Agricultural Growth in India:

Examining the Post-Green Revolution Transition

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Abstract

India has enjoyed rapid economic growth over the past forty years, GDP per capita (PPP$) accelerating from less than 1% in the 1970s to over 5.8% in the 2000s. As incomes have risen, consumer demand has shifted from staple grains toward higher valued foods, such as horticultural and livestock products. Indian farmers appear to be meeting these new growth opportunities. But as production shifts, questions are being raised about agriculture's ability to meet the basic food needs of India's 1.24 billion citizens. Central to these questions has been the waning impact of cereal grain technologies typified by the Green Revolution. Our purpose is to examine the productivity growth implications of farmers' decisions to diversify production and to assess new sources of growth in Indian agriculture. In doing so, we construct new production and productivity accounts and evaluate total factor productivity (TFP) growth, from 1980 to 2008, at the national, regional, and state levels. Results suggest renewed growth in aggregate TFP growth despite a slowdown in cereal grain yield growth. TFP growth appears to have shifted to the Indian South and West, led by growth in horticultural and livestock products.

Keywords: agricultural growth, India, Tornqvist-Thiel, TFP growth, agricultural diversification

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India has enjoyed rapid economic growth over the past forty years, GDP per capita (PPP$) accelerating from less than 1% in the 1970s to over 5.8% in the 2000s (World Bank, 2012). As incomes have risen, consumer demand has shifted toward higher valued foods, such as horticultural and livestock products (Binswanger-Mkhize and d'Souza, 2012). Indian farmers appear to be diversifying production to meet these new growth opportunities, the share of area planted to primary food grains declining in each decade since the 1980s (Singh and Pal, 2010). Our purpose is to evaluate India's agricultural performance in a post-Green Revolution time frame, a period capturing its recent agricultural diversification. In particular, we assess the national, regional, and state total factor productivity (TFP) growth implications of Indian farmers' decisions to diversify production toward meeting consumers' new food demands.

Indian farmers' production decisions have long been affected by a government policy emphasis on "Green Revolution" technologies to achieve self-sufficiency in wheat and rice. Since the 1960s, support to farmers in the form of input subsidies to seed, fertilizer, and water, as well as through grain market support prices and government procurement programs have contributed to shaping an agricultural sector that is heavily invested in specific commodities and is highly regionalized (Shreedhar, et al., 2012) Indeed, prolonged policy preferences toward the Indian North and highly subsidized irrigation-seed-fertilizer technology packages have resulted in overinvestment, some of India's rainfed areas now providing a greater return to public investment in farm productivity than found in irrigated areas supporting cereal grain production (Fan and Hazell, 2000).

We assess India's agricultural diversification in two ways. First, we decompose the sector's production growth by political boundary and commodity. Second, we decompose aggregate crop output growth into area growth and growth in aggregate crop output per hectare. The latter is further decomposed into growth in average crop yield and growth in average crop land share. Growth in average crop yield reflects changes in production per hectare and growth in average crop land share reflects changes in the allocation of resources to the production of higher valued crops. We then construct new, 1980-2008, national, regional, and state agricultural total factor productivity growth accounts to examine how diversification has affected India's agricultural performance. In constructing the productivity accounts, we pay special attention to estimating the contribution of irrigation investments to growth.

Results suggest a renewal of farm TFP growth in India following the economic reforms of the 1990s, led primarily by horticultural and livestock products and by the Indian South and West. Indeed, the high-input farming system championed by the Indian North, the epicenter of Indian Green Revolution cereal production, has been out-performed by more diverse farming systems producing higher valued commodities. Moreover, we find that growth in aggregate crop output has been largely balanced between raising average crop yields and incorporating new land in production and re-allocating existing land to higher valued commodities. Our evaluation of Indian agricultural productivity is not, however, without limitations. Notable examples include a return-to-land measurement of land's cost share and a lack of feed inputs and on-farm poultry stocks.

A Review of Indian Agricultural Productivity

Concern has been raised over India's diminishing cereal-grain yield growth rates (Ray, et al., 2012). Constructing Indian wheat, rice, and maize yields between 1957 and 2012 by decade

suggests that indeed, there does appear to be reason for concern, particularly regarding the performance of wheat and rice (Table 1).[1] Re-affirming that concern, Chand, et al. (2011) find average annual TFP growth of Indian wheat declined from 0.74% in the 1986-1995 period to 0.4% in the 1996-2005 period, while rice TFP growth fell from 2.51% in the early period to 1.61% in the later period.

If, however, we employ a more statistical approach to framing the yield growth estimates, a different impression emerges (Table 1). Chand and Parappurathu (2012) provide new estimates that differentiate India's 1960-2011 agricultural growth into six separate periods of development. Representing the yield growth estimates by these development periods suggests that post-2005 rice and wheat yields have achieved growth rates not experienced since the 1980s, and the number of states experiencing stagnant or negative growth has fallen to their lowest historical levels.

While the recent improved performance of wheat and rice yields is encouraging, evaluating agricultural performance from such partial productivity measures obscures information contained in critical capital, labor, and material inputs and therefore offers only limited insight into productive efficiency. A more informative farm performance measure is total factor productivity, or output per unit of aggregate input. But not only should all inputs be accounted for, there should also be ample commodity coverage to allow for the implications of farmers' decisions to alter their production composition. That is, evaluating agricultural performance from commodity-specific TFP growth rates omits potential sources of sectoral growth that may occur through diversification. We thus focus our Indian agricultural productivity review on nine studies that measure national TFP growth for a broad set of

commodities or for the entire sector.[2] Four of these studies employ data from the Food and Agricultural Organization (FAO) and five employ data from Indian national accounts.

The four FAO-based studies report significant variations in India's agricultural TFP growth estimates, even among similar methods and datasets. Coelli and Rao (2005) and Nin-Pratt, et al. (2010) estimate TFP using Malmquist indexes. Their results differ, Nin-Pratt, et al.'s estimate indicating growth to be half of what Coelli and Rao estimate (Table 2). Because both Malmquist estimates were extracted from broader, global analyses, individual country estimates may be affected by the dimensionality issue, or the number of commodities and countries included in the analysis (Lusigi and Thirtle, 1997). Moreover, Coelli and Rao (2005) note that if shadow prices are indeed correctly estimated, for many countries the estimates may significantly differ from the sample average due to country-specific factor abundance or scarcity. Indeed, these two issues may be why the TFP growth estimates from Coelli and Rao differ by method, their Tornqvist index (using Malmquist-derived cost shares) indicating slower TFP growth than does their Malmquist index (Table 2).

It is also interesting to note that the three Tornqvist approaches using FAO data from Table 2 examine the same time periods but also generate widely different TFP growth estimates. Coelli and Rao's (2005) average annual Tornqvist estimate of 0.90% is less than Fuglie's (2012) estimate of 1.39% per annum TFP growth, which itself is significantly slower than Avila and Evenson's (2010) estimate of 2.41% per annum. Differences between them must therefore lie in factor quality adjustments and the cost shares employed. Fuglie quality adjusts land inputs to account for irrigation investments, lowering TFP growth in countries with substantial investments in irrigated cropland, such as India. The three studies' respective cost shares weighting factor growth also differ, Coelli and Rao employ shadow cost shares from their

Malmquist index, Avila and Evenson source their cost shares from Evenson and Kislev (1975) and Fuglie's source from Evenson, Pray, and Rosegrant (1999).

The five remaining studies employ data from Indian national accounts and a Tornqvist index approach to measurement. Among those studies, however, the time periods differ and each study focuses on a select group of crops or livestock products. The differing years and commodities included make direct comparisons difficult. We therefore only briefly note that Rosegrant and Evenson (1992) select 15 crops between 1957 and 1985 and find TFP growth of those crops rose 0.98% between 1975 and 1985. Evenson, et al. (1999) select 18 crops and find over the 1977 to 1987 period a similarly low growth rate (Table 2). Chand, et al. (2010) estimate between 1985 and 2006 a low 0.53% average annual TFP growth rate, although their estimate uniquely derives from value, not volume, data and the number of commodities included is unknown. Birthall, et al. (1999) examines 9 livestock products and finds TFP rose by 1.79% between 1980/81 and 1995/96.

Of all the studies, only Fan, et al. (1999) evaluated TFP growth at the state level, accounted for both crops and livestock products, and published the annual growth estimates. State-level TFP measures are important because they allow for concise results reporting yet sufficient degrees of freedom for econometric policy analysis; accounting for the entire agricultural sector allows for a broader representation of growth, an important factor as India diversifies toward higher-valued commodities; and making public such estimates enables new policy analyses.

Our examination of farm productivity growth in India includes the broadest composition of commodities and Indian states to-date and updates the current knowledge of Indian state and regional agricultural performance by 14 years. More specifically, we examine 59 crops and 4

livestock products, between 1980 and 2008, across 16 Indian states, 5 regions, and at the national level. Importantly, we note that great care was taken to ensure consistent commodity coverage across the national, regional, and state productivity accounts.

Measuring Total Factor Productivity Growth

Our strategy is to assume that Indian farmers are producing under constant-returns-to-scale technologies to maximize profits in competitive markets. In this case, total farm revenues equal total farm costs, marginal rates of substitution are equal to corresponding price ratios, and productivity growth may be measured using observed farm prices and quantities (Jorgenson and Griliches, 1967). We measure India's agricultural total factor productivity growth using the chain-weighted Tornqvist-Theil quantity index. This particular index offers several advantages, such as being superlative, exact for the linear homogenous translog production function (Diewert, 1976). It has also been shown to be superlative under general production structures (e.g. non-homogenous and non-constant returns to scale) (Caves, et al., 1982). Moreover, because nominal prices are used in constructing the weights, it accounts for input quality changes, to the extent that factor quality improvements are reflected in higher wages and rental rates (Capalbo and Vo, 1988). And by chain-weighting the index, we avoid possible index number bias arising from the use of fixed weights to aggregate quantity growth rates (Alston, et al. 1995).

We may express the chain-weighted Tornqvist-Theil TFP growth index as

$$(1) \qquad \ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right) = \left[\sum_{j} \frac{\left(R_{ij,t} + R_{ij,t-1}\right)}{2} \ln\left(\frac{Y_{ij,t}}{Y_{ij,t-1}}\right)\right] - \left[\sum_{l} \frac{\left(C_{il,t} + C_{il,t-1}\right)}{2} \ln\left(\frac{X_{il,t}}{X_{il,t-1}}\right)\right]$$

where *i* indicates the state, regional, and national production panels, *i = 1, 2,..., 23; j* indicates the commodities included, *j = 1, 2,... 64*; *l* indicates the factors of production, *l = 1, 2, ..., 6; t*

indicates time, *t = 1980, 1981,…, 2008; R* is the revenue share; *Y* is output; *C* is the cost share, and *X* is input. Equation (1) expresses aggregate TFP growth of observation *i*, between time periods *t* and *t-1*, as the difference between aggregate output growth and aggregate input growth. Aggregate output (input) growth is defined as the sum of all commodity output (factor input) growth rates, each growth rate weighted by its respective average revenue (cost) share in the reference time periods.

We exploit the aggregate output growth measure from equation (1) to provide insight into the proportion of that growth accounted for by changes in crop area, changes in crop yields, and changes in land allocations to higher valued commodities. To this end, we first decompose aggregate output growth in log form into its area growth and aggregate crop output per hectare growth components

$$\ln\left(\frac{Y_{im,t}}{Y_{im,t-1}}\right) = \ln\left(\frac{A_{im,t}}{A_{im,t-1}}\right) + \ln\left(\frac{AY_{im,t}}{AY_{im,t-1}}\right) \tag{2}$$

where *Y* is output, *A* is area, *AY* is aggregate crop output per hectare, and subscript $m = 1, 2, \ldots 59$ represents the possible set of crops produced in political entity *i* and year *t*. Aggregate crop output per hectare is defined here as the summed product of each crop's yield *CY* and each crop's land share *CS*; that is, $AY_{it} = \sum_{m} CY_{imt} CS_{imt}$. Substituting into equation (2) our definition of aggregate crop output per hectare *AY* provides

$$\ln\left(\frac{Y_{im,t}}{Y_{im,t-1}}\right) = \ln\left(\frac{A_{im,t}}{A_{im,t-1}}\right) + \ln\left(\frac{CY_{im,t}}{CY_{im,t-1}}\right) + \ln\left(\frac{CS_{im,t}}{CS_{im,t-1}}\right). \tag{3}$$

Equation (3) states that output growth is the sum of the change in area, change in crop yield, and change in crop land share. Note that we maintain conformity with the Tornqvist-Theil approach to aggregation in equation (1) but suppress the weighting notation in equations (2) and (3).

Therefore, equation (3) informs us as to proportion of aggregate output growth accounted for by expanding area in production, by improving the performance of average crop yields, and by diversifying production to higher valued crops.

Agricultural Data

We evaluate India's agricultural performance and production diversification by constructing, from 1980 to 2008, consistent agricultural production accounts at the national, regional, and state levels (Figure 1). It is important to note that the national panel includes all Indian states and production, but the regional and state panels include only those states present in Figure 1. To validate the data, we sum all state data and compare that sample sum against national aggregate information. The 59 crop commodities and 4 livestock products included in the accounts are recorded at the state and national levels, are measured in metric tons, and their farm-gate prices are reported in rupees per quintal.[3] Appendix Table 1 provides the data sources. For the purposes of temporal data consistency, Bihar is combined with Jharkhand to form Old Bihar, Madhya Pradesh with Chhattisgarh to form Old Madhya Pradesh (Old MP), and Uttar Pradesh with Uttaranchal to form Old Uttar Pradesh (Old UP). These states split in year 2000.

India's farm commodities are aggregated into six production categories: grains, pulses, horticultural & spices, oilseeds, specialty crops, and livestock products (Table 3). For those commodities and years in which Indian national data were missing, statistics were interpolated using FAO growth rates. For those data unavailable at the state level, we interpolate using the national growth rate. Only three commodities included in the analysis directly assume national FAO quantities (melons, mangoes & guavas, and pears & quince). They were included because of their presence in the state-level production accounts.

India is the world's largest exporter of beef (FAS, 2013). Yet Indian data of meat production, recorded by the Ministry of Agriculture's Department of Animal Husbandry, Dairying, & Fisheries, is available only since 1992 and is reported as an aggregate; individual animal production statistics did not begin until 1998. Meat production therefore reflects the aggregate production from buffaloes, cattle, goats, lamb, pigs, and poultry. Meat values, collected by the Central Statistical Organization's Department of Statistics, are available since 1990.

