Rural Migration, Weather and Agriculture: Evidence from Indian Census Data

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Abstract

This study explores the three way linkage between weather variability, agricultural performance and internal migration in India at state and district level using Indian Census data. We base all the analyses on a simultaneous equation model for panel data. The elasticity of inter-state out-migration rate with respect to the per capita net state domestic product is approximately (-)0.75. The crop-wise analysis, on the other hand, shows that the (negative) elasticities are higher and more substantial for rice (-1.85) than for wheat (-0.90). The district-level analysis shows larger magnitudes of estimated change in in-migration rates to relative changes in crop yields. The results suggest that the impact of yield change on the in-migration rate depends on both the inter-play between inter- and intra-district in-migration rates as well as the crop under consideration. The study findings could thus have significant policy relevance, especially in the context of global climate change and the prospect of migration serving as a potential adaptation strategy for people adversely affected by the impact of weather variability on crop yield.

ACKNOWLEDGMENT

INTRODUCTION

Fast growing economies like India are likely to witness increasing disparity in living standards between rural and urban areas, with a corresponding increase in migration from rural to urban areas. Lewis (1954), Harris and Todaro (1970), Stark (1984) and Lucas (1997) are among those who have already offered such hypotheses on internal migration. The weather sensitivity of agriculture and the increasing vulnerability of crop yields to both weather extremes and changing weather conditions are likely to further accelerate the rural to rural and rural to urban migration. Among other factors that are likely to further increase migration from the rural areas to the cities are changing lifestyles, which could add the amenity dimension to the migration of people from harsh climates to controlled environments. Added to these is the well-recognized factor of increased educational attainments, which too could facilitate cross-country movements of people depending on network effects and geographical factors.

Against this backdrop, a few broad generalizations about migration in India are worth underscoring: (a) the absolute number of migrants from rural to urban areas has increased over time; (b) the migration rate (of the male population) has declined over time, even though the growth rate of migrants has not shown a monotonic trend; (c) the emigration rates are extremely low; (d) inter-state movements are relatively low compared to intra-state movements due to socio-cultural factors including language; and (e) short-term circular migration[1] rates dominate over long-term migration rates (for further information, see Lusome and Bhagat, 2006; Kundu and Sarangi, 2007). In this context, it would be interesting though difficult to isolate weather

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[1] In circular migration, there is possibly a continuous engagement with gainful employment both at the place of origin as well as in several other places of destination, thus involving both return and repetition in the movement of individuals or families.

induced migration from all other factors that might influence people's migration decisions in India.

In recent times, weather-induced migration operating through the agriculture channel has begun to acquire importance due to the emerging concern with climate change and its impact on agriculture. For instance, several studies have shown that climate change could have significant adverse impacts on Indian agriculture (Kumar and Parikh, 2001; Mall *et al.*, 2006; Auffhammer *et al.*, 2006; World Bank, 2008). The available evidence so far shows a significant drop in the yields of important cereal crops like rice and wheat under various climate change scenarios, the potential impacts of which in turn can trigger the migration of people associated with the agriculture sector.

While, some studies have focused on the linkages between weather variability (and climate change) and migration *per se* (McLeman and Smit, 2006; Perch-Nielsen *et al.*, 2008; Bardsley and Hugo, 2010; Dallman and Millock, 2012; Hasssani-Mahmooei and Parris, 2012), there has been increasing attention by Feng *et al.* (2010 and 2012), Marchiori *et al.* (2012), Nawrotzki et al. (2012), Barbieri *et al.* (2010), Dillon *et al.* (2011) and among others to the analyse linkages between weather variability and migration operating through the agriculture channel and the rural-urban wage differentials.

Acknowledging that migration can occur due to several reasons, this paper focuses specifically on weather-variability-induced migration operating through the channel of agricultural productivity changes. While studying the three way linkages between weather variability, agricultural yield changes and migration, the paper addresses the following issues in Indian context:

(a) What is the evidence of inter-state migration caused by weather variability induced agricultural yield changes?

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(b) How significant is the impact on migration of crop yield changes at the intra-state level? Does such migration depend on the agricultural crop under consideration?

The analysis presented in this paper is based on Indian Census data for the years 1981, 1991 and 2001 and employs 2SLS/LIML estimation for panel data. The results indicate a clear link between weather variability, crop yield decrease and migration rates of those engaged in agriculture. These results have important policy implications from climate change perspective and re-emphasize the scope for considering migration as an effective adaptation option. The rest of the paper is organized as follows: The next section provides a brief review of literature on migration patterns in India. The subsequent sections describe the methodology employed, various issues related to the data used, and the state-level and district-level results. Then, we summarize the results and use the estimated coefficients from the model to hind-cast internal migration in India with increased weather variability. The last section provides concluding observations and their policy relevance.

MIGRATION PATTERNS IN INDIA

Migration in India is primarily documented in two databases: Census data and National Sample Survey (NSS) data. While most studies have used either Census data or NSS data for their analyses (Singh, 1998; Lusome and Bhagat, 2006; Kundu and Sarangi, 2007; Bhagat, 2009), a few have used data from primary surveys (Deshingkar and Akter, 2009) to study migration patterns. Since emigrants from India are less than one percent of the total number of migrants within and outside the country, most studies focus on trends in internal migration.

