Specialization and Diversification in Agricultural Transformation: The Case of Rural Punjab, c.1900-1995 *

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Abstract

In this paper, the role of crop specialization and diversification in the process of agricultural transformation is empirically investigated for the case of Punjab. The analytical innovation of this paper is that changes in aggregate land productivity are structurally associated with inter-crop, inter-district, and inter-household reallocation of land use. This structural association enables us to characterize the nature of market development and agricultural transformation in a specific region. The empirical part is based on newly-compiled production data of Punjab's agriculture for the period c.1900-1995, where a rapid growth of agricultural production has been observed.

Quantitative results show that, first, the diversity of a traditional and subsistence agriculture went down at the macro (national), semi-macro (district), and household levels, but at a lower pace at the macro level. This change was associated with crop shifts reflecting comparative advantages. Second, even in a region with the oldest history of commercialization of agriculture in developing countries, two phases were clearly distinguished in the specialization process—the first phase in which local transactions such as intra-village sales enable each farm to specialize in crops and the second phase in which inter-regional trading becomes more efficient, inducing a rapid specialization at that level.

Keywords: diversification, comparative advantage, agricultural transformation, growth accounting, Punjab.

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1 Introduction

In this paper, the role of crop specialization and diversification in the process of agricultural transformation is empirically investigated for a developing region. The analytical innovation of this paper is that changes in aggregate land productivity are structurally associated with inter-crop, inter-district, and inter-household reallocation of land use. This structural association enables us to characterize the nature of market development and agricultural transformation in a specific region. Underlying our approach is Timmer's (1997) stylization that, in the initial period of agricultural transformation, the diversity of a traditional and subsistence agriculture might go down both at the national and household levels because of crop shifts reflecting comparative advantages, but the diversity at the national level may go up as the transformation continues. The current paper is the first attempt to quantify Timmer's stylization using actual data from developing countries.

To put the scope of this paper in a different way, this is an attempt to narrow the distance between the literature based on growth accounting and the literature using micro data. Regarding the former, historical records have shown that agricultural productivity has been growing due to introduction of modern technologies, commercialization of agriculture, capital deepening, factor shifts from agriculture to nonagricultural sectors, etc. This whole process could be called 'agricultural transformation,' to which the contribution of each of these factors has been quantified in the existing literature on growth accounting using macro data (Timmer, 1988). On the other hand, the latter literature on microeconomics of household behavior with respect to production choices and technology adoption has been rapidly expanding in the recent period (Kurosaki, 1998; Bardhan and Udry, 1999), partly due to the availability of newly-complied, high quality micro data from developing countries (Grosh and Glewwe, 1998). Since the macro statistics reflect the aggregated behavior of micro agents, it is desirable to associate quantitative changes at macro levels with those at more disaggregated levels. The current paper is an attempt in this direction.

The empirical part is based on the case of Punjab, c.1900-1995, whose data sets were newly compiled by the author at the national, regional, and farm household levels. This case is ideal for our investigation because Punjab has experienced a rapid growth of agricultural production during this period with rich accumulation of statistical data, but it still remains as a low income, developing area with substantial potential for future development.

In the followings, analytical framework is discussed in Section 2. In Section 3, the data sets used in this paper are explained briefly. Section 4 presents empirical results in the order of national level analyses, regional contrasts, and household level investigation. Findings and implications of the investigation are summarized in Section 5.

2 Agricultural Transformation and Crop Shifts

2.1 Microeconomics of Crop Shifts and Development of Rural Markets

We model the significance of crop shifts in the process of agricultural transformation with a focus on the development of rural markets. If all producers choose crops on the principle of comparative advantages and all producers face the same relative prices, land reallocation occurs only when technology or relative prices change. In agriculture, these changes should be important—e.g., introduction of irrigation or tractor technology allows farmers more freedom in cropping, resulting in land reallocation in favor of more profitable crops. On the other hand, if there exists disequilibrium in the sense that not all producers choose crops on the comparative advantage principle, there is a room for agricultural growth without these changes. By reallocating resources in a way closer to the comparative advantage principle, agricultural output can increase without technological or price changes. These are called 'disequilibrium' effects and emphasized in the literature on inter-sectoral factor reallocation (Syrquin, 1984: pp.80-82).

In the case of agriculture, however, the same phenomenon could be better interpreted as an equilibrium shift rather than a disequilibrium. Since space and transportation costs are important in crop production, the assumption that all producers face the same relative prices is not justifiable. With substantial transportation costs, farmers may optimally choose a crop mix that *does not* maximize expected profits evaluated at the market prices but that *does* maximize expected profits evaluated at the farm-level shadow prices (Omamo, 1998a; 1998b). Furthermore, the objective function of farmers may include considerations for production and consumption risk and/or domestic needs for family, which results in a production choice different from the one dictated by the expected profit maximization principle. In such a case also, the production choices by farmers could be expressed as a subjective equilibrium evaluated at the household-level shadow prices (de Janvry et al., 1991; Kurosaki, 1998).

As rural markets develop, the discrepancy between the market price of a commodity and its shadow price at the farm level is reduced, thereby the macro-level agricultural output evaluated at market prices is increased. In other words, development of rural markets is a process which allows farmers to adopt production choices that reflect their comparative advantages more closely, contributing to productivity improvement at the aggregate level evaluated at common, market prices.

[Insert Figure 1]

This microeconomic mechanism implies specific relationships between crop diversification and agricultural transformation, which are stylized for Asian agriculture in Figure 1 by Timmer (1997). He contrasts diversification of food crops at three levels: national food consumption, national food production, and production at the farm level. The diversification level of national food consumption could be higher than that of national food production if international trade allows each country to concentrate on producing crops it has comparative advantages. Production at the national level could be more diverse than that at the farm level if commercialization of agriculture allows each farmer to concentrate on producing crops he/she has comparative advantages.

During the initial phase of agricultural transformation, the diversification measures are similar at all the three levels because farmers have to grow crops they want to consume due to the absence of well developed agricultural produce markets. As rural markets develop, however, production diversity at the farm level goes down quickly, leading to crop specialization.[1] Development of agricultural produce markets enables farmers to increase the area allocated to crops for which they have comparative advantages and to depend on markets for food crops for which they do not have a comparative advantage. Initially, some of the produce markets might be 'thin' with volatile prices. In such a case, farm households may participate in the markets only marginally when they are faced with incomplete insurance markets but increase their production of lucrative crops as their constraints on consumption smoothing are eliminated (Kurosaki and Fafchamps, 1998; Kurosaki, 1998). Similarly, development of rural labor markets enables farmers to grow more market-oriented crops through reducing constraints on family labor endowments (de Janvry et al., 1991).

In Timmer's (1997) stylization, the diversification level of national production goes up again as agricultural transformation continues further. This is because a rising demand for diversified food consumption in Asia will be met mostly through national production because the non-tradable, service elements become more important. In this later phase

[1] See Omamo (1998b) for an explicit quantification of the effects of transportation costs on the farm-level diversification.

also, the diversification level continues to go down at the farm level, since the principle of comparative advantages continues to work in this phase also.

2.2 Empirical Strategy

2.2.1 Inter-Crop Shifts as a Growth Source

Based on the theoretical arguments above, three empirical tasks are derived for this paper. First, using macro data, we quantify the contribution of *inter-crop* land reallocation to agricultural growth. This will shed light on the role of agricultural trade on growth (Figure 1) from an angle different from cross-country growth regressions.