Comparing the Government of Indian (GOI) national meat production volumes with those constructed from FAO and PS&D databases provide little confidence in the GOI data (Figure 2). We direct the reader's attention to Figure 2 and the significant jump in the GOI meat volumes after 2005. While this was a period of growth, these changes also reflect a significant change in the collection of poultry data (Mehta, et al., 2003). For instance, Gujarat, Haryana, Kerala, Punjab, and Tamil Nadu show substantial production changes between 2005 and 2007, driving up the national poultry production volumes from 537 thousand tons to 1.7 million tons.[4]

Estimates of total meat values, collected by India's Central Statistical Organization, are, however, very similar to those reported by the FAO (Figure 3). We therefore choose to construct a new meat volume series based on the FAO national meat price - averaged across buffaloes, cattle, goat and sheep, and poultry - and the Indian national and state meat values (Figure 4). The FAO average national meat price is derived from FAO average meat values and volumes. Unfortunately, FAO meat values between 1980 and 1990 are unavailable. We extend the cattle and buffalo meat values back from 1990 to 1980 by applying the growth rate from the product of FAO-reported volumes and border (export) prices, while goat, sheep, and poultry FAO meat

values are extended back by applying growth from the consumer price index specific to India (World Bank, 2012).

Labor

Labor inputs consist of adult male and female laborers and are obtained from the 43rd (1987-88), 50th (1993-94), 55th (1999-00), 61st (2004-05), and 66th (2009-10) rounds of the National Statistical Survey (NSS). Because the earliest state-level labor count data available to include was from the 1987 survey, state-specific growth rates were employed, following careful consideration of state-wise and time-wise variations, from Fan, et al. (1999) to extend our state labor counts back to 1980. Fan, et al., provide agricultural employment from the NSS by Indian state and nationally for survey years 1972, 1977, 1983, 1987, and 1993. Survey years 1977 and 1983 enable our labor data to be extended back from 1987, and years 1987 and 1993 enable state-wise and time-wise labor validation. We generate continuous time-series of the labor counts through linear interpolation of survey years.

Developing a flow of labor inputs from the stock of laborers requires knowing how much time labor works in a given year, or labor's intensity. Evenson, et al. (1999) provides a fixed number of days worked for male laborers by Indian state.[5] Weighting each state's labor-days worked by their respective share of the total labor force suggests that males, at the national level, work 227 days per year. India's Ministry of Labour and Employment reports that male (female) waged agricultural laborers worked 227 (182) days per year in 1977/1978, falling to 215 (177) days worked per year in 2004/2005 (GOI, 2010). We thus employ Evenson, et al.'s (1999) state variation in male days worked for year 1978 and apply the Ministry of Labour and Employment's national average annual growth rate of days worked per year to obtain annual and state-wise variation in male labor-days worked (Table 4). Because the number of female labor

days worked by state are unknown, we assume the national number of days worked and apply the national growth rates from the Ministry of Labour and Employment. Our labor input thus accounts not only for the number of male and female laborers but also their respective labor intensities.

Wages for male laborers are reported as daily wages in rupees and are available annually by state. The national wage rate for each year is computed as a labor-quantity weighted average of state wages. Labor wages are simple averages across all operations (plowing, sowing, reaping, harvesting, weeding, and transplanting). Female wages are unavailable for most years and states. We employ the female-to-male labor wage ratios estimated by Mahajan and Ramaswami (2012), enabling the use of adjusted male wages. Female-to-male wage ratios for Himachal Pradesh are not provided by Mahajan and Ramaswami, so we assume the average of neighbor states Haryana, Punjab, and Old UP.

Land

Land area is recorded in hectares, available annually, and quality-differentiated into four groups: irrigated cropland, rainfed cropland, pasture, and fallow land. For the purposes of the present analysis, we employ net land in production; that is, if a single hectare of land experiences multiple cropping it is accounted for only once. This approach allows us to estimate the contribution to input growth accounted for by investments in irrigation, the principal factor enabling multiple plantings throughout a given year in much of India. Per-hectare land rental value is estimated as revenue net of the expenditures of the five inputs for which prices are available (labor, fertilizer, energy, livestock, and machinery) and divided by the quality-adjusted hectares of rainfed-cropland equivalents.

Land quality weights are estimated following a similar method to that described in Fuglie (2012). In the present analysis, we estimate the relative productivity impacts of differing types of land by regressing, for each state, the logged real (2004) value of aggregate yields against the share of land designated as rainfed cropland (*RC*), irrigated cropland (*IC*), pasture (*P*), and fallow land (*F*),

$$(4) \qquad \ln\left(\frac{TR_{i-7,t}}{A_{i-7,t}}\right) = \alpha RC_{i-7,t} + \beta IC_{i-7,t} + \delta P_{i-7,t} + \lambda F_{i-7,t} + \varepsilon_{i-7,t}$$

where *TR* is total revenues, specified in 2004 constant rupees; *A* is the sum of each land type; α, β, δ, and λ are coefficients to be estimated; *i*-7 indicates the inclusion of only the 16 Indian states; t indicates time; and ε_{it} is a normal error with mean zero and variance σ^2. The estimated coefficients from equation (4), once normalized by rainfed cropland's parameter value, provide the following quality weights used to aggregate each land type: irrigated cropland (3.83), rainfed cropland (1.00), pasture (0.36), and fallow land (0.15). That is, irrigated land is assumed 3.82 times more productive than rainfed cropland, which in turn is more productive than other land types. Our estimated irrigated-cropland weight is somewhat higher than the 2.99 weight estimated by Fuglie (2012) for all developing Asian countries.

Materials

Material inputs consist of synthetic crop fertilizers and electricity consumed in the agricultural sector and are recorded annually. Nitrogen, phosphate, and potash usage is recorded in metric tons of active ingredient. Fertilizer prices are recorded in rupees per metric ton and are regulated at the national level, although some state-wise variation of fertilizer prices exists due to state and local taxes. Electricity consumption is recorded as kilowatt hours (kwh) per capita. State electricity usage is estimated as per-capita consumption weighted by state population. Electricity

tariffs are specific to agriculture, are recorded as rupees per kwh, and are available from 1991 to 2008. 1980-1990 agricultural electricity tariff rates assume the general electricity tariff growth rate for those years.

Capital

Capital inputs consist of farm machinery and livestock capital. Farm machinery is proxied by the number of tractors in-use. Tractor service prices are from Evenson, et al. (1999) and the FAO. Evenson, et al., note that tractor prices are invariant across Indian states and thus estimate a single national rate from 1957 to 1987. That rate represents the price of an Eicher 24-horsepower tractor, adjusted upwards to reflect the market share of machinery of higher horsepower, and deflated by 25% to account for depreciation and debt services (Evenson, et al., 1999). To extend this rate forward from 1987 to 2008, we assume the growth rate of the border (export) price of an FAO agricultural tractor specific to India, converted from dollars to rupees using World Bank (2012) conversion factors, and similarly depreciated.

Livestock capital inputs consist of on-farm stocks of cattle, buffalo, sheep, goats, and pigs. These data are aggregated to cattle equivalents using Hayami and Ruttan's (1985, p. 450) cattle-normalized weights. An historical cattle sale price series, based on domestic or border (export) information, is unavailable from Indian sources. Neither is one available from the FAO, Indian cattle export data stop after 1995 and resume only sparsely after 2002. Rather, we employ the Asian regional cattle export price, deflated by 15% to account for depreciation and any debt services, as our livestock capital service price.

Agricultural Production's Diversification

Agricultural production values, measured in constant 2004 rupees between 1980 and 2008, have risen on average 3.01% annually. Crop production values, accounting for 72.8% of total 1980-2008 mean revenues, have risen on average 2.87% annually, and livestock production values, accounting for a smaller 27.2% mean share, have risen more rapidly on average than have crops at 3.38% annually. Evaluating India's 1980-2008 mean revenue shares by region indicates that the Indian North accounts for the largest proportion of farm revenues (30.0%), followed by the Indian South (23.3%), West (19.9%), East (16.7%), Center (7.6%), and the Northeast (2.6%).

In terms of agricultural revenues, Haryana and Old Bihar have been India's best and worst performers, their respective 1980-2008 average annual real (2004 constant) farm revenues rising 4.12% and 1.70% (Figure 5). While most Indian states have achieved real growth between 3% and 4% per annum, Old UP, Assam, Kerala, and Tamil Nadu have achieved real growth between 2% and 3% and Old Bihar and Orissa has achieved real average annual revenue growth of less than 2%.

Decomposing Output Growth by Commodity and Region

Of primary importance in the present analysis is to examine India's changing production portfolio in a manner that facilitates our understanding of the commodities and regions that are driving production and productivity growth. Average annual output growth rates, specified in 5-year averages, are provided by geographic area in Appendix Table 2.

We first decompose India's aggregate output growth by commodity and political boundary (Table 5). This approach indicates that growth has occurred somewhat regionally, the Indian North experiencing the fastest growth in grains, the South in pulses and livestock products, the West in horticultural & spice products, and Central India experiencing the fastest

growth in oilseed production. Despite these regional differences, livestock production growth has exceeded that of aggregate crop production in all regions apart from the Northeast. And among crops, horticultural & spice production growth has experienced the most rapid growth in all regions apart from the Indian North and Northeast. At the state level, this is particularly true for Gujarat, Rajasthan, Maharashtra, and Andhra Pradesh.

We further examine India's shifting commodity production shares over time (Table 6). At the national level, production of grains, pulses, oilseeds, and specialty crops have given way to that of horticultural and livestock products (Figure 6). But this characterization does not hold for all regions. For example, India's North uniquely has been increasing its specialization in grains (Figure 7), a strategy that has achieved the highest regional 1980-2008 mean revenue share but also a lower than national average output growth rate (Table 5). Central India's (i.e. Madhya Pradesh) increasing concentration of oilseed production (Figure 8), and Western and Southern India's increasing concentration of horticultural commodities (Figures 9 and 10, respectively) suggest that diversifying away from grain production may hold one key to India's agricultural productivity renewal. This does not, however, appear to hold, as both Eastern and Northeastern India have also experienced greater specialization in higher valued commodities (Figures 11 and 12, respectively) yet aggregate production growth has been below that of the Indian North (Table 5). While explaining TFP differences across states is beyond the scope of the present analysis, the policy prescriptions required to boost growth in Eastern and Northeastern India have long centered around greater investments in agricultural research and improving market and transportation infrastructure (Chand, et al., 2011; Easter, et al., 1977).

Decomposing Growth in Aggregate Crop Output per Hectare

A second approach to examining India's output growth is by decomposing it into growth due to area expansion (extensification) and growth due to raising aggregate crop output per hectare (intensification). Growth in aggregate crop output per hectare is further decomposed into changes in average commodity yields and changes in land allocations to higher valued commodities. Employing equation (4) and specifying land as gross area sown for each crop, we find that 13% of India's output growth is accounted for by expanding land in production, 55% by raising average crop yields, and 32% by re-allocating resources to produce higher valued commodities (Table 13).[6] These results indicate that half of India's aggregate output growth is due to improving average crop yields and half is due to incorporating new land in production and shifting existing land in production to higher valued commodities.

At the commodity level, to the extent that we may characterize India's production diversification as one from grains to horticultural products, we find grain production is largely propelled by improving technologies and management practices and increasing the materials, labor, and capital applied, while horticulture production is largely propelled by land extensification and shifting existing land in production to higher valued crops. More specifically, we find that 87% of grain production growth has been due to increasing average crop yields, whereas 76% of horticulture & spice production growth has been due to increasing area planted and re-allocating land to higher valued commodities. Growth in pulses, oilseeds, and specialty crops appears nearly equally divided between crop yield growth and extensification plus shifting land shares, pulses leaning more toward crop yield growth and oilseeds and specialty crops more toward land expansion and land re-allocation.

Factor Accumulation

Among India's farm production factors, machinery capital inputs have grown on average the fastest at 8.9% per annum, 2008 tractors in-use reaching 4.6 million, up from 374 thousand in-use in 1980. Machinery growth has been greatest in Orissa, Himachal Pradesh, and Old Madhya Pradesh, their respective 1980-2008 average annual growth rates rising 15%, 13%, and 11%. Interestingly, the slowest growth in machinery capital has come from Punjab, the number of tractor in use in that state rising only 5.2% on average each year over the reference period. Of course, evaluating only growth rates obscures the fact that Punjab accounted for 27% of 1980 Indian tractors in-use.

Energy and fertilizer consumption has also accelerated rapidly, total kilowatt hours consumed between 1980 and 2008 in the agricultural sector rising on average 7% per annum and synthetic fertilizer applications of active ingredient rising on average 4.3% per annum. Karnataka appears to have had the greatest increase in energy consumption, total kilowatt hours consumed rising 11.6% per annum. Old Madhya Pradesh and West Bengal were not far behind, their respective energy consumption rising by 10.9% and 10.5% per annum. Old Bihar is the Indian state with the lowest growth in energy consumption. Fertilizer applications rose very rapidly in Assam, average annual growth reaching 10.8%. Most states, however, experienced growth rates near the national average and ranged from 1.74% per annum growth in Tamil Nadu to 6.9% per annum growth in Rajasthan.[7]

Growth in India's livestock capital (herd size in cattle-equivalents) has been marginal at 0.7% per annum. There has, however, been substantial variation among states. For instance, Kerala's livestock capital has decreased on average by 2.8% each year, whereas Old Bihar's livestock capital growth rate has exceeded all Indian states at 1.8% each year, just greater than

Gujarat's rate of 1.6% each year. These figures, however, lack stocks of poultry on farms and therefore likely underestimate livestock capital input growth, particularly since poultry has been a primary driver of livestock production growth over the previous thirty years.

Labor inputs have increased by an average annual 0.67% between 1980 and 2008. Because the labor inputs are a product of labor counts (employment) and labor intensity (days worked), it is interesting to note that total employment rose by 0.85% per annum but that the annual number of days worked fell by 0.27% per annum. Aggregate labor input growth was primarily driven by a 1.6% increase in female labor, male labor increasing by a much lower 0.23%. Interestingly, though, we find that since 1999, not only has the intensity of labor decreased, but employment levels have also declined. More specifically, total employment between 1999 and 2008 fell by an average of 1.34% per annum, driven primarily by a release of female labor. Among Indian states, Kerala and Tamil Nadu were alone in experiencing a decline in labor over the entire 1980-2008 period.

Total quality-adjusted hectares, in rainfed-equivalents, have grown slowly, rising between 1980 and 2008 on average 0.8% each year. Only in Assam has the number of rainfed-equivalent hectares declined, falling on average 1.5% per annum, led by an average annual 7.3% decrease in net irrigated area. The highest average annual growth rate of land in production has occurred in West Bengal (1.5%) and Rajasthan (1.4%), these states experiencing the fastest average annual growth in net irrigated area of 2.82% and 2.88%, respectively.

Our purpose in estimating quality-adjusted land is to account for irrigation investments that enable multiple crop plantings and, in concert with seed-fertilizer technologies, aid in boosting crop yields. Net cropland in production has actually remained stagnant over the 1980-2008 period, falling by 0.02% per annum. The difference between the cost-share weighted net

cropland growth rate and the cost-share weighted rainfed-equivalent growth rate is the estimated contribution to input growth accounted for by irrigation investments. We estimate that irrigation investments accounted for 19% of India's 1980-2008 mean input growth rate (Figure 14). Note that because net land in production remained stagnant, it did not contribute to input growth.