As shown in Figures 1(a) and 1(b) for males and females respectively, internal migration rates (that is, the ratio of the migrants as a proportion of the population) in India are low and have been declining

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over the years (Jayachandran, 2006; Sivaramakrishnan *et al.*, 2007; and Topalova, 2010). Of the two, male migration rates are lower than female migration rates as marriage is commonly cited as the reason for migration by women given the practice of exogamy in many parts of India. Moreover, male migration rates have declined more sharply than female migration rates, and more so between 1981 and 1991, which according to Sivaramakrishnan *et al.* (2007) is a reflection of the jobless growth in India during this period. While the decade of 1991 to 2001 recorded a higher economic growth rate in India, the migration rates remained more or less the same as that observed in the previous decade. Though the official data on migration rates for the period 2001 to 2011 based on the latest census are still yet to come, estimates by some research studies show that migration rates may have gone up compared to the previous decades. Some studies moreover indicate that the substantially higher migration rate from the rural areas compared to the earlier inter-Census period could be attributed to distressed conditions in agriculture (Sainath, 2011) though, in the absence of detailed information, it is difficult to attribute increase the migration to agricultural distress alone.

Figure 1: Migration Rates in India: 1971 to 2001
(a) Male Migration Rates   (b) Female Migration Rates

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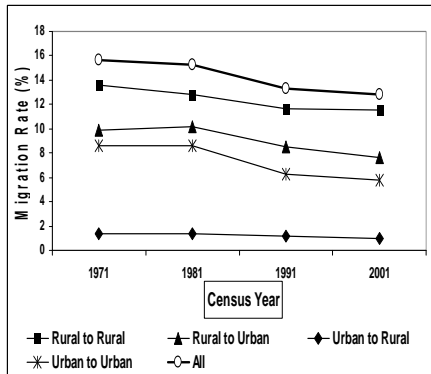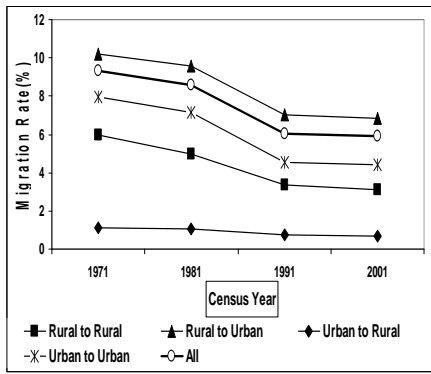
During the three decades of the declining/non-increasing migration rates, the absolute numbers of migrants have grown except for the period between 1981 and 1991 as shown in Figures 2 (a) and 2 (b). Since, for administrative purposes, India is subdivided into states and further into districts within each state, the nature and type of migrant movement can be further classified into (a) *intra-district* movement capturing within district movement from one village to another, (b) *inter-district* movement capturing movement between districts within a state, and (c) *inter-state* movement capturing movement between the states of India. Figure 2 juxtaposes these types of movement within each segment of rural-urban combinations.

Figure 2: Absolute Number of Internal Migrants in India: 1971-2001

(a): Number of Male Migrants across Rural and Urban Areas
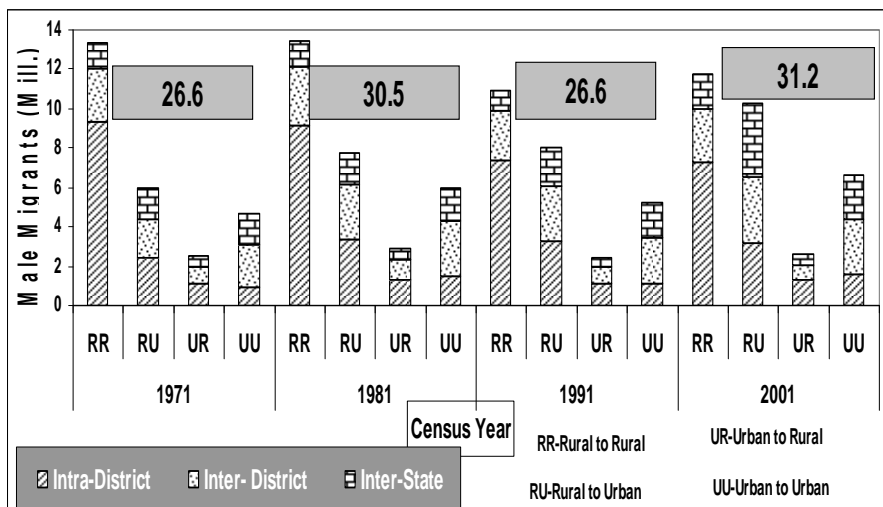
(b): Number of Female Migrants across Rural and Urban Areas
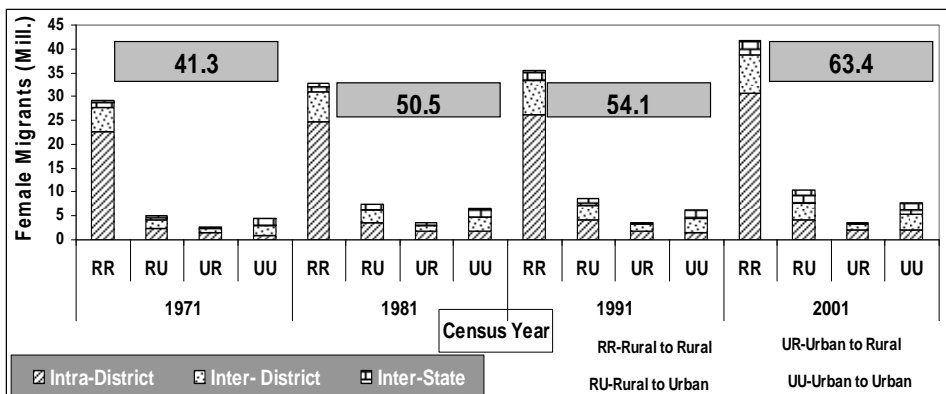
***Note: Numbers inside the figure denote the total inter-censal migrants in millions.
Source: Author's own estimation from the Census for the respective years.

