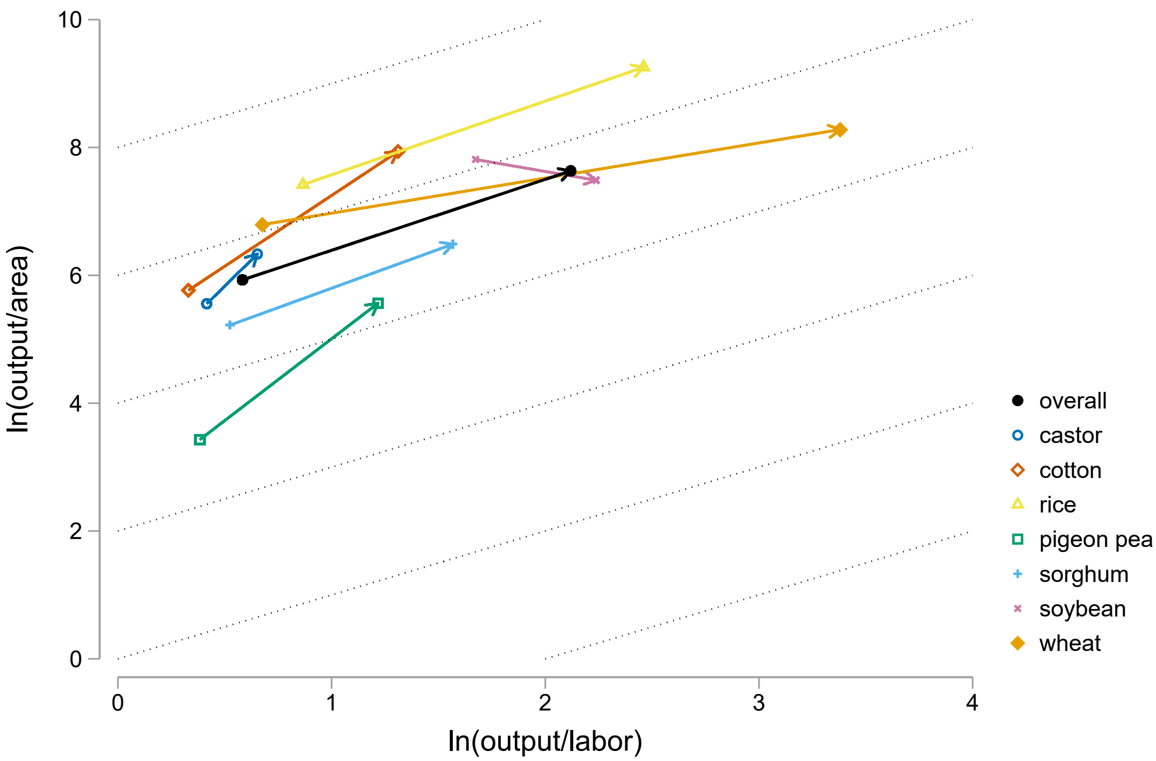
Note: Revenue is in constant 2010 Rupees. Each line is the mean and 95% confidence interval for that measure of productivity, estimated in each year using a local polynomial regression. Logs are taken using the inverse hyperbolic sine.
Source: VDSA (2015).

as a whole, households in the VDSA villages have experienced technical change biased towards land-augmenting innovations.

To further explore how productivity has changed over time, I construct a graph along the lines of Hayami and Ruttan (1985) and Timmer (1988) that compares labor and land productivity in agriculture (see Figure 10). Hayami and Ruttan (1985) conduct a cross country comparison while I examine changes across crop. Every crop saw improvements in both dimensions of productivity, except soybean, which saw an increase only in output per unit of labor. Most crops had faster increases in land productivity than in labor productivity, thus presenting patterns of change "steeper" than the 45° lines in the graph. Of the six crops cultivated since the beginning of the survey, only wheat had a "flatter" pattern of productivity improvement, meaning labor productivity increased faster than land productivity. The implication is that castor, cotton, rice, pigeon pea, and sorghum saw a decrease in area per worker while wheat saw an increase in area per worker.

There are two components to understanding what is driving induced innovation in India. First is the introduction of land saving innovations stimulated by changes in the relative prices of labor