Because we employ a 'returns-to-land' approach to measuring land's cost share, some states experienced negative land cost shares. Five states experienced a substantial number of years in which land's cost share was negative (Himachal Pradesh, Rajasthan, Old Madhya Pradesh, Old Bihar, and Kerala), nearly one per region. For Himachal Pradesh, Rajasthan, Old Bihar, and Kerala, we assume each state's respective regional cost share. Old Madhya Pradesh, however, is its own region. We therefore apply the average of neighbor states (Old UP, Old Bihar, Rajasthan, Maharashtra, Andhra Pradesh, and Orissa). For those states that experienced a one- or two-year negative land cost share, we average the prior and subsequent year's values in that state.

Weighting each of the inputs described above are factor cost shares, available in 5-year averages from Table 8. The cost share estimates suggest that labor expenditures are largely driving farm labor costs. However, labor cost shares appear to have declined concurrent with machinery capital's acceleration. We note that our 1985-1989 cost shares are very similar to the 1987 shares presented by Evenson, et al. (1999).

Combining the input growth rates with the cost shares depicted in Table 8, we estimate that India's average annual Tornqvist-Theil input growth between 1980 and 2008 has increased 1.23%. We find that while labor has had the greatest cost share, the swiftly rising tractor inputs have contributed the most to national input growth, accounting for 33% of that 1.23% average annual rate (Figure 14). Materials have contributed a further 20% to that growth rate, and

irrigation investments – or the capital stock of irrigation – have contributed another 19%. Somewhat surprisingly, labor has only accounted for 8% of national input growth. Energy and livestock capital inputs account for the remaining contributions to input growth.

Total Factor Productivity Growth

Total factor productivity indexes and average annual growth rates, for the entire agricultural sector and across the 1980-2008 period, are provided at the national and regional levels in Table 9, and by region and state in Tables 10-14.

As India has transitioned to a more diversified production composition, agriculture has experienced a renewal of TFP growth. We find that India's experienced strong average annual TFP growth of 3.60% in the 1980s, that growth slowing to 1.32% in the 1990s, but then accelerating to 3.08% between 2000 and 2008. For the entire 1980-2008 period, India's average annual TFP growth rate has been 1.9%. Among Indian states, only Orissa has achieved TFP growth of less than 1% on average each year, whereas Andhra Pradesh and Kerala have achieved TFP growth exceeding 3% per year. All remaining states achieved productivity growth rates between 1% per annum and 3% per annum over the reference period.

Surprisingly, India's northern region achieved the regional-lowest average annual 1980-2008 TFP growth rate of 1.38% (Table 9). The North's low productivity growth rate is a reflection of its deepening specialization in grains and its high-input intensification production processes. Indeed, as farmers transitioned to higher valued commodities, the fastest TFP growth rates have occurred in the Indian South and West, both regions driving the national average (Table 9). These results together indicate that as India has transitioned out of the Green Revolution, productivity growth has accelerated most rapidly in those regions which have

focused on meeting consumer demands for higher valued commodities such as horticultural and livestock products.

Prominent in Western India's productivity indexes are wide variations in year-to-year production typical rainfed agriculture. While Rajasthan and Maharashtra have achieved greater average annual productivity growth over the entire reference period, Gujarat has experienced the greatest growth since year 2000 (Table 11). Gujarat's 2000-2008 average annual TFP growth rate has accelerated at a 9.8% rate, far greater than the 1.1% and 1.4% decadal-average TFP growth rates it experienced in the 1980s and 1990s. What may account for such a high TFP growth rate? Singh and Pal (2010) note that since 1999 Gujarat has experienced 9.6% per-annum growth in agricultural GDP. Moreover, Gujarat has experienced low average annual input growth in the 2000s of 0.4%. Driving that low input growth have been declining labor inputs (-1.4%/annum) that have nearly offset growth contributions from all other inputs.

The Indian South has been the top regional agricultural performer over the previous three decades, its TFP growth rate between 1980 and 2008 reaching an average of 2.86% each year, well above all other regions and driving the national average. While productivity growth in this region has been driven by the performance of Andhra Pradesh and Kerala, the factors behind each of their TFP growth rates differ. For instance, while both states increased their production of livestock products, Andhra Pradesh achieved the highest average annual output growth rate (4.10%) among southern states by increasing its specialization in horticultural crops, whereas Kerala achieved the lowest growth rate (2.38%) as it increased its specialization in specialty crops (Table 5). Moreover, while both states experienced negative input growth over the 2000s, Andhra Pradesh's 2000-2008 average annual input growth rate decline of 0.24% is much smaller than Kerala's substantial average annual input growth rate decline of 2.08%. Indeed, Kerala's

exiting labor force (-1.47%/annum) and declining animal stocks (-2.78%/annum) have more than offset increases in land (0.43%/annum), machinery (6.48%/annum), materials (2.13%/annum), and energy (3.50%/annum). Thus, while Andhra Pradesh achieved high TFP growth through increasing production, Kerala achieved high TFP growth through decreasing input usage.

India's East, Center, and Northeast regions achieved productivity growth rates below the national average (Table 9). That is not to say there was not a high-performing state in these regions. Indeed there was, West Bengal achieving a strong average annual TFP growth rate of 2.74%, much higher than the East's 1.79% rate (Table 11). West Bengal increased its specialization in horticultural crops at the expense of greater grain and livestock production, leading it to have the highest crop production growth rate between 1980 and 2008 among all Indian states (Table 5).

Conclusions and Extensions

India has experienced substantial economic and agricultural growth over the previous thirty years. As consumers have shifted preferences to higher-valued goods such as horticultural and livestock products, the agricultural sector has responded to meet those demands, particularly in the Indian South and West. In doing so, these two regions have also achieved India's highest agricultural TFP growth rates. Yet the routes by which some states achieved their high growth rates differ; some accelerated productivity growth by boosting production while others limited input growth. This leads one to question the long-term sustainability of the productivity growth experienced by states which minimized input usage.

A potential concern for Indian policymakers has been the relatively poor farm performance of the Indian North. As this region has deepened its specialization in grain production to meet policymakers' goal of wheat and rice self-sufficiency, it has achieved the

regional-lowest TFP growth rate over the previous three decades. If this region is to continue providing the cereal grains consumed throughout India, greater emphasis should be placed on reversing the declining trend in cereal grain yield and TFP growth rates experienced over the previous decades. We do present, however, some new evidence that suggests recent wheat and rice yield growth rates may already be improving.

India's agricultural production growth has been led by the livestock sub-sector, although crops have also achieved strong growth. But not all of the crop production growth has been technologically driven; transitioning to higher valued crops has accounted for 36.5% of India's growth in aggregate crop production per hectare. Moreover, the 2000-2008 period may be dubbed a 'growth-favoring' period, as reflected by the paltry 0.17% average annual input growth rate and the robust 3.25% average annual output growth rate. Driving down aggregate input growth over this period has been a release of labor since 1999. Indeed, only Assam and Haryana did not experience that release of labor, their labor counts continuing to growth. One potential factor helping motivate India's agricultural growth renewal has been declining discrimination against agriculture from macro and price policies. India's nominal rates of assistance to agriculture, a measure indicating the distortion to gross agricultural returns induced by policy interventions, suggest that 2002 was the first year Indian farmers have experienced positive terms of trade (Anderson and Valenzuela, 2008). Positive agricultural terms of trade incentivize increased private investment in new technologies and innovative management practices that assist in boosting production possibilities.

One of the strongest criticisms that may be leveled at the present analysis is the use of a returns-to-land approach to measuring land's cost share. An alternative approach to explore is employing cost of production information to generate land rental rates. Other important

limitations of the present analysis include a lack of feed input to livestock production and on-farm poultry stocks. Including these two should boost the stagnant growth in livestock capital and account for more of the robust growth in meat production. Despite these possible changes, presented in the present analysis is the broadest and most up-to-date depiction of agricultural growth and agricultural TFP growth across Indian regions and states.

Extensions to this research include estimating the marginal impacts of irrigation investments by type (tube-well, irrigation canal, etc.) and agricultural research investments at the national and state levels. Understanding the role of various types of irrigation in India is important, particularly given the increasing reliance on private investment in tube-well irrigation (Akermann, 2012). Other policies that may be examined include agricultural development investments, market and transportation infrastructural investments, and human capital investments.

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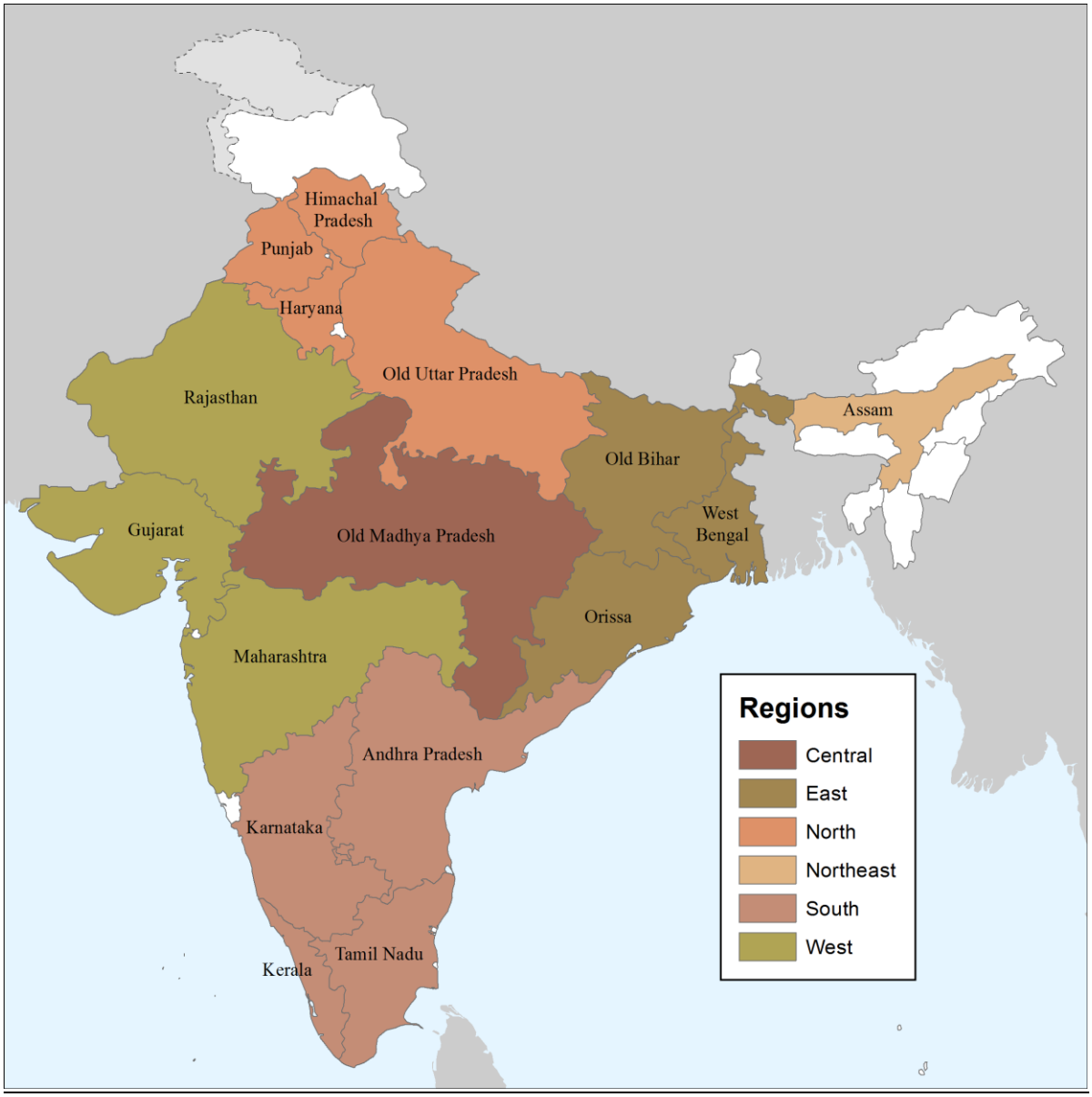
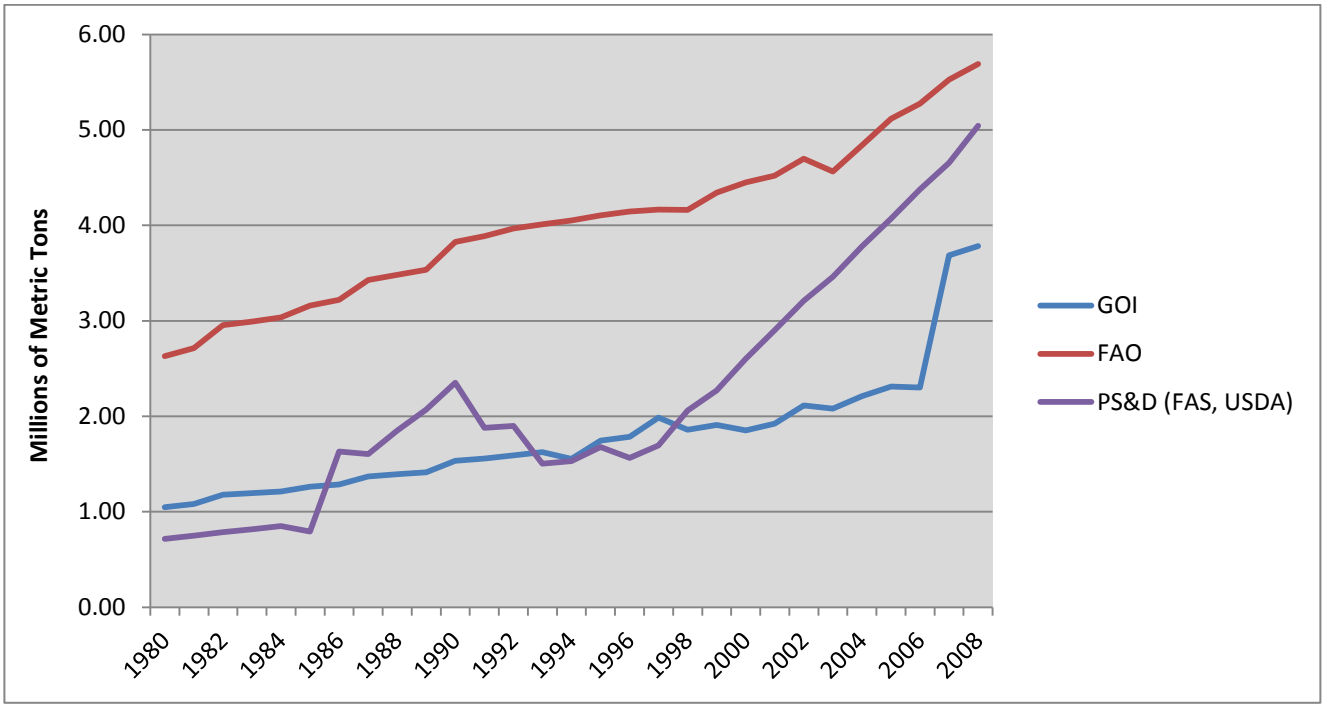
Figure 1. Map of Indian Regions and States