Algebraically, letting Q_t denote agricultural value-added or gross output in year t, A_t denote cultivated land, and Y_t denote land productivity, the agricultural growth from year 0 to year t can be decomposed as

$$\ln(Q_t/Q_0) = \ln((A_tY_t)/(A_0Y_0)) = \ln(A_t/A_0) + \ln(Y_t/Y_0), \tag{1}$$

where the first term on the right hand side shows area effects and the second term shows land productivity effects. By decomposing the total production into subsectors comprising various crops denoted by i, the land productivity effects in equation (1) is further decomposed into

$$\ln(Y_t/Y_0) \approx \frac{Y_t - Y_0}{Y_0} = \frac{1}{Y_0}\left[\sum_i s_{i0}(Y_{it} - Y_{i0}) + \sum_i (s_{it} - s_{i0})Y_{i0} + \sum_i (s_{it} - s_{i0})(Y_{it} - Y_{i0})\right], \tag{2}$$

where $s_{it} \equiv A_{it}/\sum_k A_{kt}$, which is the area share of crop i in year t. Growth accounting based on equation (2) is the first empirical task of this paper.[2]

The first term in the right hand side of equation (2) shows aggregate crop yield effects, the second term indicates crop shift effects, and the third term is a residual. Following the terminology of van Ark and Timmer (2000), the second term is called 'static land reallocation effects' and the third term is called 'dynamic land reallocation effects' in this paper. The third term shows 'dynamic' effects because it becomes more positive when the area under dynamic crops (i.e., crops whose yields are improving) increases relative to the area under non-dynamic crops. In contrast, the second term shows 'static' effects since it becomes more positive when the area under crops whose yields were initially high increases relatively.

[2] In the existing literature, while a number of empirical studies have quantified the effects of factor reallocation between agriculture and non-agriculture sectors (see Syrquin, 1984, for a survey) and van Ark and Timmer (2000) investigate the effects of labor shifts among the subsectors of manufacturing on labor productivity, there are few studies that quantify factor reallocation effects among the subsectors of agriculture.

2.2.2 Spatial Shifts as a Growth Source

Second, using more disaggregated data, we can quantify the contribution of *spatial* land reallocation to agricultural growth. With developed rural markets, individual farmers or individual subregions can specialize in crops they have comparative advantages, leading to productivity improvement at the aggregate level. This aspect corresponds to the role of commercialization of agriculture in Figure 1.

Algebraically, letting h denote a spatial unit of crop production, the yield effects for crop i in equation (2) can be further decomposed as

$$Y_{it} - Y_{i0} = \sum_h s_{hi0}(Y_{hit} - Y_{hi0}) + \sum_h (s_{hit} - s_{hi0})Y_{hi0} + \sum_h (s_{hit} - s_{hi0})(Y_{hit} - Y_{hi0}), \quad (3)$$

where $s_{hit} \equiv A_{hit}/\sum_k A_{kit}$ is the share of unit h in the cultivated area of crop i in year t. As in equation (2), the first term in the right hand side of equation (3) shows pure yield effects, the second term indicates static land reallocation effects and the third term shows dynamic land reallocation effects.

The decomposition proposed in equation (3) explicitly incorporates the effects of factor reallocation over space. In other words, so-called 'yield effects' in the existing literature based on macro data are often the mixture of pure yield effects (e.g., due to TFP shifts) and spatial reallocation effects. The spatial unit h can be a field plot, a farm household, a village, or a region, depending on the availability of data. In this paper, *inter-regional* land reallocation effects are investigated using 'district' level data (see Section 3).

2.2.3 Crop Diversification at Different Aggregation Levels

Third, if spatial reallocation of land is important, the diversification level of crop production and its dynamics should differ by aggregation levels. We investigate this implication through two indices of crop diversification adopted from concentration indices used in the industrial organization literature. As far as the author knows, this is the first attempt to apply these measures to agriculture in developing countries at different aggregation levels (Timmer, 1997: p.622). Although Timmer (1997) contrasted the production diversification only at national vs. farm levels, the comparison could be made at various aggregation levels. In this paper, crop specialization/diversification is investigated at the national (macro), district (semi-macro), and household (micro) levels.

Regarding the diversification indices, the first index is defined as

$$DIV1_t \equiv 1 - CR3_t = 1 - \sum_{i \in MAX3} s_{it}, \tag{4}$$

where $CR3_t$ is the concentration ratio of the top three crops in terms of cultivated areas. The second index is

$$DIV2_t \equiv 1 - H_t = 1 - \sum_i s_{it}^2, \tag{5}$$

where H_t is the Hirshman-Herfindahl index. Index $DIV2_t$ has an intuitive meaning of the probability of hitting different crops if two points are randomly chosen from the whole area under cultivation.

3 Data

To implement the three empirical analyses explained in the previous section, data should cover a sufficiently long period that contains the initial phase of low market development as well as the following phase of dynamic agricultural transformation. At the same time, data quality should be comparable as much as possible over the (potentially) long period. The case of Punjab, c.1900-1995 is ideal for the investigation since the region has experienced a rapid agricultural growth during this period, especially famous for its 'Green Revolution' since the late 1960s, but it still remains as a low income, developing area with substantial potential for future development. Among developing countries, Indian Subcontinent is exceptional with a rich accumulation of long term agricultural statistics collected by colonial and post-independence governments. National and regional data for this paper are estimated and compiled from these sources.

3.1 National Data

Since Punjab was divided between India and Pakistan in 1947 when the two countries achieved independence, the national data used in this paper are taken from a new data set compiled by the author that corresponds to the current border in India and Pakistan.[3] Kurosaki (2000) presents the compiled data as well as the details of data compilation procedures. Descriptive analysis of agricultural growth and changes in crop mix based on this data

[3] Strictly speaking, it is fictitious to call these two parts as 'national' data for India and Pakistan since the nation of Pakistan did not at all exist before the 1940s. We call them 'national' only for convenience to make it easier to compare the pre- and post- independence periods.

set is presented in Kurosaki (1999). The data set covers a period from 1901/02 to 1995/96.[4] Original data sources before independence are *Agricultural Statistics of India*, *Estimates of Area and Production of Principal Crops*, and various provinces' *Season and Crops Reports*. Post independence data are compiled from official government publications of agricultural statistics.

In this paper, we analyze production of principal crops, which are important in contemporary India and Pakistan, and for which detailed data on production and prices are available from the British period. For India, eighteen crops are included: rice, wheat, barley, jowar (sorghum), bajra (pearl millet), maize, ragi (finger millet), gram (chickpea); linseed, sesamum, rape and mustard, groundnut; sugarcane, tea, coffee, tobacco, cotton, and jute. The first eight commodities are foodgrains and the following four comprise the oilseeds sector. The rest are pure cash crops. These crops currently occupy more than two thirds of the total output value from the crop sector and more than a half of the total output from agriculture, and their contribution was higher in the colonial period.

For Pakistan, all twelve crops included in the major crops subsector of the national accounts are covered, i.e., rice, wheat, barley, jowar, bajra, maize, gram; rape and mustard, sesamum, sugarcane, tobacco, and cotton. The first six crops are foodgrains and the rest are cash crops including oilseeds. The major crops subsector occupies about 70% of value-added from crops and about 40% of value-added from agriculture, and its share was higher in the colonial period.