Figure 10: Patterns of change in agricultural productivity



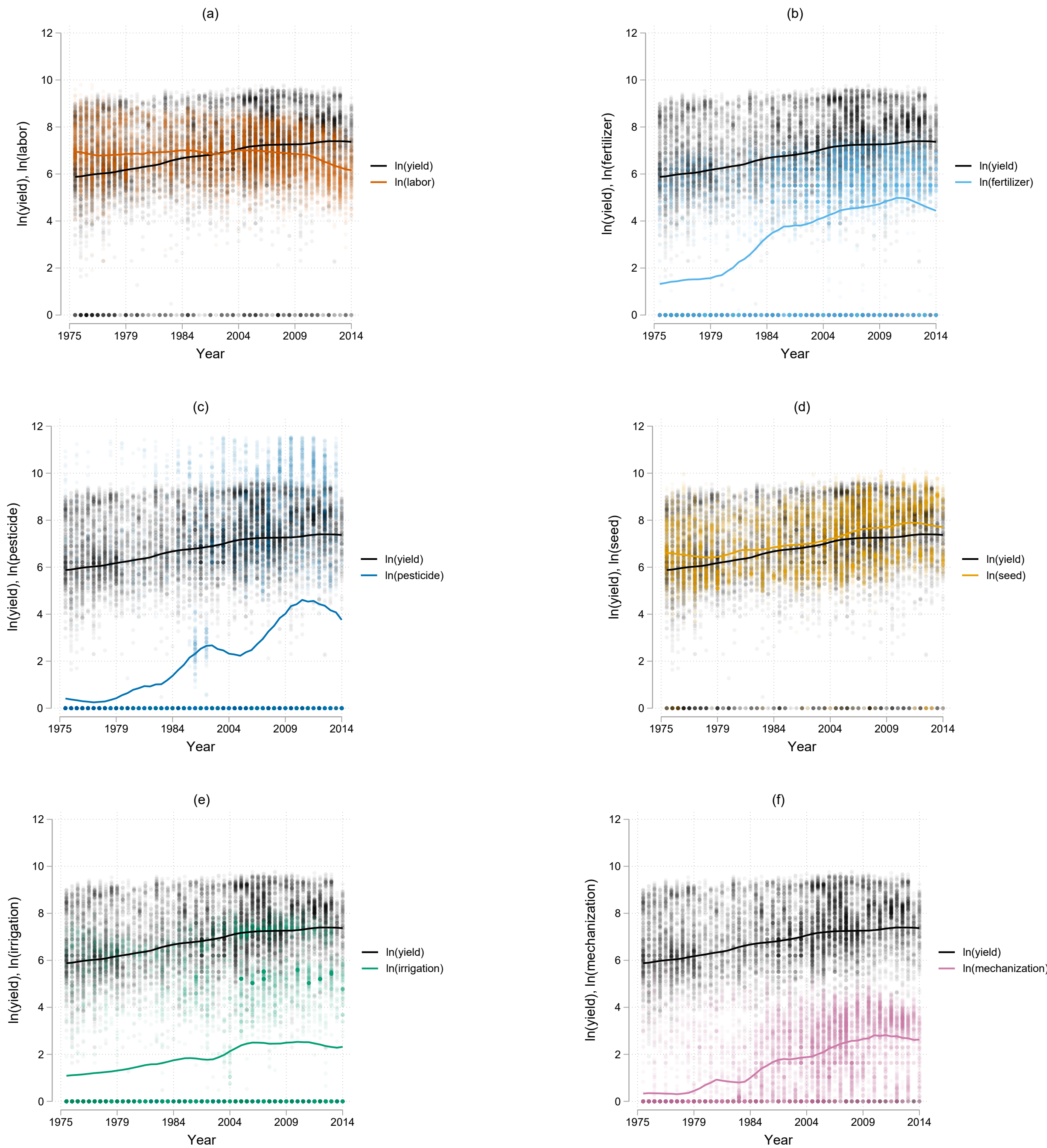
Note: The figure compares labor and land productivity in agriculture, the 1975 data points connected to the 2014 points by arrows. The one exception is soybean, where the first year of data is from 2002. Dotted lines are drawn at 45° angles. Logs are taken using the inverse hyperbolic sine.
Source: VDSA (2015).

and land. This is the typical understanding of the cause of induced innovation. But, in India there is a second factor, which is the change in input prices relative to output prices. In order to better understand the role of these two drivers of increased land productivity, I use non-parametric regressions and graph the resulting trends in output and input use over time (see Figure 11) as well as trends in the relative prices of inputs and output (see Figure 12).

In Figure 11, each panel presents a scatter plot of yields over time.[7] I then overlay input use per hectare over time, with each panel displaying a different input. Dots are semi-transparent in order to show where the bulk of the data lies. To these scatter plots I add trend lines using local polynomial regressions. Panel (a) shows that over time output per hectare has increased despite labor use per hectare decreasing. This represents an increase in labor productivity, holding land constant, which can be seen in Figure 10 by the rightward orientation of each arrow. These results are also consistent with those in Figure 9, which measures revenue (price × output) per worker

[7]The same yield data is used in each of the six panels.

Figure 11: Yield and input use over time



Note: Black dots represent plot-level yields while other colors represent plot-level labor, fertilizer, pesticide, seed, irrigation, and mechanization use per hectare. The solid lines are the mean for that variable, estimated in each year using a local polynomial regression. Dots are semi-transparent in order to show where the bulk of the data lies. Logs are taken using the inverse hyperbolic sine.
Source: VDSA (2015).

(number of agricultural labor days). While there are fewer labor days spent on agriculture in the VDSA villages in 2014 than in 1975, those fewer hours result in more output than in the past.