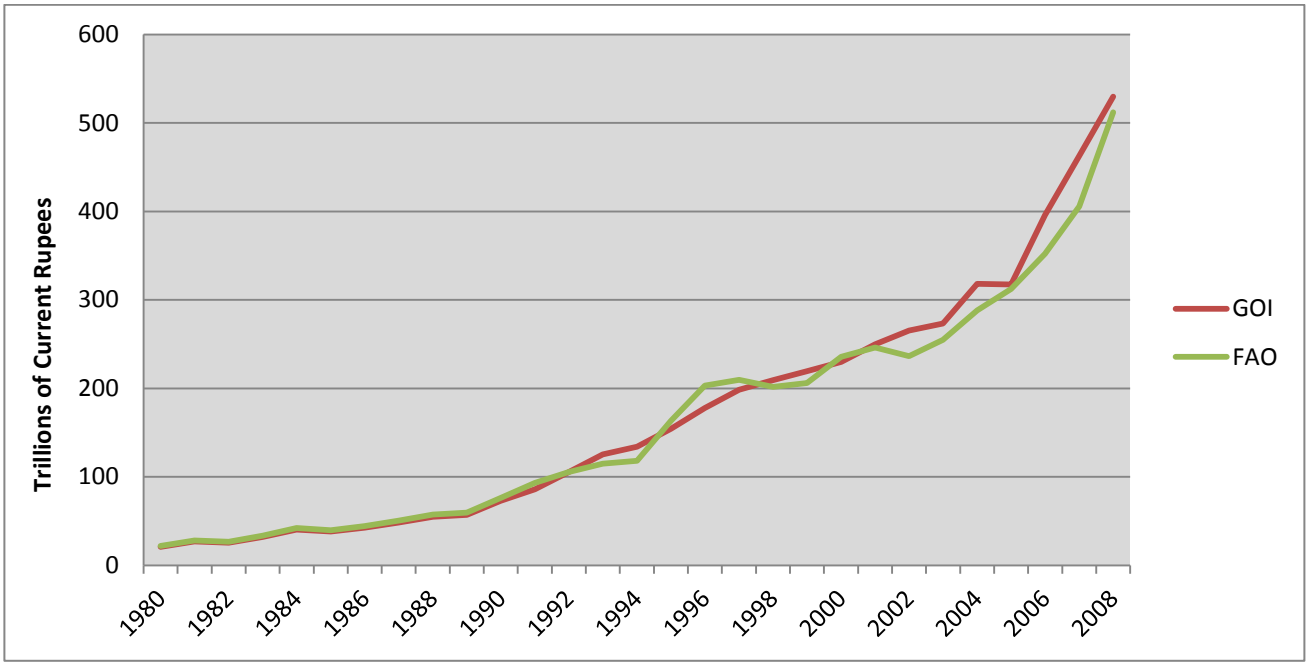
Note: Note: For the purposes of data consistency, Jharkhand is combined with Bihar to form Old Bihar, Madhya Pradesh with Chhattisgarh to form Old Madhya Pradesh, and Uttar Pradesh with Uttaranchal to form Old Uttar Pradesh. These states split in year 2000.

Figure 2. Comparing Meat Production Volumes



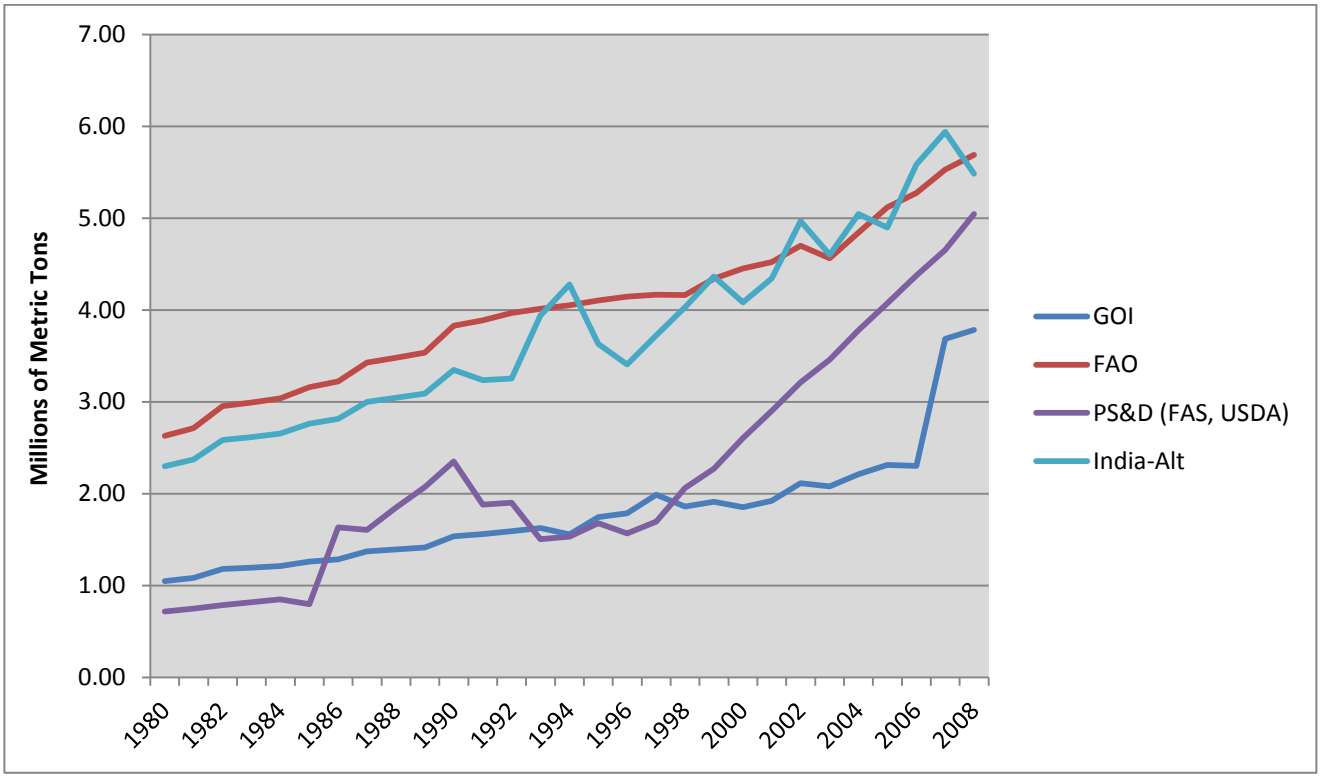
Note: Government of India (GOI) meat volumes include buffalo, cattle, goat, sheep, pig, and poultry meat. Foreign Agricultural Organization (FAO) meat volumes include buffalo, cattle, goat, sheep, pig, chicken and duck meat. Production, Supply, & Distribution (PS&D, FAS, U.S. Department of Agriculture) meat volumes include buffalo and cattle meat, pig meat, and poultry meat.

Figure 3. Comparing Meat Production Values



Note: Government of India (GOI) meat values include buffalo, cattle, goat, sheep, pig, and poultry meat. Foreign Agricultural Organization (FAO) meat values include buffalo, cattle, goat, sheep, pig, chicken and duck meat.

Figure 4. Comparing an Alternative Indian Meat Volume Series



Note: Government of India (GOI) meat volumes include buffalo, cattle, goat, sheep, pig, and poultry meat. Foreign Agricultural Organization (FAO) meat volumes include buffalo, cattle, goat, sheep, pig, chicken and duck meat. Production, Supply, & Distribution (PS&D, FAS, U.S. Department of Agriculture) meat volumes include buffalo and cattle meat, pig meat, and poultry meat. The India-Alt variable is derived from GOI state meat values and FAO national meat prices.

Figure 5. Average Annual Real (2004) Farm Revenue Growth by Indian State, 1980-2008

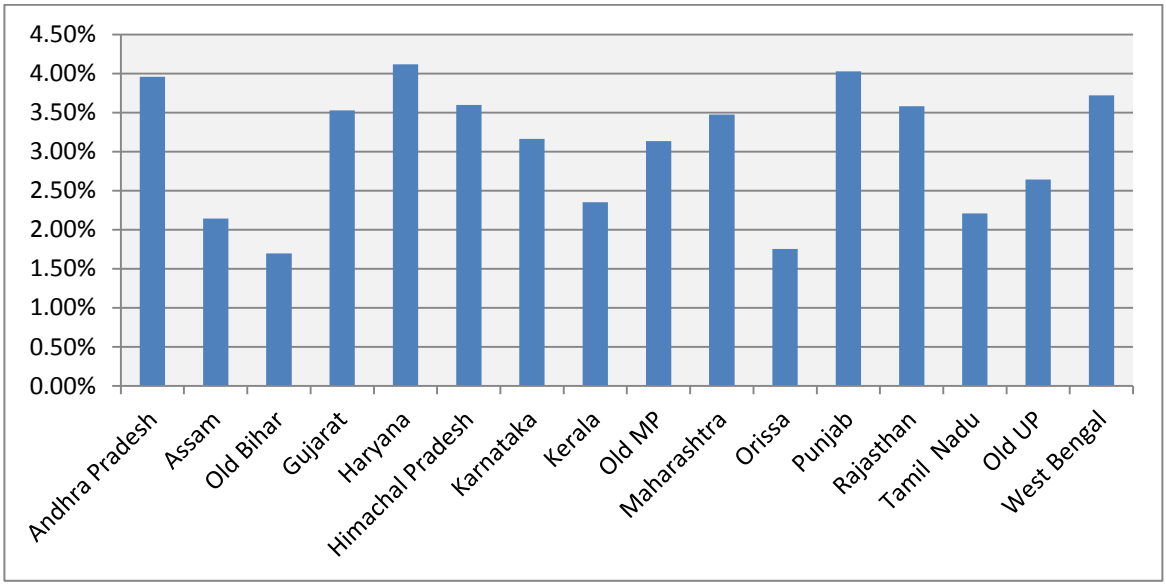
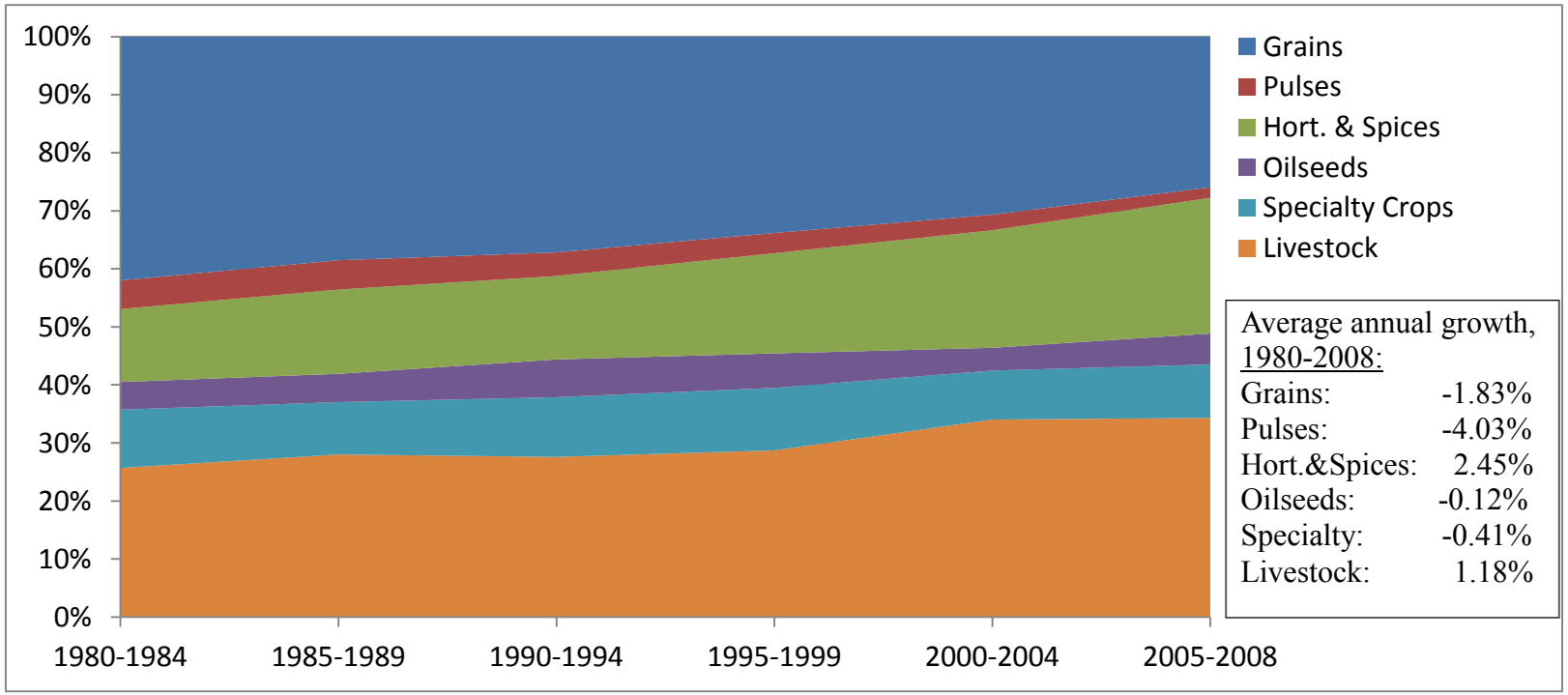
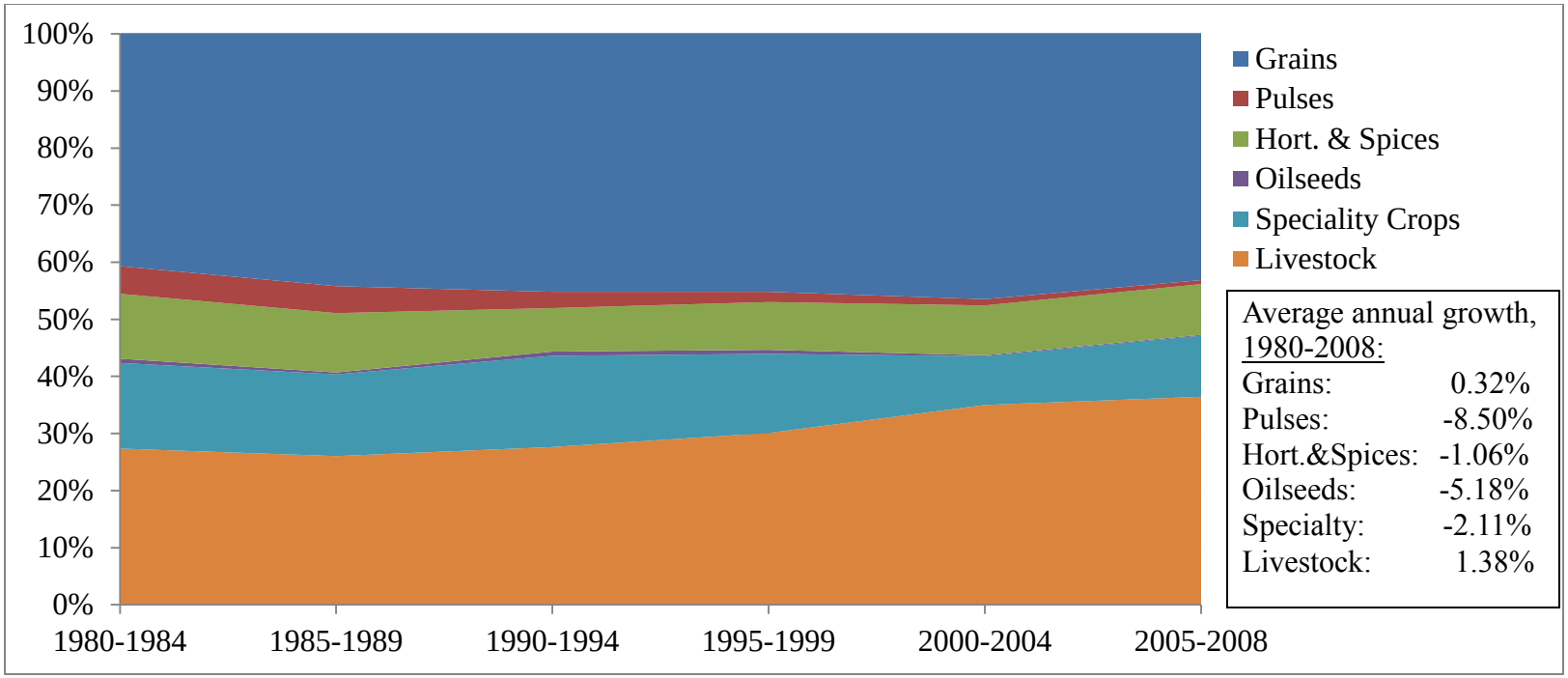