In analyzing national data based on equations (1) and (2), the gross output values from these crops were aggregated using fixed prices of 1959/60 (Pakistan) or 1960/61 (India). Ideally, the sum of value added could be a better measure but the sum of gross output values is used as a proxy due to the absence of reliable data on inputs before independence.[5] We also tried other base years (e.g., 1938/39 and 1980/81) for aggregation weights but the results reported in this paper were insensitive to the choice of base years.

[4] They are denoted in India's agricultural years. For instance, '1995/96' is a period from July 1995 to June 1996. In figures where space is limited, it is denoted as '1996' for short.

[5] We investigated the value added ratio to the sum of gross output values since the early 1950s, when India and Pakistan began to estimate national income statistics. The ratio was stable until the 1970s. During the 1970s, the ratio increased gradually and was stabilized again in the early 1980s.

3.2 Regional Data

At the regional level, the unit we chose for the analysis is 'district.' It is a basic unit of local administration for which long term statistics are available from the colonial period. The Punjab region during the colonial period consisted of the British Province of Punjab and several princely states. Since district boundaries were changed occasionally, the boundaries during 1905-1919 were chosen as the reference, resulting in 28 districts for British Punjab (called 'BP Districts' below). When a district was divided into two or more districts, the boundary adjustments were nominal. When two or more districts were merged and re-divided into several districts, crop areas were divided proportionally if more disaggregated data were not available.

In 1947, the Indian Empire was partitioned into India and Pakistan, dividing Punjab and Bengal. Among the 28 BP Districts, 15 districts of West Punjab belonged to Pakistan and the rest belonged to India. The former group is called 'WBP Districts' and the latter group is called 'EBP Districts' below. The Punjab Province of Pakistan today covers the areas of WBP Districts and the princely state of Bahawalpur. The area corresponding to Bahawalpur was divided into three, based on the district boundary of the early 1950s. The group of 18 districts spanning Pakistan's Punjab (15 WBP Districts plus 3 Bahawalpur Districts) is called 'PP Districts' below. A name list of these districts (total = 31) is given in Appendix Table 1.

For each of the 31 districts, data of cropped area and output were compiled for the twelve major crops, which are the same as those for Pakistan's national data set. District-level data before independence were drawn from various issues of *Report on the Season and Crops of the Punjab* beginning from 1901/02. Those data after independence were compiled only for PP Districts. Data compilation for EBP Districts after independence is left for further study since they experienced frequent and complicated boundary changes. Therefore, the core part of district-level analyses employs a balanced panel of 15 WBP Districts covering more than ninety years. The analyses based on this part of the data are supplemented by analyses for BP Districts before independence and analyses for PP Districts after independence.

The data set thus compiled was employed in growth decomposition according to equation (3) and in investigation of regional level dynamics of crop diversification indices. When necessary, 1959/60 Pakistan prices were used as aggregation weights. To remove temporal variation due to weather shocks and others, MA(3) was applied to cropped area data and

MA(5) was applied to output data with the mid year used in notation.

3.3 Farm-Level Data

Since 1923/24, the Board of Economic Inquiry, Lahore, issued reports called *Farm Accounts in the Punjab* in which detailed accounts of selected farms in the British Province of Punjab were presented. Initially, reports covered around ten farms; later the coverage was increased to around 30 farms. Since the Board tried to follow the same farm every year, some of the micro observations could be attributed to specific farms over an extended period. Although a care has to be taken of their small number of observations and their subjective choice of 'representative' samples, the report is a valuable source of micro information on Punjab's agriculture before independence.

After a short period of discontinuation around the Partition of 1947, the survey was resumed for the period 1949/50 - 1954/55 and since 1965/66 in West Punjab. During the mid 1970s, the Board of Economic Inquiry was reorganized as the Punjab Economic Research Institute (PERI) and the farm accounts survey was redesigned as the one based on scientific random sampling. When the random sampling procedure was adopted, the style of reports were also changed, in which only class-wise average figures were published without micro data. Therefore, this paper employs micro data available from published sources, which cover the period from 1949/50 to 1969/70 with several discontinuations.

In addition to these, farm accounts data collected by the PERI in Sheikhupura District from 1988/89 to 1990/91 are also employed in this paper. The original data were collected by the PERI for the same purpose above and compiled by the author into a three-year panel data of 59 households (Kurosaki, 1998). Therefore, this paper uses the subset of the micro data until 1969/70 that was comparable to the panel data set of 1989-91. Regarding the comparability, characteristics of geography, agronomy, history, and tenancy structure were examined, resulting in the choice of those farms in Gujranwala District and Lyallpur District.[6] Data for farms in Lyallpur are available for both pre- and post-independence periods while those in Gujranwala are available only after independence. When pooled, the number of farms in the data set was two in most years before 1947 and 11.3 per year on average after 1947.

Based on these sources, farm-level cropping patterns were sorted out into the same twelve

[6]Based on the 1905-19 district boundaries, Sheikhupura villages in the panel data 1989-91 belong to Gujranwala District but are also close to the border with Lyallpur District.

crops that were compiled for the district-level data. The two indices of crop diversification ($DIV1$ and $DIV2$) were then estimated for each farm in each year.[7]

4 Empirical Results

4.1 Agricultural Growth and Crop Shifts at the National Level

Before investigating the effects of land reallocation on land productivity, the contribution of land productivity to the overall agricultural growth is quantified in Table 1 based on equation (1). In areas currently in Pakistan, the production increased at 1.3% per annum before independence and the growth rate was accelerated to 3.7% since independence. Area effects explained 71% of the pre-independence growth whereas land productivity effects accounted for 65% of the post-independence growth. This pattern is shared with India, where the pre-independence agricultural growth was minimal and almost completely explained by area effects while land productivity effects accounted for 76% of the post-independence growth.

[Insert Table 1 and Table 2]

To what extent were these land productivity effects explained by land reallocation? Table 2 shows results of decomposition according to equation (2) to quantify the *inter-crop* land reallocation effects. In areas currently in Pakistan, yield effects explained about 70% both in pre- and post- independence periods. The rest was explained mostly by dynamic shift effects before 1947 and by both dynamic and static shift effects after 1947. In the table, contribution in each decade is also shown, which indicates that static land reallocation effects were as important as yield effects during the 1950s. This finding supports the conjecture in Kurosaki (1999) that land reallocation toward high value crops was the main engine of agricultural growth during this period.

In areas currently in India, let us investigate the post independence period only because the growth rates of land productivity were not statistically significant before independence (Kurosaki, 1999). First, although smaller than in Pakistan, the contribution of total land reallocation effects is substantial, explaining more than 20% of post-independence growth in

[7]Data used in this paper are available on request from the author. The national data are included in Kurosaki (2000). The district-level data set is a part of the 1995-2000 project "The Compilation of an Integrated Long-Term Economic Statistical Database of the Trans-Asian Region" (COE Project) implemented at the Institute of Economic Research, Hitotsubashi University. The data set will be available for public access when it is completed. See the project's home page for the latest information (address: http://www.ier.hit-u.ac.jp/COE/index.html).

land productivity. Second, the importance of static shift effects is becoming more important during more recent decades than during the 1950s and 1960s.

These results indicate that the *inter-crop* land reallocation effects are an important source of growth in land productivity both in India and Pakistan. The contrast during the colonial period suggests that international trade was more important in the areas currently in Pakistan than in those in India. We give two reasons for this. First, since the areas currently in Pakistan occupied only a part of the British Empire of India, they could enjoy the benefit of specialization within the Indian Empire. Second, the contrast could reflect the rising importance of canal colonies in Punjab (most of which belonged to the areas currently in Pakistan) as a supply source of wheat and cotton to the world market within the system of the Empire of Great Britain.