In the case of males, intra-district rural to rural movement over time is being replaced largely by inter-state rural to urban and, to some extent, by urban to urban movement with a marginal contribution from inter-district movement. Kundu (2007) observes that more developed states like Maharashtra, Punjab and Gujarat registered high levels of in-migration between 1991 and 2001 while backward states like Bihar, Uttar Pradesh, Orissa and Rajasthan either reported net out-migration or very low in-migration. Based on NSS data, Ozden and Sewadeh (2010) observe a similar pattern of migration corridors drawing people from the economically lagging states to the economically leading states due to differentials in the per capita domestic product of the states.

In the case of females too, inter-state movements have contributed to increases in migration but with a difference: there have been increases in almost all streams of migrations - rural to rural, rural to urban, and urban to urban. Thus, unlike men, women show a secular increase in migration levels even though marriage could still be the prime reason for it. Since there are no studies to date that analyse the

determinants of such changes, no clear reasons can be found for such patterns from the literature. However, one conjecture is possible: a decline in endogamy practised in some parts of the country is leading to greater rural-rural migration of women.

The above information on migration is confirmed by NSSO data which also shows declining rates of migration (Kundu and Saraswathi, 2012) over the past three decades while indicating an increase in the absolute number of migrants with a higher growth rate for the period 1993 to 2000 than for the period 1987-88 to 1993 (Nagaraj and Mahadevan, 2011).

With regard to structural reasons for migration in India, poverty is the most commonly cited factor for migration with poor people migrating to urban areas, especially during the agricultural lean seasons, to avail themselves of employment opportunities in urban areas in an attempt to smoothen their income flows (Deshingkar, 2004). However, economic opportunities have become more diverse after the changes in the economic environment brought on by liberalization and accelerated globalization, which would also account for the increasing mobility of people between rural and urban areas. But, as mentioned above, the official statistics in India show that the incidence of migration has not been on the rise in the post-liberalisation period, with several studies (see, Kundu and Sarangi, 2007; Sivaramakrishnan *et al.*, 2007; Nagaraj and Mahadevan, 2011) attributing this to the inability of the Indian statistical system to correctly estimate the short-term movements of poor migrants, who resort to circular migration as one of their livelihood strategies.

In addition to analysing the trends in and patterns of internal migration, the migration literature in India has addressed the following issues: (a) migration as an instrument of economic well-being; (b) inter-relationship between migration and human development; (c) internal-

migration and regional disparities in India; and (d) impact of globalization on migration. In this strand of migration literature, there is perhaps no study which uses secondary data sources (from the Census and/or the NSS) to study the linkage between agricultural performance and migration. The present study attempts to fill this gap with its focus on the nexus between weather, agriculture and migration.

METHODOLOGY

We base the econometric estimation on the two-equation model specified below (see Feng *et al.*, 2010).

(1) $M_{it} = \alpha + \beta Y_{it} + d_i + r_t + \varepsilon_{it}$, and

(2) $Y_{it} = \gamma + \delta T_{it} + p_i + c_t + v_{it}$

In equations (1) and (2), M_{it} is the out-migration (in-migration) rate from (to) region 'i' at period 't', Y_{it} is one of the agriculture variables (wheat yield or rice yield or per capita net state domestic product from agriculture for region 'i' at period 't'), T_{it} is the set of weather variables (represented by annual and seasonal temperature and rainfall discussed in the previous section) of region 'i' at period 't' which includes linear or quadratic terms in some of these variables. Since the analysis considers five-year durations as a time-period, the weather variability is sometimes better captured through measures of dispersion such as standard deviation than the measures of central tendency like the mean. The d_i and p_i are the coefficients for the regional (fixed) effects; r_t and c_t are coefficients to capture time (fixed) effects, and ε_{it} and v_{it} are error terms in equations (1) and (2) respectively. We include the fixed effects to capture the omitted variables that could be correlated with the variables (yield and weather) used in the model.

The first equation captures the migration-agriculture linkage while the second equation assumes yield to be endogenous in the first equation, thus using weather variables as instruments to correct for the

simultaneity bias of the coefficient of yield in equation (1). The concerned agriculture variable (primarily yield) is tested for endogeneity in equation (1) using the robust test score of Wooldridge (1995) as reported in Stata 11.0. If it is found to be endogenous, then the two equations are estimated simultaneously using the two-stage least squares (2SLS) method with robust standard errors[2]. If not, the two equations can be estimated separately using ordinary least squares (OLS) method to assess the effect of weather on agriculture and agriculture on migration. We consider various combinations of weather variables in the yield equation specification while we base the model selection on best fit statistics.

DATA DESCRIPTION

Migration Data

As mentioned in previous section, migration data in India are available from two major secondary sources – the Census data collected by the Registrar General of India and the survey data (employment-unemployment surveys or special migration surveys) collected by the NSS. Given the small sample sizes, especially at the district level, this study uses Census data for the analysis. In both these secondary sources, however, the information on migrants is recorded at the place of enumeration, thereby including details only on in-migrants, with emigrants out of the country not recorded anywhere[3].

As shown in Figure 2, the origin and destination of migrants is primarily classified based on the two sectors, rural and urban, giving four 'from-to' combinations: (i) rural to rural, (ii) rural to urban, (iii) urban to

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[2] The estimations for the state level are carried out using robust standard errors and the district-level estimations are standard errors after adjusting for cluster level variations with districts as the clusters.