Figure 6. Decomposing India's Production Growth by Output Groupings



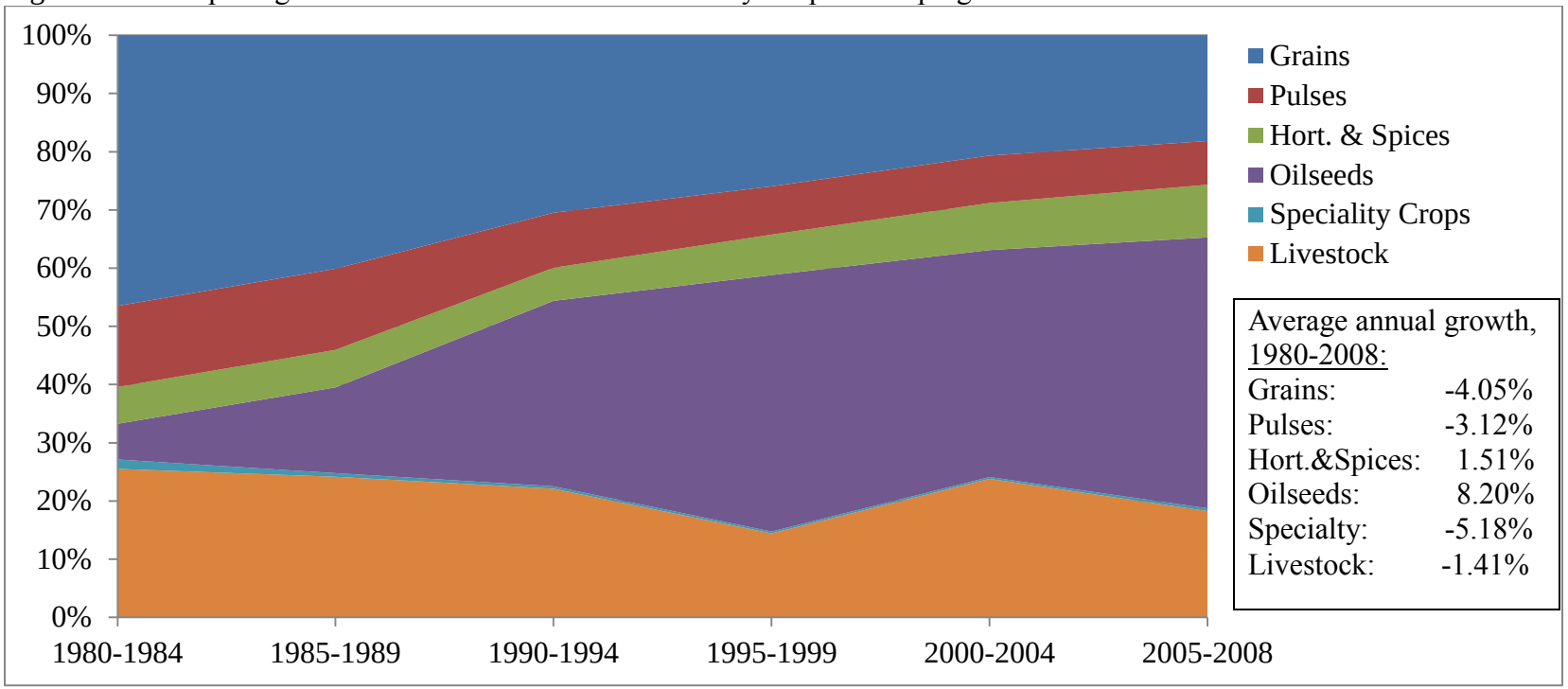
Note: Data are presented in 5-year averages.

Figure 7. Decomposing Northern India's Production Growth by Output Grouping



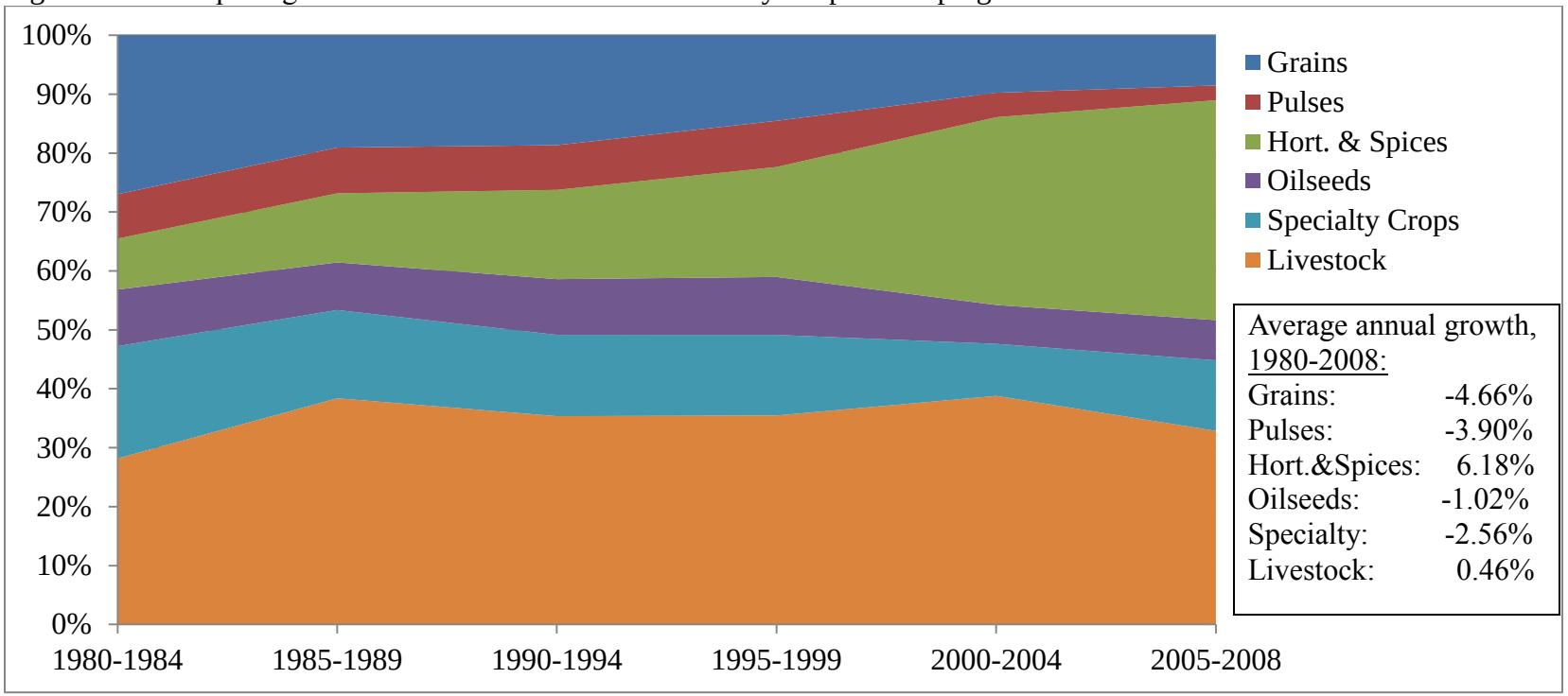
Note: Data are presented in 5-year averages.

Figure 8. Decomposing Central India's Production Growth by Output Grouping



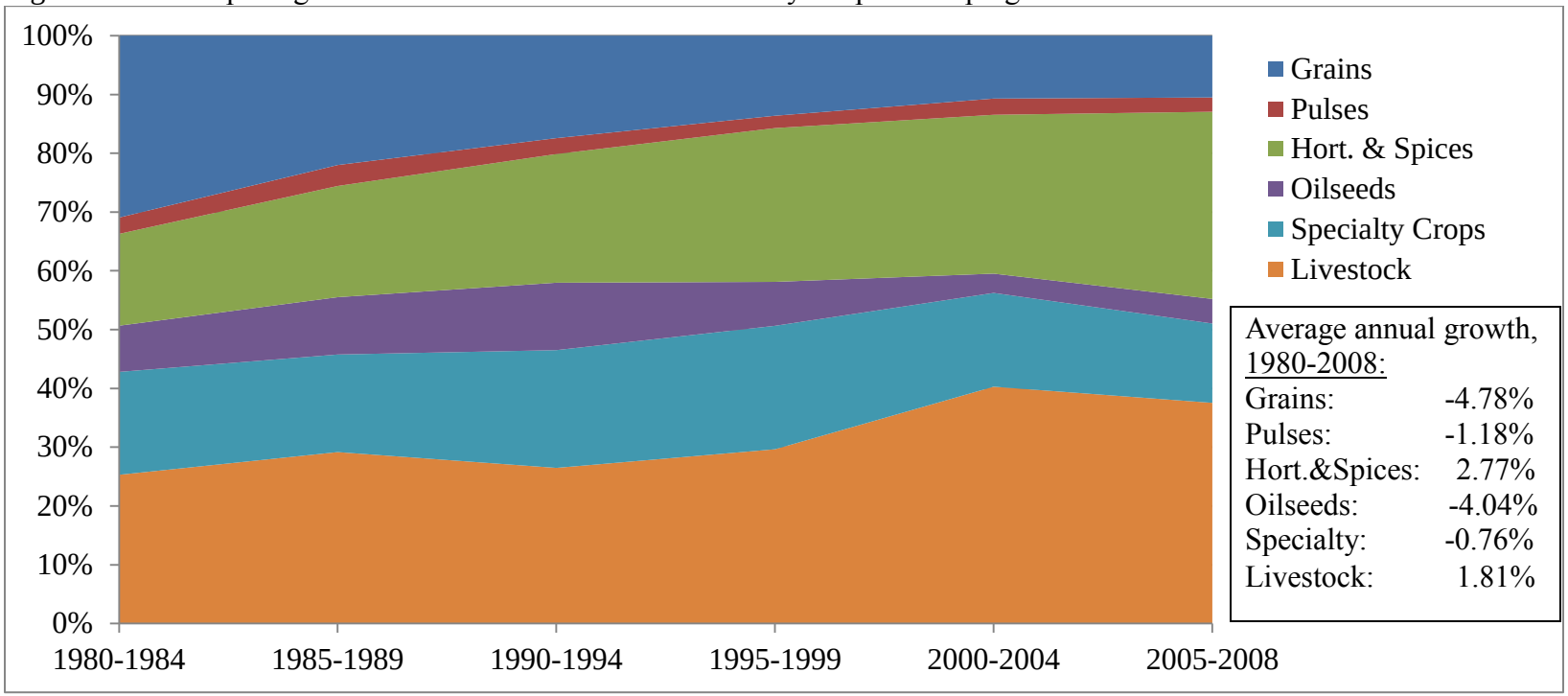
Note: Data are presented in 5-year averages.

Figure 9. Decomposing Western India's Production Growth by Output Grouping



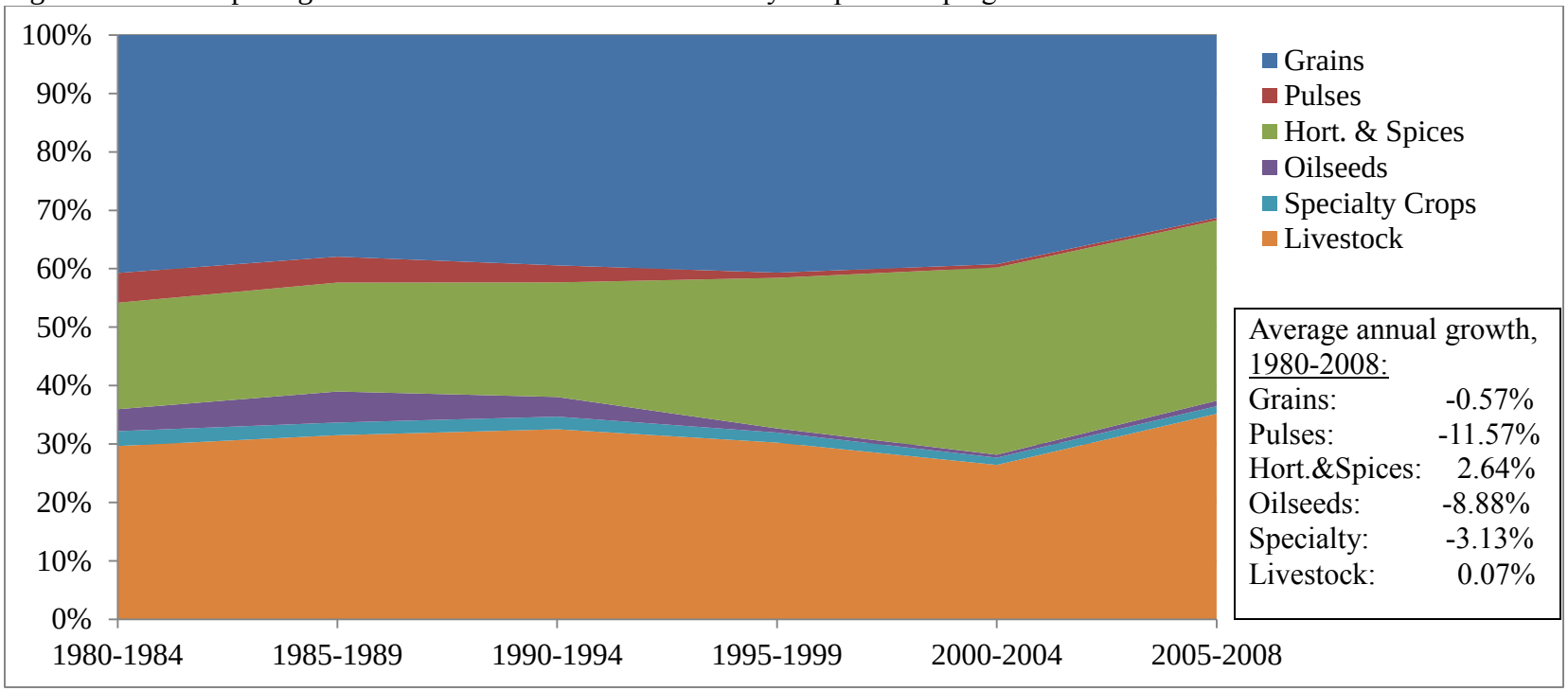
Note: Data are presented in 5-year averages.