4.2 Yield Growth and Spatial Crop Shifts at the District Level

[Insert Table 3]

Yield effects shown in Table 2 include effects of both the shifts of production functions and the land reallocation over space. Table 3 shows results of decomposition of yield changes according to equation (3). It quantifies the effects of *inter-district* land reallocation on yield changes of four major crops (wheat, rice, sugarcane, and cotton) in WBP Districts. Due to data availability[8] and MA(5) data processing, the estimation periods in Table 3 are slightly different from those in Table 2, but this difference does not affect our results qualitatively.

Growth rates of wheat yields during the pre-independence period were not statistically significant. Therefore, it does not make much sense to discuss relative contribution of pure yield vs. crop shift effects. During the post-independence period, however, the wheat yield grew at 2.6% annum on average. Table 3 shows that less than 10% of this growth was attributable to land reallocation effects among districts. In other words, 'pure yield' effects were the dominant source of growth. This does not imply that spatial land reallocation effects were negligible since we were able to quantify the *inter-district* reallocation effects only and it is possible that *inter-household* reallocation contributed to the 'pure yield' effects. Nevertheless, considering the fact that wheat is a staple food of Punjabi farmers and it is grown all over Punjab, results in Table 3 seem to suggest that spatial reallocation is not

[8] For example, *Reports on the Season and Crops of the Punjab* published district-level yield data beginning from 1907/08.

very important in the case of wheat. 'Pure yield' effects in Table 3 are the most significant during the 1960s, followed by the 1970s, i.e., decades of 'Green Revolution' in Punjab.

Results for rice show a striking contrast to wheat. Before independence, when aggregate rice yields grew at 0.27% (statistically significant at 1% level), the only source of yield growth was land reallocation. Both static and dynamic reallocation effects contributed to approximately 60% of yield growth, while pure yield effects were negative. During the post independence period, 'pure yield effects' were the only source of growth in the same way as in wheat. The improvement in pure yields was the most significant in the 1960s.

In the case of sugarcane, inter-district land reallocation effects were not significant in both pre- and post- independence periods. Decade-wise investigation also shows that aggregate yield growth of sugarcane was caused by improvements in pure yields.

An interesting finding is obtained for the case of cotton. Dynamic land reallocation effects were important in both pre- and post- independence periods. They explained more than one fourth of aggregate yield growth of cotton. Expansion of cotton production for markets both domestic and abroad was the most important development of Punjab's agriculture during the colonial period. In recent periods also, Pakistan's economy is heavily dependent on cotton production in Punjab. Our investigation has shown that the land productivity of cotton improved not only through improvements of pure crop yields but also through reallocation of cultivated land from districts whose cotton yields are stagnant to districts whose cotton yields are improving.

[Insert Figure 2]

Inter-district crop shifts discussed above are reflected in the concentration of each crops into specific districts. This aspect is shown in Figure 2, which plots the coefficients of variation (CV) among 15 WBP Districts for each of the four crops. A large CV implies that cultivation of the crop of concern is concentrated on a few districts.[9] The CV of wheat is stable all through the 20th century, with a slight increase in concentration during the last decade. The mapping between Figure 2 and Table 3 is the clearest for rice and cotton. When land reallocation effects were important in aggregate yield improvement in Table 3 (rice before independence and cotton all through the period), concentration in terms of CV also increased in Figure 2.

[9] Plots using $CR3$ show similar results.

[Insert Table 4]

From these observations, it has been shown that inter-district land reallocation was an important source of aggregate yield growth for cash crops like rice and cotton and such crops experienced gradual concentration in producing districts. These geographical shifts were associated with potential differences in comparative advantages in crop production. Table 4 shows this association more directly. Yield disparity among districts was in the range from 1.5 to 2.5 in terms of both absolute and comparative advantages. In the case of cotton, this disparity is becoming wider in the latest decade. Concentration of cropped areas into the top yield districts increased rapidly for rice in the pre independence period and for cotton all through the period. This shows that the direction of land reallocation among districts was consistent with the comparative advantage principle in the case of rice and cotton.[10] Even in sugarcane where we could not find substantial effects of inter-district land reallocation, the *direction* of land reallocation is consistent with the comparative advantage principle. This is confirmed by the fact that 'cropped area concentration' in Table 4 shows a weakly increasing trend. On the other hand, wheat, which is a staple grain crop, is associated with no trend in 'cropped area concentration.'

4.2.1 Crop Diversification at Different Aggregation Levels

4.2.2 Dynamics at the District Level

[Insert Figure 3]

How did the land reallocation among districts affect crop diversification measures at the national and regional level? To investigate the dynamics of crop diversification, two indices discussed in Section 2 were calculated for each of the 31 districts in each year. For comparison, the same indices were calculated for more macro levels also (the total of WBP, BP, and PP). Figure 3 plots these indices for the longest panel of 18 WBP Districts.

First, both of the indices show that the crop mix is more diversified at more macro levels than at the district level. Second, the difference between the two levels has been becoming wider over time. These are due to the progress of specialization at the district level. Third,

[10]Rice figures in 1981/82 and 1989/90 in Table 4 seem to suggest that the reverse reallocation occurred during the latest period. This is not correct, however. Gujranwala District, which is the largest rice growing district, was by chance ranked fourth in terms of yield comparative advantages with a small margin versus the third ranking district. If we re-calculated 'Cropped Area Concentration into the Top Yield Districts' using the ratio of top *four* divided by the bottom *four*, the ratio went up continuously to around four by 1951/52 and then stayed around that level up to 1989/90.

as is shown by the top and bottom 25% plots, the dynamics of district-level diversification indices are heterogeneous—There are several districts that are more diversified than at the province level. Fourth, the heterogeneity in dynamics is more distinct in the colonial period than in the post independence period, when the diversification level declined monotonously in most districts. Fifth, patterns are not the same between the two indices of diversification. During the colonial period, the overall pattern is a moderate decline if we use $DIV1$, while there is little trend if we are based on $DIV2$. The decline in recent years is more rapid for index $DIV2$.

To investigate further the nature of inter-district differences with respect to the dynamics of diversification indices, a simple time series model for each district h is proposed:

$$DIV_{ht} = \alpha_h + \beta_h t + u_{ht}, \tag{6}$$

where u_{ht} is an *i.i.d.* error term. This model was estimated separately for pre- and post-independence periods (NOB=44 and 45 respectively). Parameter estimates using OLS for β_h and their statistical significance are reported in Appendix Table 2. During the post-independence period, all but one $\hat{\beta}$'s are negative and statistically significant. In contrast, there are both positive and negative $\hat{\beta}$'s during the pre-independence period, some of which are statistically significantly positive.