Of the six inputs I examine, labor in panel (a) is the only one where intensity of use has decreased over time. This reflects not only the reduction in employment in agriculture (Figure 6) but the increase in yields (Figure 8) that occurred over the same time. It also reflects the increase in use of labor-saving mechanization, measured in hours, in panel (f). Using the detailed cultivation schedules to track inputs, over 90 percent of machinery use in the 1970s was electric or diesel pumps for irrigation. The 1980s saw an increase in the use of mechanical threshers, which accounted for about 20 of machine-hours. The use of irrigation pumps stayed relatively flat, though its share of machine-hours fell to 70 percent. During the 1990s, India began a process of market liberalization, reducing tariffs and interest rates, and allowing for a floating exchange rate (DeLong, 2003). This allowed for greater access to mechanical inputs which we see reflected in the VDSA data. In the second period of data collection (2001-2014), irrigation pumps accounted for only 30 percent of machine-hours and threshers fell to only 10 percent. The use of tractors now accounted for 25 percent of machine-hours while sprayers made up 20 percent. These changing dynamics in machine use shows how VDSA households were able to increase production on a fixed amount of land while at the same time reducing employment.

Along with mechanization, the use of fertilizer (kg), pesticide (Rupees), seed (Rupees), and irrigation (hours) have all increased in real and per hectare terms. This, however, does not imply that each input presents similar levels of productivity. In fact, the remaining four inputs can be divided into three categories by how their productivity has changed over time. First, in panel (d), output per Rupee of seed planted increased from 1975 till 1984 as farmers obtained higher yields for the same investment in seed. This appears to be the tail end of the Green Revolution. By the time that enumerators returned to the VDSA villages in 2001, productivity per Rupee of seed was decreasing. Seed productivity is back to where it was in the 1980s, though it is still significantly above its 1970s-levels.

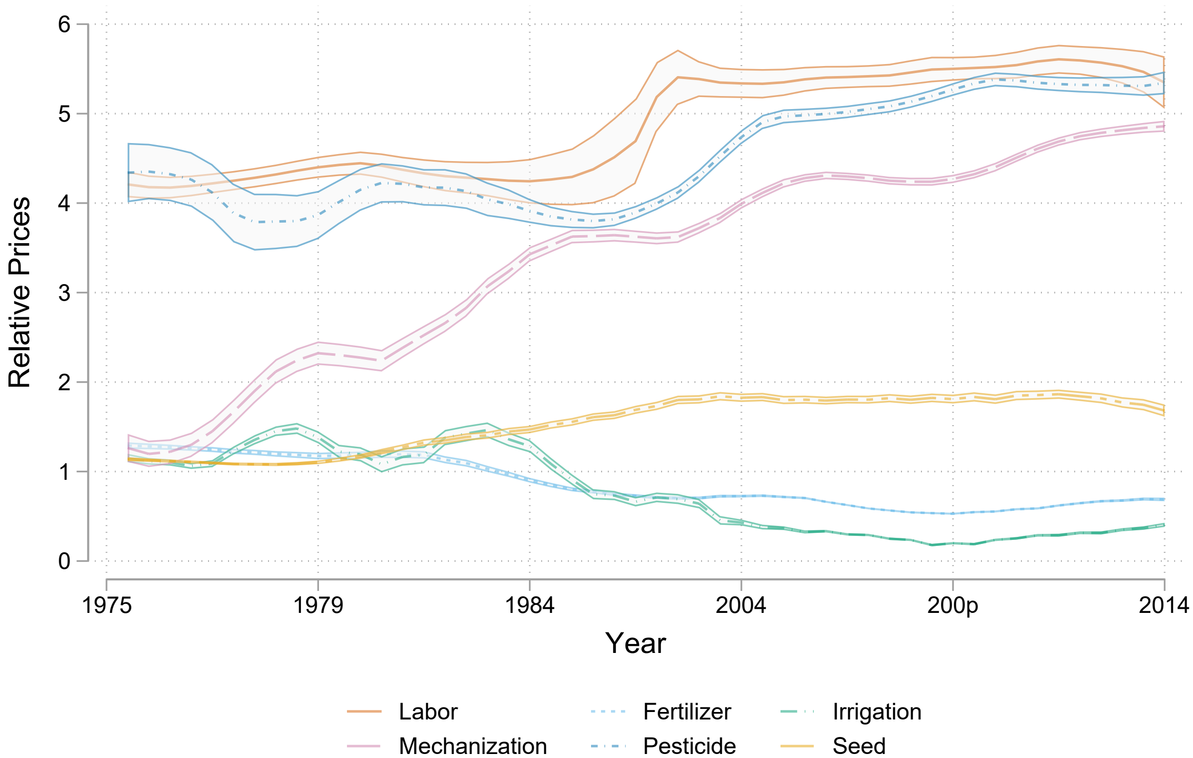
The second group of inputs includes irrigation and pesticide use in panels (c) and (e). Productivity of these two inputs has remained remarkably constant over time, so much so that the slope of a linear trend line fit to either group of data is not significantly different from zero. Yet the use of these two inputs are very different. Farmers applied slightly more irrigation in 2014 then they did in 1975, but the increase in irrigation hours per hectare has mirrored the increase in output per hectare, meaning productivity of irrigation is unchanged. In comparison, panel (c) shows the dramatic increase in pesticide use over the study period, a much larger increase in real terms relative to the increase in output. Yet this increase in pesticide use has been primarily due to farmers moving from zero pesticides to some positive amount of pesticides. The result is that, among pesticide users, productivity of pesticide has remained remarkably stable over the 40 year period, despite the increased use of sprayers to allow for more efficient application.