Figure 10. Decomposing Southern India's Production Growth by Output Grouping



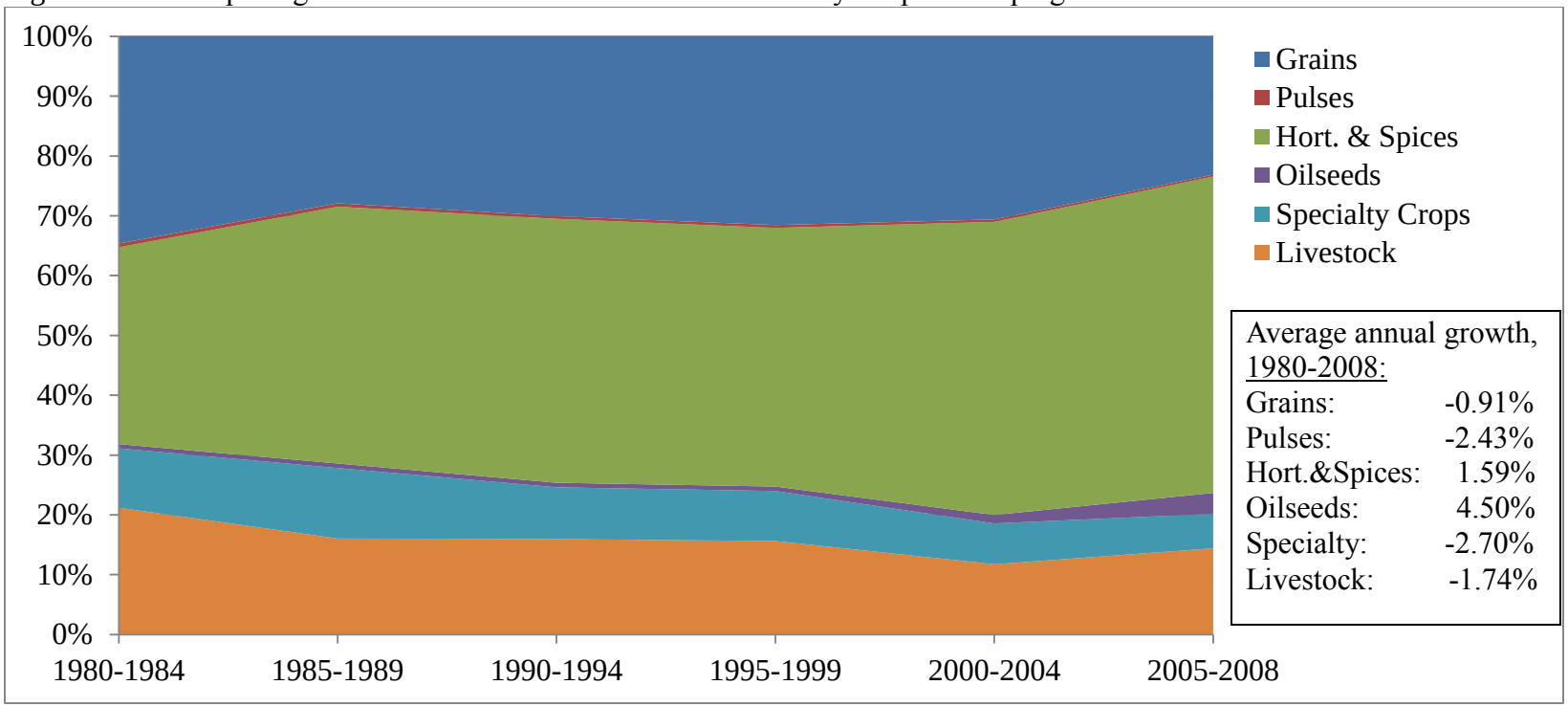
Note: Data are presented in 5-year averages.

Figure 11. Decomposing Eastern India's Production Growth by Output Grouping



Note: Data are presented in 5-year averages.

Figure 12. Decomposing Northeastern India's Production Growth by Output Grouping



Note: Data are presented in 5-year averages.

Figure 13. Decomposing Average Annual Aggregate Crop Output Growth, 1980-2008

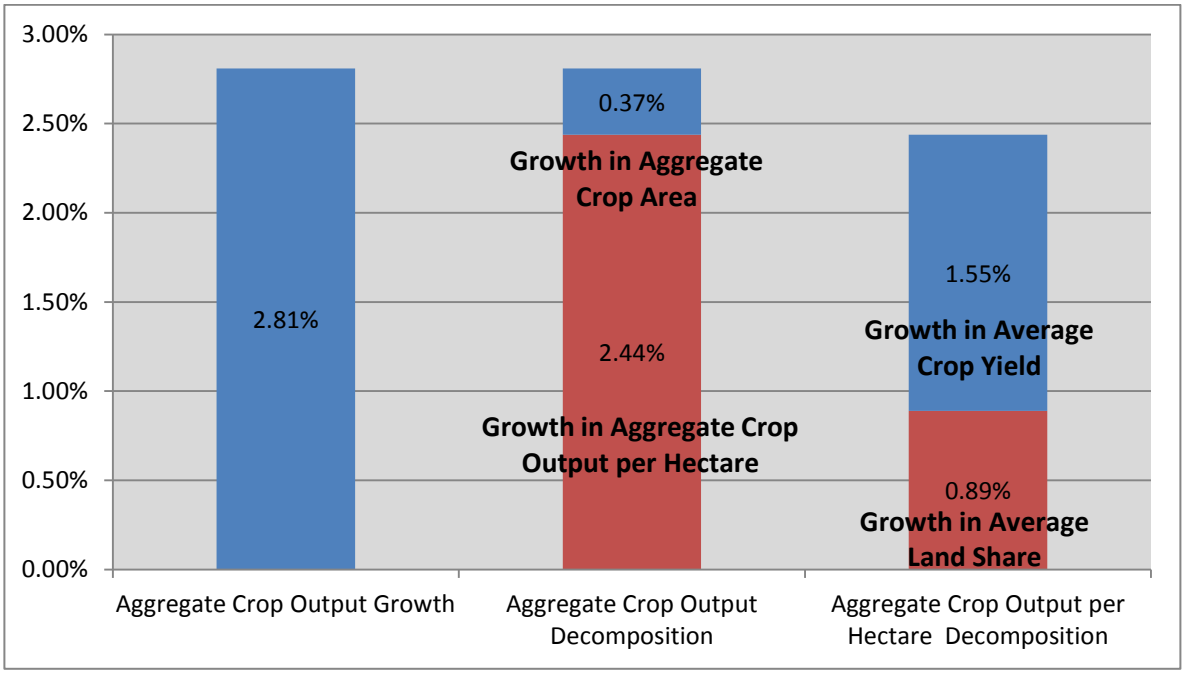


Figure 14. Average Proportions of Input Growth by Production Factor, 1980-2008

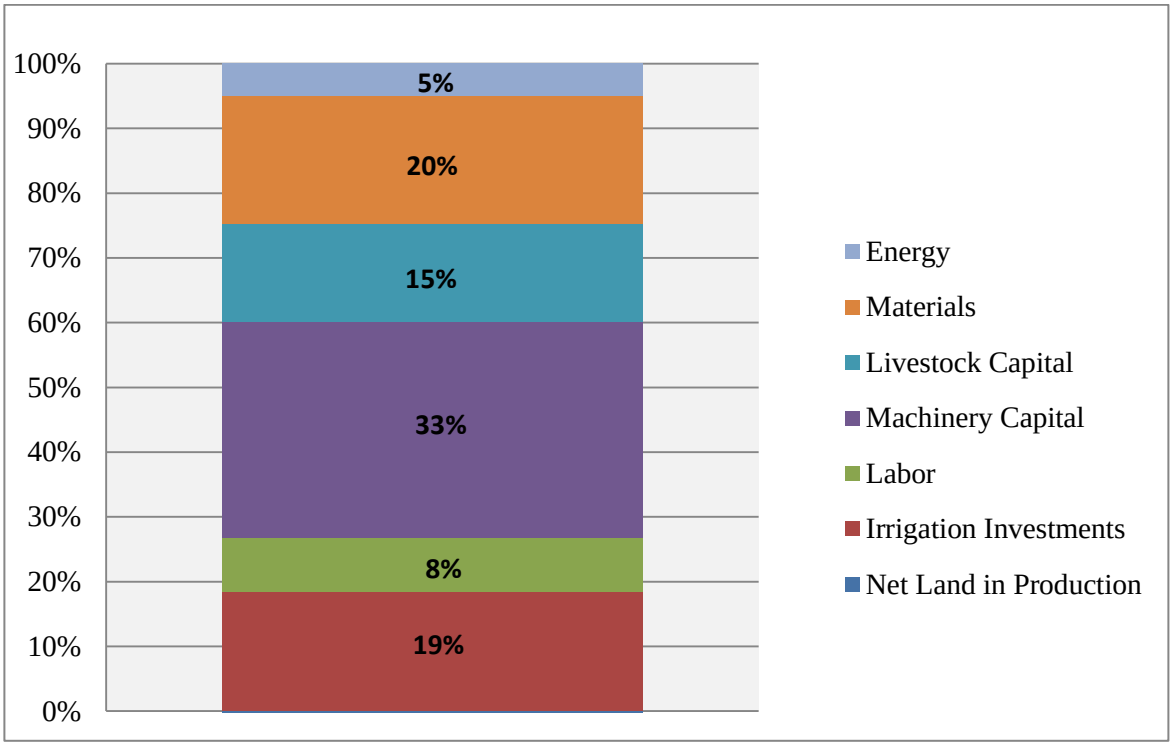


Table 1. Cereal Grain Yield Growth in India, 1957-2012

Growth Rates by Decade	Wheat		Rice		Maize	
	Yield growth per annum	States with negative or stagnant growth	Yield growth per annum	States with negative or stagnant growth	Yield growth per annum	States with negative or stagnant growth
1957-1969	3.50%	4/13	0.74%	9/13	2.00%	5/13
1970-1979	2.30%	2/13	2.43%	3/13	-0.04%	6/13
1980-1989	4.03%	3/13	3.91%	3/13	2.14%	6/13
1990-1999	1.89%	3/13	1.30%	6/13	1.65%	4/13
2000-2012	1.02%	4/13	1.69%	2/13	3.03%	4/13

Growth Rates by Development Period		Wheat		Rice		Maize	
		Yield growth per annum	States with negative or stagnant growth	Yield growth per annum	States with negative or stagnant growth	Yield growth per annum	States with negative or stagnant growth
1957-1968	Pre-Green Revolution	2.97%	5/13	0.71%	9/13	2.70%	3/13
1969-1975	Green Revolution	0.67%	4/13	1.23%	4/13	-0.73%	7/13
1976-1988	Wider Technology Dissemination	3.61%	4/13	2.19%	6/13	1.97%	5/13
1989-1995	Diversification	2.21%	4/13	1.97%	4/13	0.48%	4/13
1996-2004	Post-reform	0.97%	8/13	0.50%	8/13	2.13%	6/13
2005-present	Recovery	2.78%	1/13	1.95%	3/13	4.38%	4/13
1957-2012		2.83%		1.92%		2.09%	

Note: Stagnant yield growth is defined as growth <1%/annum. States included correspond to those available in Evenson et al. (1999). Yield growth rates from Evenson et al. (1999) are used to extend our 1980-2008 data backwards from 1980 to 1957, and growth rates from the Production, Supply, and Distribution Database (FAS, 2013) are used to extend our data forward from 2008 to 2012. Development periods above are drawn from Chand and Parappurathu (2012).

Table 2. Review of the Indian Agricultural TFP Studies

Study	Data Source	Sectors	Method	Period	Per Annum Results
Coelli and Rao (2005)	FAO	All Agriculture	Malmquist Index	1980-2000	1.40%
			Tornqvist Index	1980-2000	0.90%
Fuglie (2012)	FAO	All Agriculture	Tornqvist Index	1980-2000	1.39%
Avila and Evenson (2010)	FAO	All Agriculture	Tornqvist Index	1981-2000	2.41%
Nin-Pratt, et al. (2010)	FAO	All Agriculture	Malmquist	1980-2000	0.69%
Chand, et al. (2011)	Indian	Crops & Livestock*	Tornqvist Index	1985-2006	0.53%
Fan, et al. (1999)	Indian	Crops (19) & Livestock (2)	Tornqvist Index	1980-1994	1.96%
Rosegrant and Evenson (1992)	Indian	Crops (15)	Tornqvist Index	1975-1985	0.98%
Evenson, et al. (1999)	Indian	Crops (18)	Tornqvist Index	1977-1987	1.05%
Birthal et al. (1999)	Indian	Livestock (9)	Tornqvist Index	1980/81-1995/96	1.79%

*The crops and livestock products included are not described in the analysis.
Note: The numbers in parentheses above reflect the number of commodities included in the crop or livestock aggregations.