We tried to explain this difference among districts by district attributes (vector X_h). The estimated model is a simple, linear one:

$$\hat{\beta}_h = X_h b + u_h, \tag{7}$$

where b is a vector of coefficients to be estimated. Exogenous variables included in X_h are an intercept, district area, irrigation ratio, average annual rainy days, and road density.[11]

[Insert Table 5]

OLS estimation results are reported in Table 5. There is a sharp contrast between the two periods. During the pre-independence period, regression results for BP Districts were statistically significant (see the F statistics). Larger districts experienced a more rapid decline in diversification indices. This is because larger districts were more diversified at the

[11] Irrigation ratio and average annual rainy days were MA(3) with mid year 1921/22, when the Indus irrigation canal network was almost completed. Since information on road density was available only for recent years, the variable (corresponding to 1985) was used only for post-independence regressions. Data sources are the same as production data (see Section 3).

beginning so that once specialization starts to work according to comparative advantages, diversification could go down rapidly. More irrigated districts are associated with positive $\hat{\beta}$'s. This indicates that the irrigation development during the colonial period made technically feasible to grow diversified crops, thereby contributing to the increase in diversification indices. The plus sign of the average rainy days could be explained by the same reason.

In contrast, regression results for PP Districts during the post-independence period were only slightly significant ($DIV1$) or in-significant ($DIV2$). This is because the variation in $\hat{\beta}$'s is small and most of the small variation is statistically indistinguishable from random errors. In other words, the dynamics of diversification indices during the post-independence period was homogeneous. According to results based on $DIV1$, effects of irrigation on diversification become negative (significant at 10%). A possible reason for this contrast is the extent of crop shifts induced by irrigation. During the colonial period when large-scale irrigation was first introduced, crop shifts to high value-added crops implied a more diversified cropping pattern. During the post-independence period, however, when large-scale irrigation was becoming a decayed technology, further shifts to high value-added crops implied more specialization.

To control for differences in geographical coverage, a pooled regression model with periodic dummy variables was estimated for WBP Districts (Panel C of Table 5). Although the significance levels of individual coefficients went down, the qualitative results are the same as those of Panels A and B. The reversal of the effects of irrigation on diversification was found clearly.

[Insert Figure 4]

The process of specialization among districts in Punjab could be examined from a different angle. Before specialization occurs, the crop mix should be similar among districts as long as agronomic conditions and consumer preferences are similar. As specialization proceeds, the crop mix of one district should become more distinct from that of another district. To quantify this change, Spearman's rank correlation coefficients were calculated for cropping patterns between two districts. Since there are 15 WBP Districts, the coefficient was calculated for 105 patterns each year of choosing two. Results are plotted in Figure 4. A declining trend is clearly observed among the correlation coefficients after independence. Recently, the number of pairs with negative correlation is increasing.

From these analyses in this subsection, the following pattern of agricultural transformation is indicated for the case of Pakistan Punjab. First, land reallocation to more lucrative crops and to districts with more comparative advantages began during the colonial period in a sporadic way. Some districts experienced this specialization strongly while other districts diversified their cropping patterns. On the other hand, during the post-independence period, district-level diversification went down rapidly in almost every district. This could be attributed to a geographical integration of agricultural produce markets over districts, which was accelerated since independence.

4.2.3 Crop Diversification at Three Aggregation Levels

[Insert Figure 5]

In Figure 5, yearly averages of the farm-level indices (see Section 3.3) are plotted against the horizontal axis of indices of agricultural production per agricultural worker on the horizontal axis as a proxy for agricultural transformation.[12] For comparison, the average of district-level diversification of Gujranwala and Lyallpur (semi-macro level) and the diversification indices of the total of WBP Districts (macro level) were also plotted on the same figure.

First, both the diversification indices at macro and at semi-macro levels decline as agricultural productivity improves and the pace of decline is faster at the semi-macro level. This pattern is observed clearly, which confirms the relevance of Timmer's stylization in Figure 1. Second, micro observations show a negative relation but the variance is large, making it difficult to judge whether its pace of decline is faster or not than the decline pace at the semi-macro level. One of the reasons for this could be the small number of historical household data, which is difficult to remedy due to the limited availability of data. Therefore, we would like to interpret the pattern shown in Figure 5 as a weak evidence not inconsistent with Timmer's stylization. Third, the reversal of the macro level indices toward the direction of more diversified production is only weakly observed. According to plots based on $DIV2$, the macro level index seems to show a reverse, positive trend for the highest values of agricultural productivity, whereas plots based on $DIV1$ show a flat portion. We need to wait a decade or so for more observations with high productivity years to derive a definitive answer.[13]

[12] The number of agricultural workers were estimated by interpolating census estimates for the sum of 'cultivators' and 'agricultural laborers.' For original data sources and intermediate estimates of the undivided India, Ono and Saito (2000) was used as a reference.

[13] Another possibility could be that the reversal toward diversification at the macro level is occurring at non-major crops that are outside the scope of this paper.

[Insert Figure 6]

By converting information in Figure 5 into time series plots in Figure 6, we can decipher a three period structure rather than the dichotomous division into pre- and post- independence periods. The first period is until the late 1930s; the second is from the late 1930s to the mid 1950s; and the third covers a period since then.

During the first period, farm-level diversification indices went down steadily while district/province level indices were flat or went down only moderately. This suggests that farm-level specialization occurred before district-level specialization. This is consistent with the development process of rural markets for agricultural produce, in which intra-district (i.e., intra-village and inter-village) transactions developed first, followed by the formation of spatially wider markets over districts. Since per-capita production of 12 major crops in areas currently in Pakistan grew at a statistically significant rate, although its magnitude was much smaller than that of the post-independence growth (Kurosaki, 1999), the first period corresponds to Figures 1 and 5 as a vector at the left edge moving toward right.

The second period is a perverse one, in which diversification indices went up at the farm, district, and province levels. Since per-capita production of 12 major crops in areas currently in Pakistan did not grow at all during this period (Kurosaki, 1999), we would like to characterize this period as a backward moving period toward self-sufficiency. Each farm, each district, and each province was forced to go back to a diversified, self-sufficiency-based cropping pattern by exogenous factors during this period. These factors include disruption of world trade during WWII, the introduction of nation-wide market control under the 'War Economy' in British Empire of India, and the turmoil caused by the division of Punjab between India and Pakistan in 1947. Under these conditions, it makes sense for specialization process to be reversed. The disruption continued for a while even after 1947, for Hindu middlemen who were the major market agents in colonial Punjab migrated to India and the vacancy was not filled immediately.

When the Punjab economy was revived from the chaotic Partition, the third period began in the mid 1950s, which is continuing today. Muslim middlemen filled up the vacancy in agricultural marketing by the mid 1950s. During the third period, diversification indices went down at all levels—farm, district, and province, with the fastest decline at the district level. This seems to suggest that the nation-wide integration of agricultural produce markets was proceeding steadily during this period. This integration drove each district to concentrate on crops for which it has comparative advantages. As is shown in the previous subsection, the district-level specialization was observed uniformly across districts during this period.

5 Conclusion

In this paper, the role of crop specialization and diversification in the process of agricultural transformation is empirically investigated for the case of Punjab. In the analysis, changes in aggregate land productivity are structurally associated with inter-crop, inter-district, and inter-household reallocation of land use. The empirical part is based on newly-compiled production data of Punjab's agriculture for the period c.1900-1995—national data for India and Pakistan, district-level data for the Punjab region, and micro data of farm accounts in Punjab.

Quantitative results show that, first, a significant part of land productivity growth was attributed to inter-crop land reallocation in post-independence India and in areas currently in Pakistan (pre- and post-independence). Second, agricultural transformation in Pakistan's Punjab is characterized as the phase in which crop specialization plays a prominent role according to comparative advantages. A sign toward more diversification at the national level in the later stage was observed only weakly. Third, the pace of specialization was different from district to district during the colonial period, while the pace has been accelerated and become homogeneous since independence. The time contrast reflects the development process of rural markets —spatial integration and deepening of transactions— dealing agricultural produce in the region over this period.