[3] The 'balance equation' approach is often followed in the migration literature for assessing the number of people migrating. However, due to lack of appropriate data on gender-specific birth and death rates at the district level, the present study considers only the migration data reported directly in the Census.

rural, and (iv) urban to urban. Each of these streams of migrants can be further classified as inter-state, inter-district or intra-district migrants based on the two tiers of administrative boundaries--states at the sub-national level and districts within each state--as mentioned (see Figure 2) above.

Since it is expected that migration would take place from less productive regions to more productive regions (or more remunerative regions), the identification of the origin and destination regions of migrants becomes essential in order to carry out a study of the impact of agricultural performance (which is in turn affected by weather/climate factors after controlling for other factors) on the mobility of the people. There are some data limitations in this regard. On the one hand, the individuals who move *between* states (i.e., inter-state migrants) are identified on the basis of both the state of destination *as well as* the state of origin. On the other hand, in the case of individuals who move *within* the state, the district of origin is not indicated in the case of inter-district migrant while the place of origin is not specified in the case of intra-district migrant. Thus, in the case of a state-level analysis, it would not be possible, using Census data, to deploy the relevant migration variable, that is, out-migration, to capture the mobility of people out of a more distressed region to a less distressed region. In the case of a district-level analysis, which entails the use of in-migration data as the relevant migration variable, the expected direction of mobility would be the reverse of that envisaged for the state-level analysis.

At both these levels of regional disaggregation, the migrant data in each Census is classified on the basis of (a) duration of stay: i.e., less than one year, between one and four years, between 5 to 9 years, and 10 or more years of stay; (b) reason for migration (available only at the state level and not at the district level): i.e., marriage, place of birth, employment, and others; (c) sex: i.e., male or female. The present study focuses on fifteen major states (and the districts within these

states) of India: Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal[4].

We describe the structure of state- and district-level data in detail below. In each case, the final analysis uses the migration rate which is defined as the total (out or in) migrants as a proportion of the rural population of the respective region.

State Level

The inter-state out-migration data is organized in the following manner. We use the out-migration data from the rural areas of any given state to rural or urban area of another state as reported in the Census for the years 1981, 1991 and 2001. Based on the information provided under 'reason for migration', we consider for analysis only those groups of migrants who specify their reason for migration as employment or 'other,' Thus excluding from the analysis migrants whose reason for migration is either marriage or place of birth. The panel data model is estimated using information on two durations of stay (i.e., 1 to 4 years and 5 to 9 years) under each Census and across the states. Table 1 shows the organization of data across the three Censuses. There are 90 observations in the database for the fifteen major sates of India with two durations of stay specified for each Census year. The out-migration rate at state level refers to rural migrants as proportion of the total rural population of the origin state. The total rural population is the average of the rural population for the period under consideration with annual values for the inter-censal years obtained from the official projections of the mid-year annual populations of the origin state.

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[4] Due to non-availability of reliable data on agricultural, weather and other variables the analysis is restricted to the fifteen large states, which comprise of over 90 percent of India's population. It should be noted that the three newly-formed states (Jharkhand, Chatthisgarh and Uttaranchal) as per the 2001 Census were included within their erstwhile states (Bihar, Madhya Pradesh and Uttar Pradesh respectively) from which they were carved out.

Table 1: Organisation of Migration Data based on Duration of Stay

Sl. No.	Census Year	Duration of Stay	Migrated out between
1	1981	5 to 9 years	1972 to 1976
2	1981	1 to 4 years	1977 to 1980
3	1991	5 to 9 years	1982 to 1986
4	1991	1 to 4 years	1987 to 1990
5	2001	5 to 9 years	1992 to 1996
6	2001	1 to 4 years	1997 to 2000

District Level

As mentioned before, the number of in-migrants to the rural area of a district forms the basis of the district-level analysis. Such in-migrants include migrants who at the place of enumeration would have reported that they came into the district from another state, from another district, and from another part of the same district. In the absence of information on reasons for migration at the district level, we carry out the analysis for total migrants and male migrants separately. Since marriage is cited as the reason for migration mainly by women, focussing on male migrants would essentially capture migration for employment.

Due to changes in district boundaries across different Census years, the comparability of districts across the Census becomes complex. Thus, the analysis at the district level is restricted to the Census year of 2001– the most recent one for which migrant information is available. As for state level data, the duration of stay is also provided at the district level. A 5-9 year duration of stay would correspond to migrants having arrived between 1992 and 1996 while 1-4 years of stay would correspond to migrants having arrived between 1997 and 2000. With 504 districts spread across the major states of India and two time points, the panel data that we use for the analysis consist of 1008 observations.

The district-level in-migration rate is defined as the ratio of total migrants into a rural district as a proportion of the rural population of the

receiving district. We thus use the mid-year population projection based on district-level decadal growth rates in rural areas to estimate the population for the year 1996 while using the estimates of rural population totals from the Census of 2001 for the second period migration rate. Though, the migration data is available as a mass (or sum) of all those who arrived between the two end-points during a given period, other variables used in the econometric model (see description above) are available on an annual basis. Hence, we use the averages of these variables based on the years covering the respective periods to maintain compatibility between migration and other variables.