Table 3. Agricultural Crops and Livestock Products

Grains	Rice, Maize, Wheat, Sorghum (Jowar), Pearl Millet (Bajra), Finger Millet (Ragi), and Barley
Pulses	Pigeon Pea (Arhar), Chick Pea (Gram), Urad (Black Gram), Moong (Green Gram), Kultha (Horse Gram), and Lentils (Masoor)
Horticulture & Spices	Dry Peas, Potatoes, Tomatoes, Onions, Cabbages, Cauliflower, Green Peas, Sweet Potatoes, Tapioca, Cashew nuts, Bananas, Pineapples, Mangoes & Guavas, Oranges (2), Lemons, Grapes, Melons, Papayas, Apples, Pears & Quince, Coffee, Tea, Cardamom, Coriander, Ginger, Tumeric, Chillies, Garlic, and Arecanuts
Oilseeds	Soybeans, Groundnuts, Linseed, Sunflower seed, Castor, Nigerseed, Safflower, and Sesamum
Specialty Crops	Natural Rubber, Coconuts, Cotton, Jute, Mesta, Sannhemp, Sugarcane, Tobacco, and Guarseed
Animal Products	Wool, Eggs, Milk, and Meat

Table 4. Number of Labor Days Worked per year in India for Select Years

	State	1978	1984	1988	1993	1999	2004
	Andhra Pradesh	230	227	228	238	225	218
	Assam	210	208	208	217	205	199
	Old Bihar	210	208	208	217	205	199
	Gujarat	215	213	213	223	210	204
	Haryana	244	241	242	253	239	231
	Himachal Pradesh	233	230	231	241	228	220
	Karnataka	217	215	215	225	212	206
	Kerala	255	252	253	264	249	242
Male	Old UP	239	236	237	247	234	226
	Maharashtra	240	237	238	248	235	227
	Orissa	210	208	208	217	205	199
	Punjab	244	241	242	253	239	231
	Rajasthan	215	213	213	223	210	204
	Tamil Nadu	293	290	290	303	287	278
	Old UP	210	208	208	217	205	199
	West Bengal	210	208	208	217	205	199
	India	227	224	225	235	222	215
Female	India	182	187	189	203	192	177

Table 5. Tornqvist-Theil Output Indexes, Average Annual Growth, 1980-2008

	All Agriculture	Livestock Products	All Crops	Grains	Pulses	Horticulture & Spices	Oilseeds	Specialty Crops
India	**3.14%**	**4.02%**	**2.81%**	**2.27%**	**1.33%**	**3.84%**	**2.84%**	**3.08%**
North	**2.93%**	**4.10%**	**2.44%**	**2.96%**	**-1.34%**	**2.17%**	**0.56%**	**1.76%**
Punjab	2.76%	3.86%	2.25%	2.90%	-7.78%	3.33%	-1.98%	-0.23%
Haryana	3.46%	4.02%	3.17%	3.84%	-4.81%	4.43%	5.03%	1.43%
Himachal Pradesh	3.31%	3.31%	3.28%	1.47%	-0.48%	4.70%	-2.60%	1.41%
Old UP	2.95%	4.29%	2.44%	2.88%	-0.85%	1.62%	0.17%	2.98%
West	**3.52%**	**4.32%**	**3.16%**	**1.82%**	**2.18%**	**6.44%**	**3.41%**	**1.74%**
Gujarat	3.60%	4.34%	3.29%	1.47%	1.38%	5.76%	2.69%	2.41%
Rajasthan	3.79%	4.34%	3.61%	3.19%	-0.23%	9.03%	7.83%	2.00%
Maharashtra	3.75%	4.82%	3.34%	0.68%	3.61%	6.48%	3.90%	2.33%
Central	**3.47%**	**4.12%**	**3.17%**	**1.79%**	**2.10%**	**4.15%**	**7.99%**	**0.86%**
Old MP	3.47%	4.12%	3.17%	1.79%	2.10%	4.15%	7.99%	0.86%
East	**2.67%**	**3.18%**	**2.46%**	**2.52%**	**-3.33%**	**3.60%**	**-1.88%**	**1.29%**
Old Bihar	2.13%	2.21%	1.99%	2.16%	-0.89%	2.22%	1.79%	0.76%
Orissa	1.47%	6.25%	0.73%	1.50%	-6.13%	2.78%	-6.47%	-0.27%
West Bengal	3.92%	3.60%	4.03%	3.32%	-2.05%	5.59%	4.83%	3.02%
Northeast	**1.97%**	**1.26%**	**2.14%**	**1.74%**	**0.87%**	**2.59%**	**4.15%**	**0.91%**
Assam	1.97%	1.26%	2.14%	1.74%	0.87%	2.59%	4.15%	0.91%
South	**3.38%**	**4.49%**	**2.95%**	**1.16%**	**3.33%**	**4.71%**	**1.61%**	**3.42%**
Andhra Pradesh	4.10%	4.81%	3.76%	1.62%	4.42%	7.12%	1.52%	3.23%
Karnataka	3.23%	4.58%	2.83%	1.98%	2.38%	4.46%	2.63%	1.23%
Kerala	2.38%	3.65%	1.86%	-3.11%	-2.51%	0.74%	-7.78%	4.31%
Tamil Nadu	2.51%	4.24%	1.81%	0.19%	0.49%	3.75%	0.58%	3.01%

Table 6. Average Annual Changes in Commodities' Share of Output Growth, 1980-2008

	Grains	Pulses	Horticulture & Spices	Oilseeds	Specialty Crops	Livestock Products
India	**-1.83%**	**-4.03%**	**2.45%**	**-0.12%**	**-0.41%**	**1.18%**
North	**0.32%**	**-8.50%**	**-1.06%**	**-5.18%**	**-2.11%**	**1.38%**
Punjab	0.30%	-23.40%	0.78%	-10.15%	-6.21%	1.23%
Haryana	1.17%	-17.12%	2.52%	2.31%	-2.82%	-0.16%
Himachal Pradesh	-4.43%	-7.90%	3.14%	-11.05%	-3.78%	-0.70%
Old UP	-0.03%	-6.83%	-1.85%	-5.08%	-0.18%	1.74%
West	**-4.66%**	**-3.90%**	**6.18%**	**-1.02%**	**-2.56%**	**0.46%**
Gujarat	-4.77%	-5.26%	5.11%	-1.88%	-1.53%	0.84%
Rajasthan	-2.45%	-8.84%	10.06%	6.46%	-3.81%	-1.69%
Maharashtra	-8.25%	-1.94%	5.51%	-1.55%	-2.81%	0.95%
Central	**-4.05%**	**-3.12%**	**1.51%**	**8.20%**	**-5.18%**	**-1.41%**
Old MP	-4.05%	-3.12%	1.51%	8.20%	-5.18%	-1.41%
East	**-0.57%**	**-11.57%**	**2.64%**	**-8.88%**	**-3.13%**	**0.07%**
Old Bihar	-0.39%	-4.74%	1.41%	-0.10%	-2.52%	-0.46%
Orissa	-1.70%	-17.60%	2.58%	-16.98%	-4.21%	7.99%
West Bengal	-1.06%	-11.15%	3.73%	2.15%	-3.04%	-1.50%
Northeast	**-0.91%**	**-2.43%**	**1.59%**	**4.50%**	**-2.70%**	**-1.74%**
Assam	-0.91%	-2.43%	1.59%	4.50%	-2.70%	-1.74%
South	**-4.78%**	**-1.18%**	**2.77%**	**-4.04%**	**-0.76%**	**1.81%**
Andhra Pradesh	-5.17%	-1.21%	5.82%	-5.92%	-2.72%	0.57%
Karnataka	-2.99%	-1.90%	2.42%	-1.91%	-2.74%	1.15%
Kerala	-12.33%	-13.92%	-2.85%	-20.57%	1.90%	1.85%
Tamil Nadu	-5.90%	-5.14%	1.39%	-4.49%	-0.35%	3.48%

Table 7. Average Annual Changes in Factor Volumes, 1980-2008

Input:	Male Labor	Female Labor	Total Labor	Land	Machinery Capital	Livestock Capital	Materials	Energy
Units:	Days Worked per Year	Days Worked per Year	Days Worked per Year	Quality-adjusted (rainfed-equivalents) Hectares	Tractors in Use	Animal Stocks in Cattle-equivalents	Metric Tons of Synthetic Fertilizer, Active Ingredient	Kilowatt Hours of Electricity
India	**0.23%**	**1.60%**	**0.67%**	**0.82%**	**8.90%**	**0.71%**	**4.28%**	**7.08%**
North	**0.07%**	**2.90%**	**0.87%**	**0.96%**	**7.24%**	**0.43%**	**3.64%**	**4.98%**
Punjab	-0.89%	4.57%	0.39%	0.40%	5.20%	-0.14%	2.75%	5.29%
Haryana	-0.09%	3.91%	1.07%	0.85%	7.94%	1.35%	5.21%	7.03%
Himachal Pradesh	-0.86%	1.52%	0.36%	0.62%	13.47%	0.23%	2.81%	2.53%
Old UP	0.26%	2.74%	0.94%	1.16%	8.39%	0.40%	3.68%	3.91%
West	**0.49%**	**1.34%**	**0.85%**	**0.99%**	**8.82%**	**0.95%**	**5.38%**	**6.81%**
Gujarat	0.71%	2.60%	1.41%	1.01%	8.25%	1.62%	4.59%	3.79%
Rajasthan	0.19%	0.75%	0.45%	1.36%	9.81%	0.94%	6.87%	7.28%
Maharashtra	0.54%	1.20%	0.81%	0.55%	9.05%	0.55%	5.21%	6.62%
Central	**0.99%**	**1.92%**	**1.30%**	**1.13%**	**11.42%**	**0.81%**	**5.51%**	**10.89%**
Old MP	0.99%	1.92%	1.30%	1.13%	11.42%	0.81%	5.51%	10.89%
East	**0.18%**	**1.44%**	**0.45%**	**0.74%**	**8.70%**	**0.94%**	**5.31%**	**4.52%**
Old Bihar	-0.07%	0.85%	0.14%	0.57%	8.40%	1.78%	5.44%	2.73%
Orissa	0.00%	2.26%	0.67%	0.23%	15.07%	0.01%	5.73%	3.28%
West Bengal	0.65%	1.64%	0.82%	1.46%	7.16%	0.59%	5.01%	10.53%
Northeast	**-0.27%**	**4.30%**	**0.53%**	**-1.52%**	**8.29%**	**1.29%**	**10.80%**	**4.90%**
Assam	-0.27%	4.30%	0.53%	-1.52%	8.29%	1.29%	10.80%	4.90%
South	**-0.21%**	**0.88%**	**0.19%**	**0.39%**	**8.03%**	**0.04%**	**3.64%**	**8.46%**
Andhra Pradesh	0.11%	1.22%	0.56%	0.29%	6.14%	0.58%	4.35%	9.33%
Karnataka	0.55%	1.68%	0.96%	0.83%	9.14%	0.01%	4.57%	11.58%
Kerala	-1.86%	-0.54%	-1.47%	0.43%	6.48%	-2.78%	2.13%	3.50%
Tamil Nadu	-0.62%	0.08%	-0.37%	0.00%	8.44%	-0.34%	1.74%	6.44%

Table 8. Input Cost Shares in 5-Year Averages, 1980-2008

	Land	Labor	Machinery Capital	Livestock Capital	Materials	Energy
1980-84	25%	51%	1%	17%	5%	1%
1985-89	20%	52%	2%	20%	4%	1%
1990-94	17%	55%	4%	19%	4%	1%
1995-99	18%	56%	5%	17%	4%	1%
2000-04	23%	56%	5%	12%	4%	1%
2005-08	32%	45%	7%	12%	3%	1%

Table 9. National and Regional TFP Growth Rate Indexes, 1980-2008

	India	North Region	West Region	Central Region	East Region	Northeast Region	South Region
1980	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1981	1.12	1.18	1.05	1.31	1.18	1.15	0.97
1982	1.16	1.19	1.17	1.34	1.10	1.16	1.10
1983	1.14	1.22	1.12	1.33	1.06	1.22	1.03
1984	1.27	1.27	1.25	1.55	1.29	1.30	1.13
1985	1.29	1.29	1.24	1.44	1.32	1.31	1.18
1986	1.36	1.36	1.20	1.61	1.42	1.40	1.22
1987	1.37	1.36	1.20	1.54	1.44	1.39	1.26
1988	1.32	1.29	1.11	1.73	1.35	1.44	1.27
1989	1.46	1.36	1.42	1.80	1.44	1.37	1.33
1990	1.46	1.36	1.39	1.76	1.45	1.37	1.34
1991	1.45	1.38	1.37	1.82	1.40	1.40	1.29
1992	1.41	1.35	1.14	1.62	1.39	1.45	1.40
1993	1.45	1.33	1.40	1.70	1.27	1.42	1.40
1994	1.50	1.37	1.27	1.88	1.42	1.47	1.52
1995	1.52	1.41	1.39	1.83	1.39	1.54	1.55
1996	1.49	1.40	1.29	1.89	1.40	1.57	1.53
1997	1.57	1.54	1.55	1.94	1.44	1.74	1.58
1998	1.56	1.49	1.49	1.84	1.57	1.79	1.55
1999	1.64	1.51	1.59	1.99	1.55	1.84	1.74
2000	1.64	1.58	1.46	2.01	1.56	1.86	1.74
2001	1.62	1.54	1.41	1.65	1.51	1.85	1.87
2002	1.72	1.55	1.60	1.85	1.67	1.80	1.84
2003	1.57	1.53	1.38	1.58	1.54	1.70	1.72
2004	1.76	1.55	1.82	2.02	1.77	1.66	1.84
2005	1.75	1.58	1.65	1.96	1.69	1.60	1.98
2006	1.88	1.66	1.85	2.02	1.83	1.63	2.17
2007	1.97	1.73	1.98	2.08	1.99	1.50	2.30
2008	2.10	1.80	2.32	2.09	2.11	1.52	2.46
1980-2008 Growth Rate:	1.91%	1.38%	2.02%	1.62%	1.79%	1.49%	2.86%

Table 10. National and Northern Regional TFP Growth Rate Indexes, 1980-2008

	India	North Region	Punjab	Haryana	Himachal Pradesh	Old UP
1980	1.00	1.00	1.00	1.00	1.00	1.00
1981	1.12	1.18	1.03	1.12	1.14	1.28
1982	1.16	1.19	1.08	1.12	1.12	1.27
1983	1.14	1.22	1.10	1.17	1.06	1.32
1984	1.27	1.27	1.11	1.24	1.11	1.38
1985	1.29	1.29	1.16	1.21	1.12	1.41
1986	1.36	1.36	1.21	1.35	1.29	1.43
1987	1.37	1.36	1.20	1.31	1.20	1.46
1988	1.32	1.29	1.21	1.10	1.09	1.42
1989	1.46	1.36	1.21	1.39	1.17	1.46
1990	1.46	1.36	1.28	1.33	1.25	1.44
1991	1.45	1.38	1.23	1.37	1.19	1.48
1992	1.41	1.35	1.27	1.32	1.20	1.43
1993	1.45	1.33	1.29	1.41	1.17	1.39
1994	1.50	1.37	1.31	1.41	1.17	1.44
1995	1.52	1.41	1.32	1.47	1.27	1.49
1996	1.49	1.40	1.32	1.42	1.29	1.48
1997	1.57	1.54	1.45	1.52	1.31	1.67
1998	1.56	1.49	1.33	1.50	1.35	1.62
1999	1.64	1.51	1.37	1.53	1.62	1.62
2000	1.64	1.58	1.50	1.54	1.63	1.71
2001	1.62	1.54	1.45	1.48	1.48	1.64
2002	1.72	1.55	1.45	1.49	1.43	1.67
2003	1.57	1.53	1.43	1.44	1.48	1.68
2004	1.76	1.55	1.46	1.46	1.64	1.67
2005	1.75	1.58	1.55	1.51	1.72	1.67
2006	1.88	1.66	1.59	1.64	1.60	1.78
2007	1.97	1.73	1.61	1.74	1.35	1.87
2008	2.10	1.80	1.67	1.78	1.63	1.93
1980-2008 Growth Rate:	1.91%	1.38%	1.55%	1.44%	1.59%	1.42%