Estimated patterns of the crop diversification dynamics at different aggregation levels are generally consistent with Timmer's (1997) stylization that, in the initial phase of agricultural transformation, the diversity of a traditional and subsistence agriculture might go down both at the national and household levels but at a higher pace at the household level. This paper shows further that, by comparing the time series plots with the Timmer-type plots with agricultural transformation on the horizontal axis, we can characterize the nature of market development and agricultural transformation of a specific region in a more profound way.

Our case of Punjab shows that, even in a region with the oldest history of commercialization of agriculture in the Indian Subcontinent, two phases could be distinguished in the specialization process. First, local transactions enable each farm to specialize in crops for which they have comparative advantages. Intra-village transactions are likely to be the most important among these local transactions. Second, as agricultural transformation proceeds, inter-district trading becomes more efficient, inducing specialization at the district level. In parallel to the two phase structure in agricultural produce markets, Kurosaki and Fafchamps (1998) found a two phase structure in risk sharing also—intra-village risk sharing by Punjab farmers during the late 1980s to early 1990s was economically efficient while inter-village risk sharing was inefficient, forcing farmers to self-insure against bad luck that is common to the villagers. Spatial development of rural markets in developing countries is a complicated process, for which more empirical research is called for.

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Table 1. Decomposition of Growth in the Total Gross Output Values

	Average annual growth rates(%)			Relative contribution (%)	
	Land productivity effects	Area effects	Total	Land productivity effects	Area effects
A. Areas currently in Pakistan					
1901/02 – 1910/11	0.99	3.33	4.32	23.0	77.0
1911/12 – 1920/21	-0.19	-0.13	-0.33	59.8	40.2
1921/22 – 1930/31	-1.15	0.51	-0.64	179.7	-79.7
1931/32 – 1940/41	1.86	0.95	2.81	66.2	33.8
1941/42 – 1950/51	-0.19	0.24	0.05	-411.8	511.8
1951/52 – 1960/61	1.66	1.78	3.44	48.2	51.8
1961/62 – 1970/71	3.93	1.92	5.85	67.2	32.8
1971/72 – 1980/81	1.75	1.49	3.24	54.0	46.0
1981/82 – 1990/91	2.64	0.86	3.50	75.5	24.5
1991/92 – 1995/96	-0.48	1.40	0.93	-51.5	151.5
1901/02 – 1946/47	0.38	0.92	1.30	29.4	70.6
1947/48 – 1995/96	2.38	1.29	3.67	64.9	35.1
B. Areas currently in India					
1901/02 – 1910/11	-0.26	1.29	1.04	-24.7	124.7
1911/12 – 1920/21	-0.40	-0.48	-0.88	45.5	54.5
1921/22 – 1930/31	-0.41	0.33	-0.08	524.8	-424.8
1931/32 – 1940/41	0.10	0.13	0.24	43.5	56.5
1941/42 – 1950/51	-1.45	0.92	-0.53	271.4	-171.4
1951/52 – 1960/61	2.34	1.90	4.24	55.2	44.8
1961/62 – 1970/71	1.89	0.64	2.53	74.7	25.3
1971/72 – 1980/81	2.12	0.50	2.62	80.9	19.1
1981/82 – 1990/91	3.23	-0.02	3.21	100.6	-0.6
1991/92 – 1995/96	2.41	0.60	3.01	80.0	20.0
1901/02 – 1946/47	-0.01	0.49	0.48	-1.6	101.6
1947/48 – 1995/96	2.18	0.69	2.87	76.0	24.0

Source: Calculated from Kurosaki (1999), Tables 1, 2.
Notes: See equation (1) for decomposition.

Table 2. Contribution of Inter-Crop Land Reallocation to Growth in Land Productivity

	Average annual growth rates(%)				Relative contribution (%)		
	Yield effects	Static L.R. effects	Dynamic L.R. effects	Total	Yield effects	Static L.R. effects	Dynamic L.R. effects
A. Areas currently in Pakistan							
1901/02 – 1911/12	1.84	-0.19	0.09	1.74	105.4	-10.8	5.4
1911/12 – 1921/22	0.06	-0.05	0.02	0.02	254.3	-226.2	71.9
1921/22 – 1931/32	-0.35	0.03	0.02	-0.31	113.4	-8.5	-4.9
1931/32 – 1941/42	1.51	0.16	0.32	1.99	75.8	8.2	16.0
1941/42 – 1951/52	-0.80	0.18	0.03	-0.58	136.6	-30.6	-6.0
1951/52 – 1961/62	1.03	0.85	0.03	1.92	53.8	44.4	1.8
1961/62 – 1971/72	3.37	0.52	0.28	4.16	80.8	12.5	6.7
1971/72 – 1981/82	1.72	0.63	0.13	2.49	69.2	25.4	5.4
1981/82 – 1991/92	2.36	0.05	0.21	2.63	89.8	2.1	8.1
1991/92 – 1995/96	0.89	0.14	0.00	1.03	87.1	13.2	-0.4
1901/02 – 1947/48	0.55	-0.03	0.22	0.74	74.5	-4.0	29.6
1947/48 – 1995/96	2.38	0.48	0.61	3.47	68.6	13.8	17.6
B. Areas currently in India							
1901/02 – 1911/12	0.90	0.00	-0.04	0.85	105.1	-0.1	-5.1
1911/12 – 1921/22	-0.35	-0.07	0.26	-0.17	209.5	43.8	-153.3
1921/22 – 1931/32	-0.34	0.14	0.05	-0.14	234.6	-97.2	-37.4
1931/32 – 1941/42	-0.36	0.30	-0.06	-0.12	290.9	-239.7	48.8
1941/42 – 1951/52	-1.48	0.30	-0.01	-1.20	124.0	-25.1	1.1
1951/52 – 1961/62	2.76	0.14	-0.01	2.89	95.3	5.0	-0.3
1961/62 – 1971/72	1.55	0.15	0.20	1.90	81.6	8.0	10.3
1971/72 – 1981/82	1.83	0.35	0.09	2.28	80.6	15.4	4.0
1981/82 – 1991/92	3.11	0.43	0.14	3.68	84.4	11.8	3.8
1991/92 – 1995/96	1.59	0.39	0.04	2.03	78.6	19.4	2.0
1901/02 – 1947/48	-0.24	-0.05	0.23	-0.06	423.5	82.2	-405.7
1947/48 – 1995/96	2.59	0.23	0.53	3.36	77.1	7.0	15.9

Source: Estimated by the author.
Notes: See equation (2) for decomposition. ‘L.R.’ is short for ‘land reallocation.’