In contrast to the constant returns provided by irrigation and pesticide, returns to fertilizer have diminished over time. Similar to pesticide, the use of fertilizer has rapidly increased, though unlike pesticide, the amount of output gained from a unit of fertilizer was lower in 2014 than it was in 1975. Over the 40 years, output per kilogram of fertilizer has continually decreased, except for a slight uptick since 2009. This suggests over-investment in this land-augmenting technology, as farmers are adding ever increasing amounts of fertilizer but getting smaller and smaller increases in output. Returns per kilogram of fertilizer are now below where they were in the late 1970s. This is unlikely due to any biophysical response of seeds to fertilizer but rather reflects overuse of fertilizer resulting from the Indian Government's subsidy program. Starting in 1979 the government began to subsidize the price of complex fertilizer, such as DAP (Sharma and Thaker, 2010). Fertilizer use in the VDSA responded almost immediately, increasing from what had been fairly stable levels of use in the 1970s. The economic liberalization in the 1990s reduce restrictions on fertilizer inputs while extending and expanding price subsidies (Prasad, 2009). The effects of these policies are likely the cause of the increased use, and eventual overuse, of fertilizer by VDSA households.

Besides changes in national policy, differences in the application of and returns to inputs can be explained by differences in the local prices of inputs relative to local output prices. Figure 12 estimates the change in the relative price of each input to output using local polynomial regressions. In examining the results, a clear story emerges for many of the inputs. Over the 40 year period, labor prices have risen relative to output prices. This increase in the price of labor supports evidence of structural transformation coming from the first stylized fact. It also is one explanation for why labor input use has fallen over time in the VDSA villages. Similarly, farmer responses to the fall in the relative price of fertilizer and irrigation comport with basic economic reasoning. As the relative price of fertilizer has fallen, use of the input has increased. In fact, it has increase so much that returns to fertilizer are now decreasing. With irrigation, the level of input use has increased as the price has fallen. However, unlike with fertilizer, the returns to an hour of irrigation have remained constant over time. This may be because it is easy to observe when too little or too much water has been applied, whereas fertilizer's effects are delayed and less visible, making it easier to over-apply fertilizer.

Unlike fertilizer and irrigation, the price of pesticide, seed, and mechanization have all increased. Yet farmers have not responded to these price increases by reducing input use, as they did with labor. Rather, application rates of pesticide, seed, and mechanization have all increased as the price has increased. In the case of pesticides, the increased use has been commensurate with increases in output. Despite the higher relative price for pesticide in 2014 compared to 1975, a unit of pesticide results in about the same amount of output. While this suggests that farmers are not over-applying pesticides like they are fertilizers, the profitability of pesticide use has fallen. A similar story can be told regarding seed application rates, where the relative price, and one would assume the relative value, of seed has increased. Yet in the ten year period between 2004 and 2014, the amount of

Figure 12: Relative prices of inputs and output



Note: Relative prices are calculated as the real price of an input divided by the real price of output. Each line is the mean and 95% confidence interval for that price, estimated in each year using a local polynomial regression. Logs are taken using the inverse hyperbolic sine.
Source: VDSA (2015).

output produced from each Rupee spent on seeds declined. This again suggests that farmers are spending more money on improved inputs without translating them into increased yields or higher profit.

At first glance, the relationship between the relative price of mechanization and the increased use of machinery appears to contradict the law of demand. Compared to all other inputs, the price of mechanization has risen the most, increasing five-fold. At the same time, the number of hours a household uses machinery has risen eight-fold. Curiously, the returns to an hour of mechanization have decreased over time. It appears that farmers in the VDSA villages are using more machinery at ever higher costs while also getting less output from that machinery. A plausible solution to this conundrum is to recall that the types of machines used in village India tend to be labor-saving. Unlike Timmer's (1988) "new continent" path for induced innovation, which increases the amount of land an individual can cultivate, the mechanization of Indian agriculture has been as a substitute for labor. The majority of machinery hours (89 percent) were used for either the pumping of water, the spraying of chemicals, the threshing of grain, the preparing of fields, or transportation. In an environment where the availability of agricultural labor is decreasing, resulting in an increase in the price of labor, an increase in the use of labor-saving machinery, despite increasing prices, can make economic sense. Future research will need to investigate this phenomenon, especially since it appears that farmers are no longer getting the same level of output per unit of mechanized input.

Summarizing the data presented in Figures 9-12, there is clear evidence of technical change in the VDSA villages following a path of induced innovation. This path is the same one that the nation of India as a whole has followed - increased productivity along the intensive, as opposed to the extensive, margin. All crops, save for wheat and the late introduced soybean, have followed this same pattern of more rapid growth in productivity per unit of land compared to productivity per unit of labor. Driving this increased land productivity is an increase in land-enhancing inputs as well as changes in the relative price of inputs to output. However, these changes in production practices have resulted in the overuse of some inputs, such as fertilizer.