Table 11. National and Western Regional TFP Growth Rate Indexes, 1980-2008

	India	West Region	Gujarat	Rajasthan	Maharashtra
1980	1.00	1.00	1.00	1.00	1.00
1981	1.12	1.05	1.05	1.16	0.98
1982	1.16	1.17	1.16	1.27	1.12
1983	1.14	1.12	1.03	1.38	1.07
1984	1.27	1.25	1.16	1.64	1.14
1985	1.29	1.24	1.21	1.53	1.15
1986	1.36	1.20	1.03	1.64	1.13
1987	1.37	1.20	1.21	1.60	1.05
1988	1.32	1.11	0.77	1.28	1.26
1989	1.46	1.42	1.51	1.85	1.31
1990	1.46	1.39	1.30	1.67	1.41
1991	1.45	1.37	1.19	1.89	1.36
1992	1.41	1.14	1.02	1.45	1.16
1993	1.45	1.40	1.29	1.73	1.43
1994	1.50	1.27	1.04	1.44	1.46
1995	1.52	1.39	1.29	1.84	1.39
1996	1.49	1.29	1.10	1.67	1.40
1997	1.57	1.55	1.32	2.14	1.59
1998	1.56	1.49	1.33	2.33	1.37
1999	1.64	1.59	1.36	2.27	1.62
2000	1.64	1.46	1.07	1.96	1.67
2001	1.62	1.41	1.04	1.96	1.58
2002	1.72	1.60	1.34	2.35	1.66
2003	1.57	1.38	1.13	1.66	1.60
2004	1.76	1.82	1.85	2.50	1.65
2005	1.75	1.65	1.61	2.11	1.65
2006	1.88	1.85	1.89	2.03	1.86
2007	1.97	1.98	1.88	2.24	2.12
2008	2.10	2.32	2.28	2.51	2.42
1980-2008 Growth Rate:	1.91%	2.02%	1.82%	2.29%	2.43%

Table 12. National and Eastern Regional TFP Growth Rate Indexes, 1980-2008

	India	East Region	Old Bihar	Orissa	West Bengal
1980	1.00	1.00	1.00	1.00	1.00
1981	1.12	1.18	1.15	1.35	1.11
1982	1.16	1.10	1.06	1.33	1.03
1983	1.14	1.06	1.05	1.22	0.99
1984	1.27	1.29	1.17	1.62	1.24
1985	1.29	1.32	1.19	1.46	1.35
1986	1.36	1.42	1.28	1.69	1.38
1987	1.37	1.44	1.31	1.62	1.43
1988	1.32	1.35	1.17	1.40	1.50
1989	1.46	1.44	1.24	1.59	1.55
1990	1.46	1.45	1.21	1.65	1.59
1991	1.45	1.40	1.22	1.54	1.53
1992	1.41	1.39	1.07	1.57	1.68
1993	1.45	1.27	1.01	1.15	1.69
1994	1.50	1.42	1.17	1.33	1.77
1995	1.52	1.39	1.14	1.29	1.75
1996	1.49	1.40	1.16	1.31	1.74
1997	1.57	1.44	1.25	1.11	1.81
1998	1.56	1.57	1.29	1.41	1.92
1999	1.64	1.55	1.23	1.45	1.94
2000	1.64	1.56	1.28	1.33	1.95
2001	1.62	1.51	1.25	1.25	1.87
2002	1.72	1.67	1.32	1.51	2.08
2003	1.57	1.54	1.30	1.17	1.98
2004	1.76	1.77	1.49	1.60	2.11
2005	1.75	1.69	1.35	1.63	2.05
2006	1.88	1.83	1.53	1.76	2.12
2007	1.97	1.99	1.77	1.85	2.19
2008	2.10	2.11	1.84	1.94	2.37
1980-2008 Growth Rate:	1.91%	1.79%	1.26%	0.62%	2.74%

Table 13. National and Southern Regional TFP Growth Rate Indexes, 1980-2008

	India	South Region	Andhra Pradesh	Karnataka	Kerala	Tamil Nadu
1980	1.00	1.00	1.00	1.00	1.00	1.00
1981	1.12	0.97	1.01	0.96	1.00	0.92
1982	1.16	1.10	1.15	1.05	1.08	1.09
1983	1.14	1.03	1.15	1.01	1.02	0.89
1984	1.27	1.13	1.22	1.11	1.08	1.03
1985	1.29	1.18	1.13	1.23	1.18	1.21
1986	1.36	1.22	1.23	1.12	1.14	1.34
1987	1.37	1.26	1.19	1.26	1.19	1.33
1988	1.32	1.27	1.24	1.23	1.24	1.35
1989	1.46	1.33	1.38	1.23	1.25	1.36
1990	1.46	1.34	1.35	1.25	1.32	1.38
1991	1.45	1.29	1.29	1.18	1.33	1.33
1992	1.41	1.40	1.39	1.33	1.45	1.43
1993	1.45	1.40	1.37	1.30	1.59	1.48
1994	1.50	1.52	1.52	1.38	1.72	1.59
1995	1.52	1.55	1.48	1.36	1.72	1.77
1996	1.49	1.53	1.52	1.43	1.81	1.53
1997	1.57	1.58	1.63	1.48	1.82	1.45
1998	1.56	1.55	1.48	1.42	1.89	1.63
1999	1.64	1.74	1.70	1.58	1.97	1.87
2000	1.64	1.74	1.69	1.59	1.94	1.86
2001	1.62	1.87	1.86	1.73	2.01	1.94
2002	1.72	1.84	1.99	1.55	1.95	1.86
2003	1.57	1.72	1.89	1.55	1.91	1.57
2004	1.76	1.84	2.26	1.42	1.92	1.61
2005	1.75	1.98	2.33	1.60	2.02	1.82
2006	1.88	2.17	2.37	1.82	2.40	2.03
2007	1.97	2.30	2.54	1.73	2.52	2.32
2008	2.10	2.46	2.87	1.94	2.41	2.23
1980-2008 Growth Rate:	1.91%	2.86%	3.22%	2.07%	3.31%	2.73%

Table 14. National and Central and Northeastern Regional TFP Growth Rate Indexes, 1980-2008

	India	Central Region	Northeast Region
1980	1.00	1.00	1.00
1981	1.12	1.31	1.15
1982	1.16	1.34	1.16
1983	1.14	1.33	1.22
1984	1.27	1.55	1.30
1985	1.29	1.44	1.31
1986	1.36	1.61	1.40
1987	1.37	1.54	1.39
1988	1.32	1.73	1.44
1989	1.46	1.80	1.37
1990	1.46	1.76	1.37
1991	1.45	1.82	1.40
1992	1.41	1.62	1.45
1993	1.45	1.70	1.42
1994	1.50	1.88	1.47
1995	1.52	1.83	1.54
1996	1.49	1.89	1.57
1997	1.57	1.94	1.74
1998	1.56	1.84	1.79
1999	1.64	1.99	1.84
2000	1.64	2.01	1.86
2001	1.62	1.65	1.85
2002	1.72	1.85	1.80
2003	1.57	1.58	1.70
2004	1.76	2.02	1.66
2005	1.75	1.96	1.60
2006	1.88	2.02	1.63
2007	1.97	2.08	1.50
2008	2.10	2.09	1.52
1980-2008 Growth Rate:	1.91%	1.62%	1.49%

Appendix Table 1. Agricultural Production Data Sources

Series	Level of Aggregation	Source
Crop production	State	Agricultural Statistics at a Glance (1980-2009), Directorate of Economics & Statistics, Department of Agriculture and Co-operation, Ministry of agriculture, Government of India
Wool production	State	Indiastat.com, accessed in 2010-11, Datanet India Pvt. Ltd. New Delhi, India
Eggs production	State	Bulletin on Food Statistics (1980-1995), Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.
Milk production	State	Basic Animal Husbandry Statistics (1999, 2006, 2008, 2010) Department of Animal Husbandry and Dairying & Fisheries, Ministry of Agriculture, Government of India.
Meat production	State	Department of Statistics, Central Statistical Organization, Government of India Food and Agricultural Organization (FAOSTAT)
Farm animals in stock	State	Livestock Census Report (1982, 1987, 1992, 1997, 2003, 2007), Department of Animal Husbandry and Dairying & Fisheries, Ministry of Agriculture, Government of India.
Farm level commodity prices	State	Agricultural Statistics at a Glance (1980-2009), Directorate of Economics & Statistics, Department of Agriculture and Co-operation, Ministry of agriculture, Government of India Farm harvest prices of principal crops in India (2004-2009). Directorate of Economics & Statistics, Department of Agriculture and Co-operation, Ministry of agriculture, Government of India
Farm wages	State	Agricultural Wages in India (1980-2009), Dept. of Agriculture & Cooperation, Ministry of Agriculture, Government of India.
Agricultural land use	State	Agricultural Statistics at a Glance (1980-2009), Directorate of Economics & Statistics, Department of Agriculture and Co-operation, Ministry of agriculture, Government of India Land Use statistics at a Glance (1996-97:2005-06), Directorate of Economics & Statistics, Department of Agriculture and Co-operation, Ministry of agriculture, Government of India
Farm labor	State	National Sample Survey Office, National Statistical Organization, NSS-ROUNDS (43rd round, 1987, 50th round, 1993-94, 55th round, 1999-00, 61st round, 2004-05, 66th round, 2009-10), Ministry of Statistics & Program Implementation, Government of India

Appendix Table 1. Agricultural Production Data Sources, Continued

Series	Level of Aggregation	Source
Fertilizer use	State	Indian Harvest, Accessed in 2010-11, Centre for Monitoring Indian Economy Pvt. Ltd. Mumbai, India.
Fertilizer prices	State	Fertilizer Statistics (1980-2009), The Fertilizer Association of India, New Delhi. India
Electricity consumption	State	http://www.epwrfits.in/index.aspx, accessed in November 2011, India Time Series data. Economic and Political Weekly Research foundation, Mumbai, India.
Electricity tariffs	State	All India Electricity Statistics-A general Review (1995-2009), Central Electricity Authority, Ministry of power, Government of India.
Animal stock service prices	National	Food and Agricultural Organization (FAOSTAT)
Agricultural tractors in use	State	Agricultural Research Data Book (2004-2010), Indian Agricultural Statistics Research Institute (Indian Council of Agricultural Research - ICAR), New Delhi, India.
Agricultural tractor rental rates	National	Evenson, et al. (1999) and the Food and Agricultural Organization (FAOSTAT)

Appendix Table 2. Tornqvist-Theil Output Index Growth Rates in 5-Year Averages, 1980-2008

	India	North Region	Punjab	Haryana	Himachal Pradesh	Old UP	West Region	Gujarat	Rajasthan	Maharashtra	Central Region	Old MP
1980-1984	6.18%	7.56%	5.02%	6.10%	4.44%	9.54%	5.91%	3.48%	11.65%	4.68%	10.92%	10.92%
1985-1989	3.33%	2.73%	2.31%	3.96%	2.07%	2.80%	2.64%	0.73%	1.42%	4.73%	7.01%	7.01%
1990-1994	3.38%	2.49%	3.10%	3.78%	2.31%	2.28%	1.79%	0.19%	0.01%	3.86%	4.80%	4.80%
1995-1999	2.94%	2.77%	2.00%	1.97%	2.90%	3.50%	5.60%	5.48%	8.25%	4.33%	2.69%	2.69%
2000-2004	1.25%	0.99%	0.83%	1.51%	2.98%	1.03%	4.75%	12.51%	4.86%	-0.31%	0.31%	0.31%
2005-2008	5.89%	3.55%	1.84%	5.77%	-0.34%	3.63%	11.22%	10.25%	7.83%	13.01%	2.84%	2.84%
1980-2008	3.14%	2.93%	2.76%	3.46%	3.31%	2.95%	3.52%	3.60%	3.79%	3.75%	3.47%	3.47%

	East Region	Old Bihar	Orissa	West Bengal	Northeast	Assam	South Region	Andhra Pradesh	Karnataka	Kerala	Tamil Nadu
1980-1984	5.40%	4.10%	8.86%	4.92%	5.97%	5.97%	2.99%	6.88%	2.87%	0.21%	-1.02%
1985-1989	3.33%	2.47%	2.05%	4.95%	2.02%	2.02%	3.98%	5.80%	3.18%	2.38%	2.61%
1990-1994	1.52%	0.71%	-4.32%	5.25%	2.83%	2.83%	5.73%	5.20%	5.65%	6.45%	6.32%
1995-1999	2.81%	1.67%	1.96%	4.43%	1.11%	1.11%	2.49%	2.92%	3.77%	1.36%	0.95%
2000-2004	2.57%	2.68%	2.88%	2.52%	0.27%	0.27%	-1.68%	3.42%	-4.13%	-1.39%	-8.21%
2005-2008	5.41%	8.86%	4.36%	2.94%	0.59%	0.59%	6.98%	8.40%	4.77%	2.19%	7.89%
1980-2008	2.67%	2.13%	1.47%	3.92%	1.97%	1.97%	3.38%	4.10%	3.23%	2.38%	2.51%

Endnotes

[1] We extend our own 1980-2008 wheat, rice, and maize yields back to 1957 using Indian state- and commodity-specific data from Evenson, et al. (1999) and forward to 2012 using commodity-specific data from the Production, Supply, and Distribution (PS&D) database (FAS, 2012).

[2] Our productivity literature review thus omits other important studies, such as Easter, et al. (1977) and Kumar, et al. (2008). Easter, et al. employ a production function approach to explain India's 1960s agricultural value growth in its wheat and rice regions, whereas Kumar, et al. employ a Tornqvist index to examine crop-specific TFP growth rates by Indian state between 1971 and 2000.

[3] 1 quintal = 100 kg.

[4] 2006 poultry production volumes from the 2006 and 2010 Basic Animal Husbandry Statistics databooks were missing.

[5] Evenson, et al. (1999) fail to provide the number of labor days worked for Assam, Himachal Pradesh, and Kerala. Assam thus assumes the average of Old Bihar and West Bengal, Himachal Pradesh assumes the average of Haryana, Punjab, and Old UP, and Kerala assumes the average of Tamil Nadu and Karnataka.

[6] India's total gross area in production has grown 0.33% per annum between 1980 and 2008, highly comparable to the 0.37% per annum growth rate in the sum of each commodity's gross sown area.

[7] Material and energy prices faced by producers are heavily subsidized. We thus test our 1980-

2008 average annual TFP growth estimate by doubling fertilizer prices and employing the general electricity tariff rather than the tariff specific to agriculture. These steps raise (lower) our national-level average annual input (TFP) growth index by 0.20%.