Table 3. Contribution of Inter-District Land Reallocation to Growth in Aggregate Crop Yields

	Average annual growth rates (%)				Relative contribution (%)		
	Pure yield effects	Static L.R. effects	Dynamic L.R. effects	Total	Pure yield effects	Static L.R. effects	Dynamic L.R. effects
A. Wheat							
1911/12 – 1921/22	-0.27	0.11	0.04	-0.12	220.8	-89.3	-31.5
1921/22 – 1931/32	0.13	-0.16	-0.05	-0.09	-151.3	190.5	60.9
1931/32 – 1941/42	-0.41	0.03	0.00	-0.39	106.1	-7.2	1.1
1941/42 – 1951/52	0.65	0.08	0.07	0.80	81.6	10.0	8.4
1951/52 – 1961/62	-0.75	0.03	0.00	-0.72	103.2	-3.6	0.4
1961/62 – 1971/72	4.21	0.07	0.30	4.57	92.1	1.4	6.5
1971/72 – 1981/82	2.76	0.14	-0.04	2.86	96.4	4.9	-1.3
1981/82 – 1989/90	1.78	0.11	0.01	1.90	93.7	5.5	0.7
1911/12 – 1951/52	-0.03	0.02	0.06	0.04	-76.8	40.2	136.7
1951/52 – 1989/90	2.46	0.09	0.09	2.64	93.3	3.3	3.4
B. Rice							
1911/12 – 1921/22	1.40	0.26	0.77	2.43	57.5	10.6	31.9
1921/22 – 1931/32	-0.57	0.28	-0.13	-0.41	137.9	-69.0	31.2
1931/32 – 1941/42	-0.33	0.21	0.02	-0.10	343.4	-218.1	-25.3
1941/42 – 1951/52	-0.67	-0.07	0.14	-0.60	111.8	11.9	-23.6
1951/52 – 1961/62	-0.27	0.00	0.10	-0.16	164.1	-2.4	-61.6
1961/62 – 1971/72	4.39	0.10	-0.06	4.42	99.2	2.2	-1.4
1971/72 – 1981/82	-0.43	0.19	-0.14	-0.38	111.8	-49.4	37.6
1981/82 – 1989/90	-0.93	-0.07	-0.04	-1.04	89.7	6.3	4.0
1911/12 – 1951/52	-0.08	0.18	0.17	0.27	-27.4	64.0	63.4
1951/52 – 1989/90	0.72	-0.03	-0.03	0.66	108.7	-4.5	-4.2

Table 3. (continued)

	Average annual growth rates (%)				Relative contribution (%)		
	Pure yield effects	Static L.R. effects	Dynamic L.R. effects	Total	Pure yield effects	Static L.R. effects	Dynamic L.R. effects
C. Sugarcane							
1911/12 – 1921/22	2.53	0.31	-0.36	2.48	102.1	12.4	-14.5
1921/22 – 1931/32	1.06	0.12	-0.03	1.15	91.7	10.7	-2.5
1931/32 – 1941/42	-0.33	-0.07	-0.17	-0.57	56.9	12.9	30.3
1941/42 – 1951/52	5.01	0.24	0.08	5.33	94.1	4.4	1.5
1951/52 – 1961/62	-0.32	-0.03	0.18	-0.16	199.1	16.4	-115.5
1961/62 – 1971/72	2.04	0.19	0.02	2.25	90.7	8.4	0.9
1971/72 – 1981/82	0.38	-0.19	0.11	0.30	125.6	-61.8	36.2
1981/82 – 1989/90	-0.16	0.11	0.09	0.04	-396.1	274.4	221.6
1911/12 – 1951/52	2.44	0.13	-0.04	2.53	96.4	5.0	-1.5
1951/52 – 1989/90	0.64	0.02	-0.01	0.65	99.1	2.5	-1.7
D. Cotton							
1911/12 – 1921/22	0.85	0.09	0.39	1.33	63.7	6.8	29.5
1921/22 – 1931/32	0.30	0.08	-0.03	0.34	87.1	23.2	-10.3
1931/32 – 1941/42	3.26	-0.07	-0.04	3.15	103.4	-2.3	-1.1
1941/42 – 1951/52	0.68	-0.13	0.25	0.79	85.3	-16.3	31.0
1951/52 – 1961/62	2.30	0.10	-0.01	2.39	96.1	4.3	-0.4
1961/62 – 1971/72	3.96	-0.03	0.52	4.45	89.1	-0.8	11.7
1971/72 – 1981/82	-2.14	0.02	0.34	-1.78	119.9	-1.0	-18.9
1981/82 – 1989/90	14.54	0.44	1.06	16.04	90.6	2.8	6.6
1911/12 – 1951/52	1.26	-0.04	0.44	1.66	75.9	-2.5	26.7
1951/52 – 1989/90	4.35	0.01	1.84	6.21	70.1	0.2	29.7

Note: See equation (3) for decomposition.

Table 4. Absolute and Comparative Advantages and Cropped Areas
(Four Major Crops, Western British Punjab Districts)

	Yield Disparity [1]								Cropped Area Concentration into the Top Yield Districts [4]			
	Absolute advantage[2]				Comparative advantage [3]							
	Wheat (1)	Rice (2)	Sugar-cane (3)	Cotton (4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
1911/12	2.09	1.39	1.40	1.65	1.82	1.44	1.53	1.51	1.37	0.08	0.09	0.80
1921/22	1.80	1.52	1.45	1.72	1.73	1.61	1.67	1.57	1.79	1.50	0.14	1.86
1931/32	2.24	1.37	1.22	1.77	2.18	1.59	1.54	1.60	1.35	4.47	0.17	4.98
1941/42	1.71	1.34	1.41	1.56	1.60	1.53	1.26	1.47	1.37	3.46	0.89	5.35
1951/52	1.61	1.48	1.95	2.27	1.47	1.94	1.36	1.44	1.03	4.38	0.23	4.18
1961/62	2.13	1.67	1.72	1.94	1.44	1.91	1.41	1.34	1.41	3.75	0.73	17.45
1971/72	4.16	2.77	1.79	2.34	2.15	1.82	2.12	1.97	2.35	2.71	0.84	9.57
1981/82	2.06	1.43	2.24	2.29	1.59	1.39	1.76	2.32	1.31	1.17	1.13	13.04
1989/90	1.87	1.48	1.57	5.22	2.05	1.34	2.21	4.67	0.63	1.12	0.98	44.84

Notes: Districts with a negligible area under the crop of concern (less than 10ha) were excluded from the analysis.
1.'Yield Disparity' shows the ratio of the average yield of the top three districts to that of the bottom three.
2. Yield disparity according to 'Absolute advantage' is based on the district ranking of yield levels of each crop in absolute terms (kg/ha).
3. Yield disparity according to 'Comparative advantage' is based on the district ranking of per-acre gross revenue levels of each crop relative to other three crops (ratio of Rs/ha of the crop of concern to the average of Rs/ha of the three other crop).
4. This shows the following ratio:
(Sum of the areas under the crop of concern in the three districts that were ranked top three in terms of comparative advantage in yield disparity ranking) ÷ (Sum of the areas under the crop of concern in the three districts that were ranked bottom three).