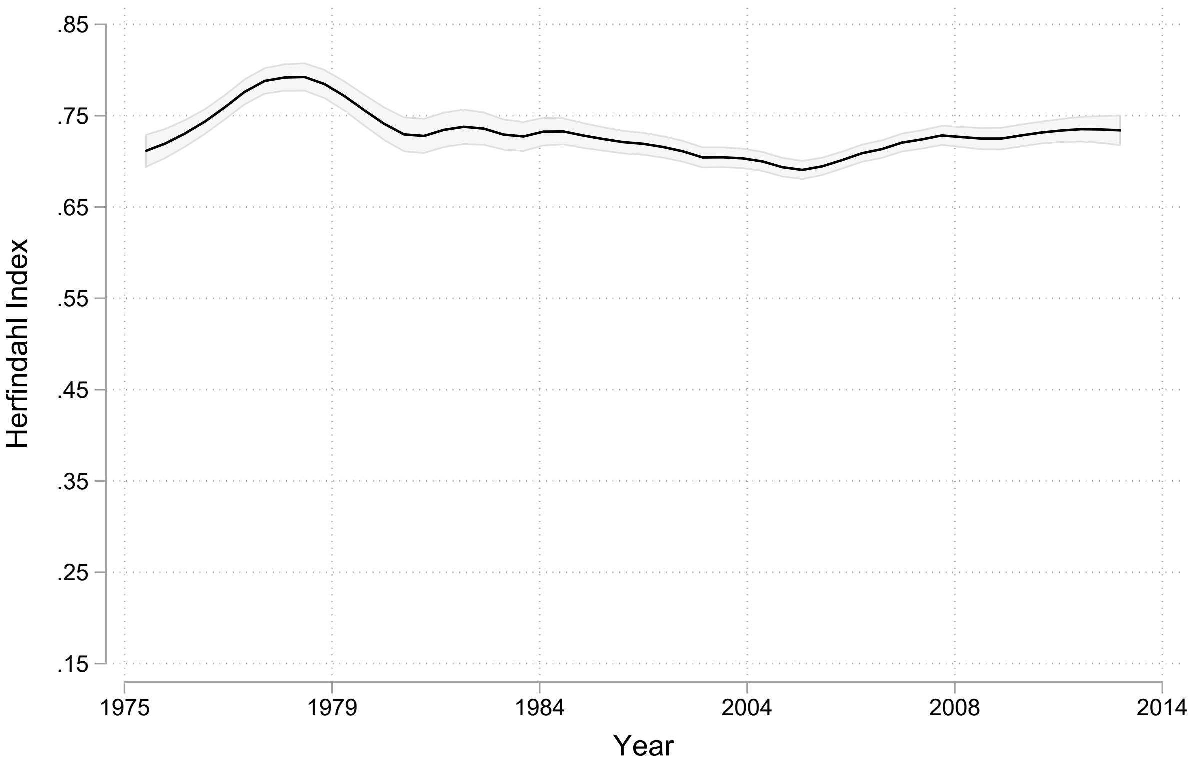
Stylized Fact 4 *Within agriculture, specialization increases.*

Besides technical change, another potential driver of productivity is increased specialization. At the national-level, the *prima facie* evidence is that the degree of specialization in Indian agricultural has not changed since the 1960s. This could be the result of calculating the Herfindahl index at the nation-level, especially for a country like India, that spans several agro-ecological zones. It is not hard to believe that Indian agriculture will never be particularly specialized as each region produces products suitable to its climate, soil, and tastes, though evidence from the U.S. suggests the index could increase. Thus, the VDSA is particularly valuable as it tracks agricultural production in a single region over a 40 year time span.

Figure 13 graphs changes in the Herfindahl index over time. Here the Herfindahl index is calculated first by summing at the household-level the value of each crop in each year. I then total the value of agricultural production for each household in each year and each crop's share in total value. From this I calculate the index for each household and use a local polynomial regression to estimate the change in the mean and variance over time. Similar to the national data, there is only a small change to the level of specialization over time. Again, the slope of a linear trend line is not different than zero. However, unlike India as a whole, the average household in the VDSA is highly specialized. Most households cultivated multiple crops but focus on a single primary crop that generates most of their production value.

That the VDSA villages are more specialized in crop production relative to the whole of India is not particularly surprising. What is surprising is the level of specialization that I observe in the VDSA, given previous research on these villages. Early work by Binswanger and Rosenzweig (1986), Rosenzweig (1988), and Townsend (1994) explored how households in the villages attempted to cope with risk by diversifying their portfolio of income sources. This included relying