Rural Population

We obtain the rural population across states for the 1972 to 2000 period from EOPP (2010)[5]. We then average the rural population for different years, corresponding to the periods given in Table 1 for the respective states. We use district level Census data provided by the Registrar General of India in 2001 for assembling population data. We use the total rural population in 1996 in a district as the numeraire for estimating the migration rate into a district for migrants arriving between 1992 and 1996. For this purpose, we use the inter-censal rural population growth rate for a district between 1991 and 2001 to interpolate for the year 1996. We carry out a similar exercise to estimate the rural male population. For those arriving between 1997 and 2001, we obtain the district-level total rural population and total rural male population directly from the Census 2001 in order to calculate the respective in-migration rates within a district.

Weather Data

We estimate the state- and district-level weather data from the gridded data on temperature and precipitation. The gridded data is based on the database recently released by the India Meteorological Department

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[5] Sourced from EOPP India States Data http://sticerd.lse.ac.uk/eopp/_new/data/Indian_Data/default.asp).

(Rajeevan *et al.,* 2005; Srivastava *et al.,* 2009). The temperature data is based on gridded daily temperature data for the period 1969-2005 at $1^{o}x1^{0}$ lat/lon resolution, whereas the rainfall data is based on gridded daily rainfall data for the period 1951-2003 at $1^{o}x1^{0}$ lat/lon resolution. We generate the year-wise weather data at the state and district level through surface interpolation[6].

Agricultural Data

We put together data on crop yields for the years 1972 to 2000 at the state level as reported in the *Indiastat* portal which in turn is collated from the data provided by the Ministry of Agriculture, Government of India. We assemble the district level data on crop yields for the years 1992 to 2000 from the *Indian Harvest* database of CMIE, where the crops covered include rice and wheat. We carry out the analysis separately for the two crops for two main reasons. The results from climate change impact studies indicate that the effect of weather/climate variability is different across these two crops (Krishnamurthy, 2012) since rice cultivation is not only more widespread but is also more labor intensive than wheat cultivation. It is therefore logical to expect larger migration from a region when the rice productivity declines. The drawback of carrying out separate analyses for each crop would be that it does not capture the substitution possibilities that a household may explore between the two crops in an attempt to adjust to the changing weather/climatic conditions.

Besides rice and wheat yields, we also use the per capita net state domestic product from agriculture for each of the states. We take the yearly net state domestic product (with base year 1970-71) from the *Indiastat* portal.

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[6] This data was provided by Dr. Chandrakiran Krishnamurthy, who has used the same in Krishnamurthy (2012). The gridded areas do not make a distinction between rural and urban segments of a district.

Data Structure and Interpretation of Results

We base the state-level analysis on a panel dataset of 90 observations formed out of fifteen cross-section (states) units for six time points (that are five-year averages covering the period from 1972 to 2000). The district-level dataset, on the other hand, is a panel of 1008 observations formed out of 504 cross-section (district) units for two time points which are five-year averages covering the period from 1992 to 2000[7]. The econometric analysis described above for the state and district level uses the fraction of out and in migrants, respectively, as the dependent variable. We define these fractions respectively as the ratio of total rural out-migrants from a state to the total rural population of the sending state, and as the ratio of total (or male) rural in-migrants into a district to the total (or male) rural population of the receiving district. The independent variables include, (i) total annual rainfall, average annual temperature and rainfall/temperature corresponding to various seasons; and (ii) crop yield (for rice or wheat) and per-capita net state domestic product from agriculture. Since wheat is not grown in some parts of the country, we exclude some observations reporting close to zero yields from the analysis while using the wheat yield. Table 2 provides a summary of the data source with the basic definitions as they are used in the study.

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[7] However, not all districts have data on rice or wheat for the time-periods under consideration. Hence, the sample size is reduced to 734 for wheat and 798 for rice in the final analysis.

Table 2: Summary of Data Used in the Study

Sl. No.	Variables	Source/Definition	Unit
1	Rural 'Out' (or 'In') Migrants	Census of India	Numbers
2	Rural Population	EOPP India Database (state); Census of India 2001 (district)	Numbers
3	Net State Domestic Product from Agriculture (nsdpAg)	EPW Research Foundation	Rs. (lakhs) at 1970-71 constant prices
4	Rural Out Migration Rate (Dependent Variable in state-level analysis)	Ratio of rural out migrants to total rural population of origin State	Proportion
5	Rural In Migration Rate (Dependent Variable in district-level analysis)	Ratio of rural in migrants to total rural population of destination district	Proportion
6	Total and Seasonal Rainfall (Independent Variables)	India Meteorological Department	Millimeters
7	Average and Seasonal Temperature (Independent Variables)	India Meteorological Department	Degrees Celsius
8	(Logarithm of) Rice Yield (Independent Variable)	www.indiastat.com/agriculture; *India Harvest* (CMIE)	Tonnes per hectare
9	(Logarithm of) Wheat Yield (Independent Variable)	www.indiastat.com/agriculture; *India Harvest* (CMIE)	Tonnes per hectare
10	(Logarithm of) Per capita nsdpAg (Independent Variable)	Ratio of nsdpAg to total rural population	Rs. per person

It may be relevant for the inter-state analysis to link the poorer agricultural performance (as influenced by weather variables) of a given region with a higher out-migration rate from that region. The direction of influence of change in agricultural performance (affected as it is by weather variables) on 'in-migration' into a district, however, is not easy to hypothesize *ex-ante*. As mentioned earlier, the 'in-migrants' into a district include three different streams – those who migrate from another state, from another district and from another part of the same district. The interplay between these different streams of in-migrants and the crop under consideration would, therefore, influence the overall sign of the agriculture variable in the migration equation. For instance, one would expect that if agricultural performance in a district deteriorates, there could be more within district mobility and less inter-district movement. Thus, if separate estimations are carried out using either within district movement or between district movement, the sign of the coefficient of the relevant agricultural variable in equation (1) mentioned above would be negative in the former case and positive in the latter case. The crop under consideration – wheat or rice – could also have an influence on which of these movements dominate, given their relative labor intensity and nature of use (staple *vs.* non-staple).