Table 5. Determinants of Trends in District-Level Diversification Indices

	L.H.S Variable =					
	$\hat{\beta}$ based on $DIV1$			$\hat{\beta}$ based on $DIV2$		
A.Pre-Independence, BP Districts						
Intercept	-0.0006	(-1.082)		-0.0012	(-2.679)	**
District area	-0.0012	(-3.080)	***	-0.0007	(-2.192)	**
Irrigation ratio	0.0006	(2.054)	*	0.0015	(5.699)	***
Average annual rainy days	0.0005	(1.857)	*	0.0004	(1.732)	*
Number of observations		28			28	
Adjusted R^2		0.235			0.535	
F(3,24)		3.76	**		11.34	***
B.Post-Independence, PP Districts						
Intercept	0.0068	(2.285)	**	0.0011	(0.411)	
District area	-0.0036	(-2.413)	**	-0.0013	(-1.002)	
Irrigation ratio	-0.0018	(-1.825)	*	-0.0008	(-0.978)	
Average annual rainy days	-0.0013	(-0.793)		-0.0016	(-1.189)	
Road density	-0.0029	(-1.374)		0.0005	(0.262)	
Number of observations		18			18	
Adjusted R^2		0.315			-0.089	
F(4,13)		2.95	*		0.65	
C.Two Periods Pooled, WBP Districts						
Intercept	0.0012	(0.308)		-0.0014	(-0.425)	
Dummy for post-independence period(D)	0.0024	(0.434)		0.0032	(0.695)	
District area	-0.0018	(-0.922)		-0.0005	(-0.280)	
District area$*D$	0.0006	(0.224)		-0.0010	(-0.409)	
Irrigation ratio	0.0003	(0.362)		0.0019	(2.813)	***
Irrigation ratio$*D$	-0.0022	(-1.980)	*	-0.0025	(-2.613)	**
Average annual rainy days	-0.0006	(-0.367)		0.0001	(0.107)	
Average annual rainy days$*D$	-0.0023	(-1.036)		-0.0020	(-1.045)	
Number of observations		30			30	
Adjusted R^2		0.505			0.256	
F(7,22)		5.23	***		2.43	*

Notes: (1) Results of OLS estimation are reported with t statistics in parentheses, where *** shows significance at 1%, ** at 5%, and * at 10% (two sided t test).
(2) All the explanatory variables except the intercept and the dummy were standardized (divided by the mean).

Appendix Table 1. District Names

Name (ABC order)	Belonging BP	WBP	PP	Notes ('Current' refers to 1992)
Ambala	1	0	0	Currently, in Haryana State, India
Amritsar	1	0	0	Currently, in Punjab State, India
Attock	1	1	1	Also called 'Cambellpur'. Includes a part of current Chakwal District
Bahawalnagar	0	0	1	Former Bahawalpur State
Bahawalpur	0	0	1	Former Bahawalpur State
Dera Ghazi Khan	1	1	1	Includes current Rajanpur District
Ferozpore	1	0	0	Currently, in Punjab State, India
Gujranwala	1	1	1	Includes a part of current Sheikhupura District
Gujrat	1	1	1	
Gurdaspur	1	0	0	Currently, in Punjab State, India
Gurgaon	1	0	0	Currently, in Haryana State, India
Hissar	1	0	0	Currently, in Haryana State, India
Hoshiarpur	1	0	0	Currently, in Punjab State, India
Jhang	1	1	1	
Jhelum	1	1	1	Includes a part of current Chakwal District
Jullundur	1	0	0	Currently, in Punjab State, India
Kangra	1	0	0	Currently, in Himachal Pradesh State, India
Karnal	1	0	0	Currently, in Haryana State, India
Lahore	1	1	1	Includes a part of current Sheikhupura District. Includes current Kasur District
Ludhiana	1	0	0	Currently, in Punjab State, India
Lyallpur	1	1	1	Current name is Faisalabad. Includes current Toba Tek Singh District
Mianwali	1	1	1	Includes current Bhakker District
Montgomery	1	1	1	Current name is Sahiwal. Includes a part of current Vehari District. Includes current districts of Okara and Pakpatan
Multan	1	1	1	Includes a part of current Vehari District. Includes current districts of Khanewal and Lodran
Muzaffargarh	1	1	1	Includes current Layyah District
Rahim Yar Khan	0	0	1	Former Bahawalpur State
Rawalpindi	1	1	1	Includes current Islamabad Area
Rohtak	1	0	0	Currently, in Haryana State, India
Shahpur	1	1	1	Current name is Sargodha. Includes current Khushab District
Sialkot	1	1	1	Includes a part of current Sheikhupura District. Includes current Narowal District
Simla	1	0	0	Currently, in Himachal Pradesh State, India
Number of districts	28	15	18	

Note: 'BP' refers to 'British Punjab', 'WBP' to 'Western British Punjab', and 'PP' to 'Pakistan Punjab'.

Appendix Table 2. Trends of Diversification Indices

	1901/02 – 1944/45				1947/48 – 1991/92			
District (ABC order)	$DIV1 = 1 - CR3$		$DIV2 = 1 - H$		$DIV1 = 1 - CR3$		$DIV2 = 1 - H$	
Ambala	-0.0007	***	-0.0002					
Amritsar	0.0026	***	0.0020	***				
Attock	-0.0020	***	-0.0028	***	-0.0013	***	-0.0040	***
Bahawalnagar					-0.0030	***	-0.0023	***
Bahawalpur					-0.0065	***	-0.0040	***
Dera Ghazi Khan	0.0001		0.0001		-0.0025	***	-0.0022	***
Ferozpore	0.0008	*	0.0005	***				
Gujranwala	-0.0012	***	0.0003	*	-0.0045	***	-0.0038	***
Gujrat	-0.0009	***	0.0000		-0.0025	***	-0.0012	***
Gurdaspur	-0.0003	***	-0.0002					
Gurgaon	-0.0002		-0.0003					
Hissar	-0.0030	***	-0.0033	***				
Hoshiarpur	-0.0001		0.0000					
Jhang	-0.0007	***	0.0007	*	-0.0003		-0.0009	***
Jhelum	-0.0012	***	-0.0009	***	-0.0003		-0.0014	***
Jullundur	-0.0001		-0.0008	***				
Kangra	-0.0010	***	-0.0006	***				
Karnal	-0.0002		-0.0001					
Lahore	0.0018	***	0.0025	***	-0.0053	***	-0.0040	***
Ludhiana	0.0003	*	0.0000					
Lyallpur	-0.0015	***	0.0009	***	-0.0015	***	-0.0014	***
Mianwali	-0.0022	***	-0.0015	***	-0.0006	***	-0.0017	***
Montgomery	-0.0025	***	0.0009	***	-0.0037	***	-0.0027	***
Multan	-0.0021	***	0.0010	***	-0.0034	***	-0.0029	***
Muzaffargarh	0.0001		-0.0002		-0.0022	***	0.0006	***
Rahim Yar Khan					-0.0046	***	-0.0032	***
Rawalpindi	-0.0013	***	-0.0013	***	-0.0026	***	-0.0013	***
Rohtak	-0.0008	**	-0.0006	***				
Shahpur	-0.0007	**	0.0028	***	0.0003	**	-0.0004	***
Sialkot	0.0005	**	-0.0001		-0.0057	***	-0.0032	***
Simla	0.0001		-0.0002	*				
Sum of 15 WBP Districts	-0.0010	***	0.0008	***	-0.0015	***	-0.0009	***
Sum of 28 BP Districts	-0.0007	***	0.0001					
Sum of 18 PP Districts					-0.0018	***	-0.0010	***

Notes: (1) Parameter estimates for β in equation (6) are reported in this table.
(2) Two-sided t tests results: *** = significant at 1%, ** = at 5%, * = at 10%.

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Figure 1. Relationships among Alternative Measures of Food Crop Diversification during the Agricultural Transformation

Source: Timmer (1997), Figure 1.

Figure 2. Coefficients of Variation among Districts in West British Punjab Districts
Four major crops (1901/02 - 1991/92)

Source: Drawn by the author. See the text for data sources. The same applies to the following figures.

Figure 3. Crop Diversification Indices in West British Punjab Districts (1901/02 - 1991/92)

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