Figure 13: Specialization in household agriculture

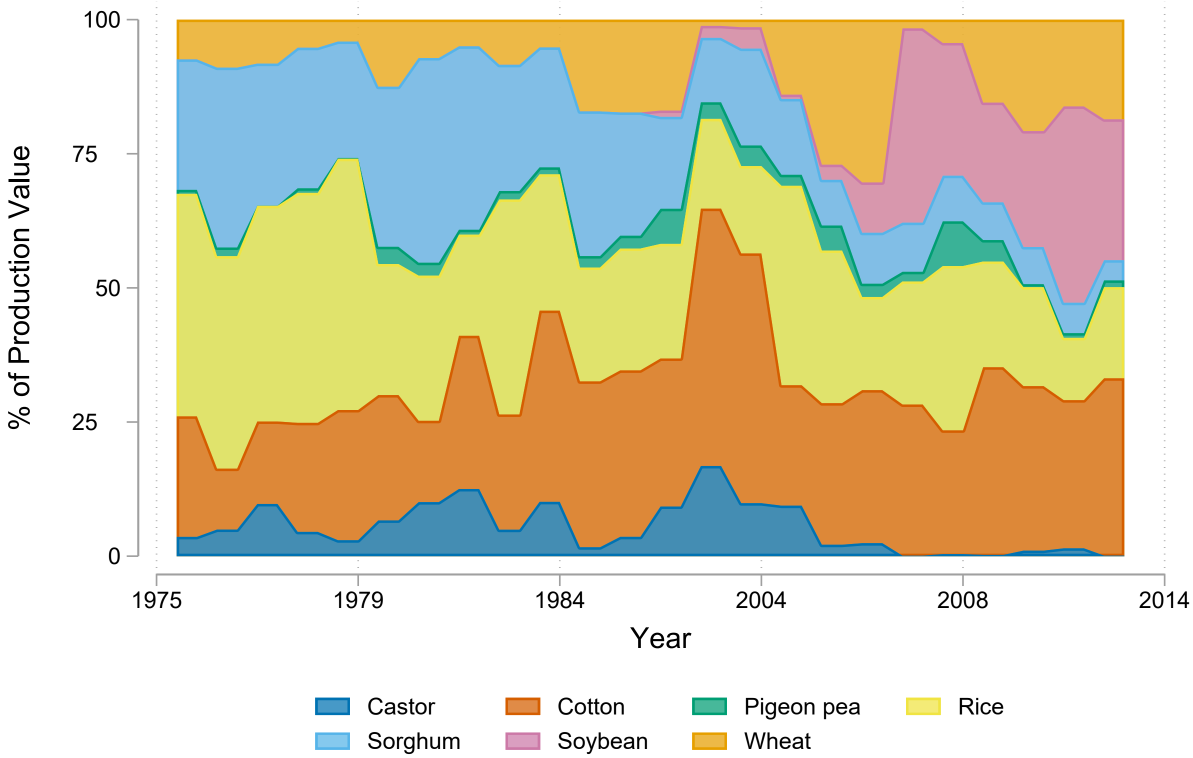


Note: Herfindahl index is calculated each year at the household-level as $H = \sum s_i^2$, where i is the crop type. Shares are measured using production value, calculated with data on the unit price of output collected as part of the cultivation schedule of the survey, converted to constant 2010 Rupees. The graph presents mean and 95% confidence interval for the Herfindahl index, estimated in each year using a local polynomial regression.
Source: VDSA (2015).

on neighbors to insure against idiosyncratic shocks (Townsend, 1994), and the use of migration (Rosenzweig, 1988) and diversification in crop production (Binswanger and Rosenzweig, 1986) to insure against covariate shocks. These studies have contributed to the notion that for small-holder farmers diversification is a viable way to deal with the exigencies of being poor (Michler and Josephson, 2016). Yet, as all these authors have noted, the optimal portfolio mix, be it for employment or crops, depends on the relative magnitudes of the variance and covariance of wages or yields. In the case of crop production by VDSA households, it may be the case that specializing in a few crops with sufficiently low covariance, because they are grown in different seasons or have different input requirements, allows for a sufficient portfolio mix while also allowing households to specialize and take advantage of the Ricardian theory of comparative advantage.

To explore this idea, I examine the production value for each crop as a share of total value. Households tend to specialize in two of four crops, growing either sorghum or wheat in *Rabi* and either cotton or rice in *Kharif*. This focus on a single crop in each season results in a relatively high

Figure 14: Share of production value for each crop



Note: Shares are the sum of the production value of each crop in each year. Production value is measured using data on the unit price of output collected as part of the cultivation schedule of the survey, converted to constant 2010 Rupees.
Source: VDSA (2015).

Herfindahl index while also allowing households to preserve a portfolio mix with sufficiently low covariance. It is also interesting to note that while the Herfindahl index has not changed over time, the household pattern of production has evolved. Households have replaced one type of crop with another, while maintaining a clear two-season primary cropping focus. In 1975 two crops dominated production: sorghum and rice (see Figure 14), making up over 60 of total production value. Over time, the value share of production of these two crops has shrunk, only to be replaced by cotton or soybean in *Kharif* and wheat in *Rabi*. This change likely reflects a combination technological advances and market forces. For cotton, the introduction of genetically-modified *Bt* cotton in 2002 has had substantial impact on yield and income for adopters (Kathage and Qaim, 2012). Less dramatic has been the impacts of genetic improvements to soybean (Agarwal et al., 2013). These technological advances were aided by the increase in commodity prices in the late 2000s associated with the Global Food Price Crisis. In particular, soybean and cotton prices continued to increase even as most other commodity prices stabilized or declined after the Great Recession. The result is that households continue to innovate in production, by adopting new crops and by applying new input technologies, even as they remain focused on a small set of crops.