Two other issues stand out, which would have implications for the interpretation of the results from the econometric model. Firstly, what appears to be a flow of people into a given geographical region is actually to be interpreted as a stock of people residing in a particular region after having moved out of another region. Thus, it is quite possible that certain individuals are more mobile than has been captured at the time of enumeration and that this feature may be more prominent among certain streams of migrants. Thus, individuals who undertake shorter and frequent spells of movement outside their place of enumeration may not be captured by the migration data of the Census. A second related issue is that the migration rate within the five-year duration (from each Census) can be seen as the annualised value for that

period and not an end of the period rate accumulated over the five-year period. Thus, the results are interpreted as the average annual changes in the migration rate for unit changes in agricultural productivity all else remaining the same.

WEATHER VARIABILITY, AGRICULTURE AND INTER-STATE OUT-MIGRATION

Inter-state out-migration rates from rural areas form a very small proportion of total migration rates. However, differences exist among states both with regard to these rates and their annual temporal variations as shown in Figure A.1 in Appendix A. Similarly, (the logarithm) of per capita net state domestic product from agriculture also varies sufficiently across states (see Figure A.2). Figure A.3 moreover shows the variability across states for the two major cereal crops grown in India. It shows that rice yields are larger than wheat yields in many states, which is attributable to the fact that some states (mainly in southern India) either primarily grow rice or only. Wheat growing areas, on the other hand, are predominantly located in the north-western part of the country. In regions where both these crops are grown such as Punjab, Haryana, or Rajasthan, we may note that productivity for wheat has improved more than that for rice. Variations in temperature and rainfall across the states are shown in Figures A.4 and A.5, respectively. Given relatively small time-scales involved, the temporal variation in the weather variables is not substantial but inter-state variations are quite obvious.

Per Capita Net State Domestic Product of Agriculture and Out-migration

We first analyse the influence of agriculture on migration by estimating the relationship between the per-capita net state domestic product in agriculture (pcnsdpAg, henceforth) and the inter-state-out-migration rate

using the weather variables as the instruments in the approach as outlined in equations (1) and (2) above. The results reported in Table 3 show that there is no evidence for endogeneity of per-capita net state domestic product in the migration equation. We present the OLS estimates for agriculture and migration equations separately in Table 3 (see columns 4 and 5), and for a reduced form equation that describes migration as a function of pcnsdpAg and weather variables in columns 6 and 7. We estimate all these equations with fixed effect for time (representing the duration of stay as shown in Table 1) and cross-section (states) [8].

The annual average temperature and annual total rainfall are the weather variables that turn out to be significant in the estimations. Though we also considered other variables such as the standard deviation of these two variables, monsoon rainfall and summer temperatures, they did not turn out to be significant. In the agriculture equation (model 1a in Table 3), the weather variables jointly influence the pcnsdpAg as seen from the significant value of the F-statistic while the t-statistic shows that only annual total rainfall influences pcnsdpAg after controlling for the other variables. From this model, it can be inferred that pcnsdpAg increases with better rainfall. The estimates from the migration equation (Model 1b) show that pcnsdpAg has a significant negative influence on migration, indicating that a ten percent decrease in pcnsdpAg will lead to a 0.03 percent increase in inter-state out-migration.

Table 3 also reports the estimates of the migration equation with pcnsdpAg and weather variables as regressors (see Model 2).

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[8] In all the analyses presented here, the fixed effects specification is favored over the random effects specification. This is to be expected given that in both the agriculture and migration equations the omitted variables are likely to be correlated with weather and yield respectively. Further, the cross-section units (states/districts) are not randomly selected samples but the entire 'population'.

Table 3: Estimated Coefficients for Agriculture and Migration Equations (State-level)

Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
	LIML (Agriculture Equation)		Model 1a-OLS (Agriculture Equation)			
Annual Average Temperature	0.157	0.142	0.157	0.156		
Annual Total Rainfall	0.0004[*]	0.016	0.0004[**]	0.016		
Intercept	-3.260	0.274	-3.260	0.289		
Adjusted R^2	0.9189		0.9189			
Test for Joint Significance of Weather Variables			$F(2,68) = 3.23^{**}$	0.0458		
	LIML (Migration Equation)		Model 1b-OLS (Migration Equation)		Model 2-OLS (Migration Equation)	
Logarithm of per-capita NSDP-Ag	0.00023	0.942	-0.0031[***]	0.007	-0.0035[***]	0.001
Annual Average Temperature					0.000520	0.545
Annual Total Rainfall					0.000001	0.316
Intercept	0.0018	0.676	0.0064[***]	0.000	-0.0086	0.715
Adjusted R^2	0.8248		0.8102		0.8081	
Test for Joint Significance of Weather Variables					$F(2,67)= 0.45$	0.637
Test for Endogeneity[#]	$\chi^2(1)= 1.225$	0.2684				
Number of Observations	90		90		90	

Notes: Agriculture and migration equations use per-capita Net State Domestic Product and inter-state out-migration rate as the dependent variables respectively; Models 1a & 1b respectively report OLS estimates for Agriculture and Migration Equations separately; Model 2 reports single equation OLS estimates of the Migration Equation with agriculture and weather variables as regressors; all the models are estimated with fixed effects for time and states although the estimated coefficients are not reported here; *** denotes p-value ≤0.01, ** denotes p-value ≤ 0.05 and *denotes p-value≤0.10; # Test for endogeneity is the Wooldridge's (1995) robust score test and the null hypothesis is that the variable(s) are exogenous. The test statistic value and p-value show that the null hypothesis is not rejected.