Stylized Fact 5 *Farm income first declines but then increase.*

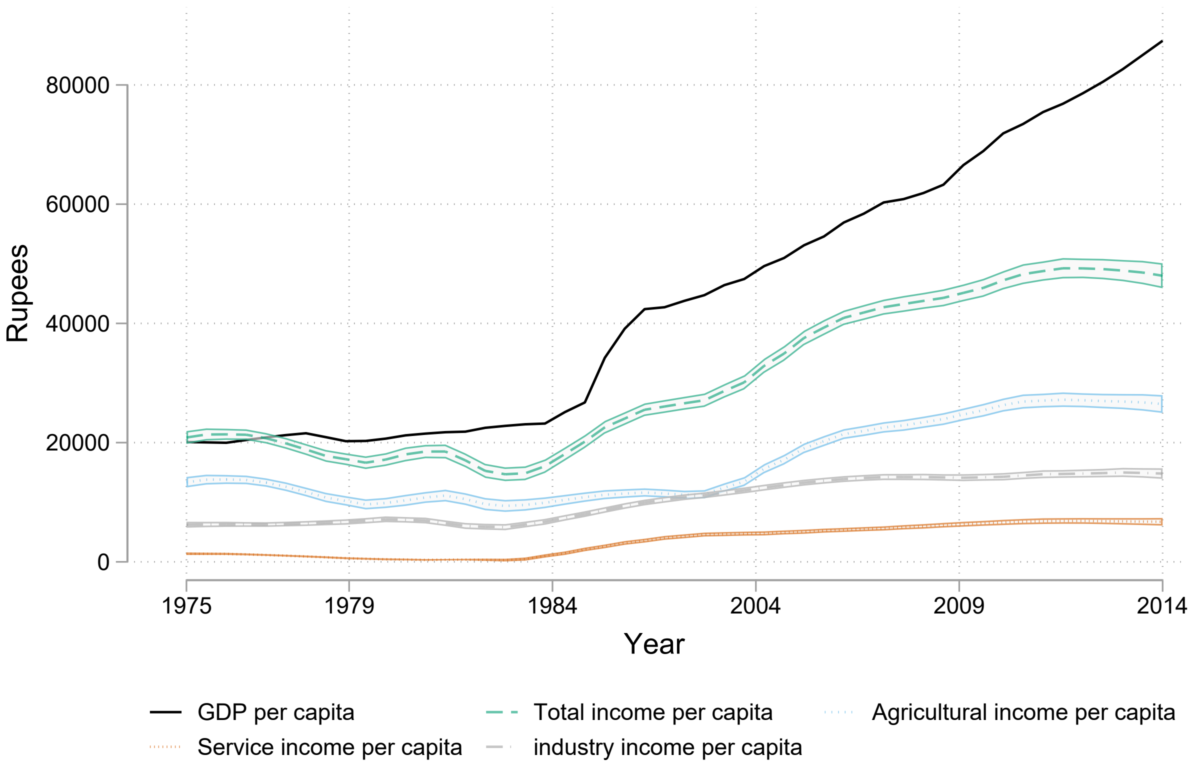
Figure 15: Agriculture earnings gap

Note: Earnings gap is measured at the household as income share minus employment share. Each line is the mean and 95% confidence interval for the variable, estimated in each year using a local polynomial regression.
Source: VDSA (2015).

In developed countries, the historical trend was for agricultural employment and output to initially fall together. At some point, though, employment would fall faster than output, resulting in a increase in agricultural earnings per household and a closing of the earnings gap. In the national data there was clear evidence of an agricultural earnings gap and some evidence that this gap was slowly closing. In the VDSA household data we see that agricultural income and employment have already converged, if an earnings gap ever existed (see Figure 15). In the initial years of the VDSA data, the earnings gap hovered around zero, with agricultural income and employment generally declining at the same rate. However, starting around 2004, both agricultural income and employment began to grow, coinciding with the global rise in food prices. During the decade from 2004 to 2014, agricultural income increased at a faster rate than agricultural employment, resulting in a positive earnings gap, which has persisted long after the Global Food Price Crisis abated in 2009.

The fifth stylized fact is not just about agricultural income, measured by the agricultural earnings gap, but is more broadly about farm income, which includes non-farm income earned by the farm household. Agricultural income per farm may or may not exceed agricultural employment per farm because of the continued existence of small, part-time farms. But, farm household income should eventually increase. In developed countries such as the United States, farm income is now well above the U.S. median income, but the share of agricultural income for the farm household is below that median (Tomich et al., 1995). Figure 16 explores this phenomenon by comparing sectoral and total per capita income for the VDSA households with GDP per capita in India.

Figure 16: Farm household income



Note: Total income is the sum of income earned in each of the three sectors by the entire household in a given year, converted to constant 2010 Rupees. This is then divided by the total number of members in the household. GDP per capita is converted from constant 2010 USD to constant 2010 Rupees using the exchange rate on 31 December 2010. Each line is the mean and 95% confidence interval for that measure of income, estimated in each year using a local polynomial regression.
Source: VDSA (2015), World Development Indicators.