The estimates show that the weather variables do not influence migration (as observed from the F-statistic for joint significance as well as the t-statistic for individual significance of the weather variables) after controlling for state-level and temporal variations and pcnsdpAg. The results further demonstrate that pcnsdpAg has a negative and significant impact on the inter-state out-migration rate. The magnitude of impact is similar to that reported for Model 1b. In other words, the elasticity of the migration rate with respect to pcnsdpAg is about 0.75 (when we take the average migration rate across states as 0.004).

Based on the recognition that the migration rates may be influenced more by yield changes, the subsequent analyses focus on the application of the approach outlined in equations (1) and (2) above keeping crop yields as the potential endogenous variables. Tables 4a and 4b present the results for wheat yield and out-migration rates while Tables 5a and 5b give the results for rice yield and out-migration rates.

Wheat Yield and Out-migration

In the agriculture equation, we identify three weather variables – the June-September mean temperature, the October-November mean temperature, and the standard deviation of January-March rainfall – as appropriate instruments[9] after examining several other combinations of temperature and rainfall variables. While the temperature prior to the sowing season (i.e., the June-September temperature) has a positive influence on wheat yield, the increase in growing period temperature (i.e., the October-November temperature) negatively influences the yield after controlling for the effect of other variables. On the other hand, an increase in the variability of rainfall during the harvest period of wheat could adversely affect the yield, all else remaining the same. The robust test score (Wooldridge, 1995) is significant at 9 percent indicating that

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[9] The choice of instruments is based on the overall goodness of fit of the estimated equation and their joint/individual statistical significance.

the wheat yield is endogenous in the migration equation at a higher level of significance. The OLS estimates, however, show that the wheat yield is not significant in the inter-state out-migration equation. Moreover, the test for weak instruments does not reject the null of weak instruments (Stock and Yogo, 2005). Stock and Yogo (2005) have further suggested that with weak instruments it may be preferable to estimate the coefficients using the LIML methods rather than the 2SLS. The LIML estimates are larger in magnitude with a higher p-value when compared to the 2SLS estimates. Using the estimated LIML coefficient of the wheat yield in the migration equation, a 10 percent decrease in the wheat yield would lead to a 0.048 percent increase in the out-migration rate.

Table 4a: Estimated Coefficients for Wheat Yield Equation with Weather Variables (First Stage) (State Level)

Variables	Coefficient	p-value
June-September Temp.	0.328^{**}	0.027
October-November Temp.	-0.169	0.136
Std. Dev. of January-March Rainfall	-0.002^{**}	0.041
Intercept	-5.657	0.147
Adjusted R^2	0.936	
F-statistic for Overall Significance of the Model	$F(21, 58) = 301.32^{***}$	0.000
F-Statistic for Joint Significance of Weather Variables$^{\$}$	$F(3, 58) = 3.20^{**}$	0.0299

Note: *** denotes *p*-value ≤0.01, ** denotes *p*-value ≤ 0.05 and *denotes *p*-value ≤0.10. The coefficients reported here are from the first stage estimations. $^{\$}$ This also serves as a test for weak-instruments in a model with one endogenous variable. The rule of thumb as in Stock and Yogo (2005) is that the instruments are weak if the F-statistic is less than 10.

Table 4b: Estimated Coefficients for Inter-State Out-Migration with Wheat Yield (Second Stage) (State Level)

	OLS		2SLS		LIML	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Logarithm of Yield, lnY	-0.00066	0.348	-0.0036[**]	0.054	-0.0048[*]	0.085
Intercept	0.0017[***]	0.001	-0.00036	0.799	-0.0012	0.558
Adjusted R^2	0.782		0.747		0.711	
Test for Endogeneity	χ^2 **(1) =** 2.75[*] $\qquad$ **p-value** = 0.097					
Test for Weak Instruments	**Cragg-Donald Wald F statistic** = 3.796 $\qquad$ **Critical Value** = 9.08[$]					

Notes: (1) *** denotes p-value ≤0.01, ** denotes p-value ≤ 0.05 and * denotes p-value ≤0.10; (2) Test for endogeneity is the robust score χ^2 test based on Wooldridge (1995) with the null hypothesis that the regressor is exogenous; (3) Test for weak instruments is based on Stock and Yogo (2005) with the null hypothesis that the instruments are weak and the alternative hypothesis is strong. (4) Cragg-Donald Wald F statistic is obtained from STATA 11.0 using ivreg2 command. (5) $ reports the 10 percent maximal IV relative bias also obtained from STATA 11.0.

Rice Yield and Out-migration

The results in Table 5a for the first equation show that an increase in the average annual temperature has a negative influence on the rice yield while the non-linear effect (captured through the square term) has a positive effect. However, both the variables can be considered to be significant only at the 13-14 percent level of significance. Moreover, the two variables turn out to be the 'appropriate' instruments only in the case of rice while several other weather variables including rainfall were not significant even at this level of significance. However, it is possible that this result is triggered by the fact that different varieties of rice may be grown in any given year and the fact that the data is aggregated over five year time-periods and across significantly large geographical areas.