Farm household income has indeed increased over the VDSA survey period, and initially this increase closely tracked income at the national-level. The increase in income for the VDSA households has come from an increase in income from all three sectors. However, what has been driving the income gains are increases in income from agriculture, which has nearly tripled since 2001. By comparison, incomes from industry and service have each increased by around 50 percent. While income in the VDSA villages has substantially increased over the study period, the villages have begun to fall behind mean income in India, as measured by GDP per capita. The overall impression is that households in the VDSA villages are engaged in an agricultural transformation from subsistence to commercial agriculture instead of the broader structural transformation from agriculture to industry and services that is occuring at the national-level. This unique path is indicative of the uniqueness of the VDSA villages themselves, which are rural and semi-arid. The concern is that the continued focus on agriculture, while profitable, is resulting in a decrease in relative income. Investigating how VDSA households could better participate in the gains in income at the national-level would be a fruitful line of new research, since little to no evidence exists on how the integration of these rural households into the global economy has changed over time.

5 Lessons Learned

That the national-level stylized facts are present in the household data should provide encouragement to governments, donor agencies, and development practitioners. While the data cannot speak to causal directionality regarding if development is trickling down or trickling up, it does show that households in village India are participating in the larger overall development trends. That said, the differences between national and village outcomes are informative.

First, while agriculture's share of income initially declined, since 2004 it has been on the rise in the VDSA villages. Second, yields in the VDSA villages are increasing, though for many crops they still lag behind national averages. Third, households in the VDSA have increased output per hectare at a more rapid rate than at the national-level, though this growth is associated with the overuse of some inputs. Fourth, VDSA households practice a highly specialized form of agricultural production, transforming their crop portfolio as new seed technology has become available. Finally, unlike in the national data, there is no evidence of an agricultural earnings gap in the VDSA village, though household income per capita has fallen further and further behind GDP per capita.

The overall impression is that households in the VDSA villages are engaged more in an agricultural transformation than a structural transformation as outlined in Timmer (1988). While there has been movement out of agriculture and into industry and service, the importance of agriculture as a source of income has actually grown in the last decade. This reflects the increased commercialization and industrialization of agriculture in these villages, yet income per capita has not increased as fast as GDP per capita. What explains the process of development in the VDSA villages remains an open question. The villages may simply be unique among other villages in rural India, charting their own path parallel to but distinct from their neighbors' and the nation's as a whole. Alternatively, the differences may be indicative of how rural villages in India participate in the nation's overall economic growth, focusing on agriculture-led growth instead of rural industrialization or rural-urban migration.

What this means for policymakers is that the transformation in village India broadly follows the national trends, though one must be cognizant of where the differences lay. It also means that, unlike in Christiaensen (2017), the primary stylized facts of structural transformation that policymakers and economists have come to believe in are true; at least in India. Stylized facts help set the development policy agenda and that I find evidence for these stylized facts in both the macro and micro data should provide confidence in the now almost 70 year old story we tell ourselves about agriculture's role in the process of development.

What this evidence does not mean is that specific policies, past or present, work. Nor should the results in this paper be taken to imply that the micro-focused development agenda of the past several decades has significantly impacted the ongoing transformation in India. Much of the transformation in village India occurred during the 11 year gap from 1990 to 2000 when the VDSA was dormant. Since 2000, the changes taking place in village India have been more muted. This slowdown does not appear to be the inevitable reduction in the rate of change as growth rates converge. Rather, to some extent, it appears to be the continued focus on smallholder agriculture unaccompanied by any growth in industrial and service income.

The evidence presented here also raises a number of questions for policymakers. First and foremost is, has macroeconomic policy driven changes that have trickled down to the household or have microeconomic interventions driven changes for the household that, when aggregated, have had a macroeconomic impact? On the one hand, the recent development focus on microeconomic interventions does not appear to be manifesting itself in dynamic growth for the VDSA villages. On the other hand, structural transformation was clearly underway in the villages during the 1970, immediately after the introduction of Green Revolution technology and prior to economic liberalization in India. A second question raised by the data is, why has there been no increase of specialization in agricultural production? While even commercial farms tend to be multi-product firms, that no linear trend towards specialization or diversification exists is curious. A third question is, why is income per capita falling further behind GDP per capita? Is the failure of VDSA households to capitalize on recent growth due to where India is in the development process, implying that they will eventually see their income catch up? Or are key policies that allowed farm income to rise above median income in developed countries missing in India? A final question raised by the data is, how much additional improvement in yields, and by extension income, can be achieved by interventions at the household-level? While much has changed in village India in the past 40 years, agricultural production in the villages is still defined by smallholder farmers. As Collier and Dercon (2014) point out, the radical transformation one would expect to see as agriculture moves from subsistence to commercial production has not materialized. To what extent is this the result of the current micro-focused development policy that looks to increase productivity through genetic gains and improved efficiency in input and output markets? Are there alternative policy proscriptions, such as those that facilitate rural to urban migration, that are better suited to helping India complete its ongoing structural transformation?

While this paper raises as many questions as it answers, the key lesson is that even in village India households are able to engage in the process of development. They adopt new technologies that are biased towards scare resources, allowing them to increase production and release labor for wage earning in the industrial and service sectors. That the macroeconomic stylized facts of structural transformation have micro-foundations should not be surprising, however this is the first paper to demonstrate that this intuition does in fact hold.

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