As Table 5b shows, the robust score test statistic strongly supports the endogeneity of the rice yield in the inter-state out-migration equation although the weather variables are weak instruments as seen from the corresponding test-statistic value in the same table. The estimated coefficient of the rice yield (based on 2SLS and LIML) in the migration equation suggests that a 10 percent decrease in the rice yield will lead to a 0.074 percent increase in the out-migration rate. The higher value of the semi-elasticity of rice yields compared to wheat yields may be due to the larger number of people involved in rice cultivation than wheat cultivation (as mentioned earlier), which leads to higher mobility when yields decline.

Table 5a: Estimated Coefficients for Rice Yield Equation with Weather Variables
(First Stage) (State Level)

Variables	Coefficient	p-value
Average Annual Temp.	-1.467	0.135
Square of Average Annual Temperature	0.028	0.136
Intercept	19.381	0.128
Adjusted R^2	0.932	
F-statistic for Overall Significance of the Model	$F(21,68) = 130.45^{***}$	0.000
F-Statistic for Joint Significance of Weather Variables	$F(2,68) = 1.14$	0.3249

Notes: Same as Table 4a.

Table 5b: Estimated Coefficients for Inter-State Out-Migration with Rice Yield (Second Stage) (State Level)

	OLS		2SLS		LIML	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Logarithm of Yield, lnY	0.0027[***]	0.008	-0.0074[*]	0.094	-0.0076[*]	0.096
Intercept	0.00072	0.205	0.006[**]	0.011	0.0061[**]	0.012
Adjusted R^2	0.796		0.558		0.545	
Test for Endogeneity	χ^2 **(1) =** 5.74[**] **p-value** = 0.0166					
Test for Weak Instruments	**Cragg-Donald Wald F statistic** = 0.964 **Critical Value** = 19.93[$]					

Notes: Same as Table 4b.

Studies such as Ozden and Sewadeh (2010) have argued that inter-state migration in India is influenced by socio-cultural factors including language. They have suggested that specific migration corridors exist in India for inter-state movement. Our analysis based on the sub-sample of the states Bihar, Karnataka, Haryana, Madhya Pradesh, Maharashtra, Punjab, West Bengal, Gujarat, Rajasthan and Uttar Pradesh representing the dominant migration corridor when it comes to inter-state movement in India, however, did not provide support for greater elasticity of migration in response to crop yield changes.

In the wheat yield as well as in the rice yield equations, the time dummies are significant and positive for all the years at 1 percent level of significance with "1972-76" as the reference period, indicating that five-year average yields have increased systematically over time after accounting for inter-state variations. Similarly, the state dummies capture the inter-state variations in five-year average yields (after accounting for temporal variations and weather variations across states) with Andhra Pradesh as the reference state. The results indicate that about five of the 14 wheat growing states and seven of all the states

growing rice have significantly different yields, with some lower and some higher than that for the reference state as expected. Moreover, the inter-state out-migration rates also show far less variability, either over time or across states, as can be expected following the stylized facts discussed in above section.

WEATHER VARIABILITY, AGRICULTURAL YIELD AND DISTRICT-LEVEL IN-MIGRATION

Though the results based on the state-level data show indication for the weather-agriculture-migration linkage, the statistical inference does not strongly support it. Thus, in order to increase the variability in the concerned data set, we use a similar analysis using district-level migration information. As mentioned in above section, we base the district-level analysis on in-migration reported at district level from the 2001 Census data. As in the case of the state-level analysis, the approach outlined in equations (1) and (2) above is adopted keeping crop (wheat and rice, separately) yields as potential endogenous variables. Since the district-level data does not indicate the reason for migration, we carry out the analysis separately for male migrants and total migrants. Table 6 gives a summary of the mean and variation in the district-level data.

Table 6: Mean and Standard Deviation in Select Variables across Districts and over Time

Variables		Mean	Standard Deviation	Minimum	Maximum	Observations
Proportion of Total In-Migrants	Overall	0.0404	0.0147	0.0	0.1279	N = 798
	Between		0.0135	0.0	0.0953	n = 428
	Within		0.0059	0.0078	0.0730	T-bar = 1.864
Proportion of Male In-Migrants	Overall	0.0173	0.0153	0.0	0.0996	N = 798
	Between		0.0139	0.0	0.0703	n = 428
	Within		0.0062	-0.0131	0.0478	T-bar = 1.864
(Log of) Rice Yields	Overall	0.2466	0.6841	-1.9661	1.5707	N = 798
	Between		0.6750	-1.8326	1.5041	n = 428
	Within		0.2155	-0.8276	1.3208	T-bar = 1.864
(Log of) Wheat Yields	Overall	0.4910	0.6038	-2.5257	1.7596	N = 734
	Between		0.6150	-2.5257	1.5109	n = 397
	Within		0.1749	-0.4208	1.4028	T-bar = 1.848

Tables 7 and 8 report the estimated coefficients for the male migration rate and total migration rate, for the intra- and inter-district migration rate, and for the two crops separately, the results of which are discussed below.

Wheat Yield and In-Migration

In the wheat yield (agriculture) equation, we identify the three weather variables – the June-September temperature, the January-March temperature, and the annual total rainfall – as the appropriate instruments after considering several combinations of such weather variables available in the database. While an increase in pre-sowing temperature (June-September) and annual total rainfall will have a positive influence on the yield, an increase in temperature during the harvest period will adversely affect the yield (see Table 7a).

Table 7b reports the estimated coefficient of the wheat yield intra-district and inter-district migration and all migrants separately for

total and male migrants.   In all the cases the test for endogeneity suggests that the crop yield is endogenous in the migration equation and provides justification for the use of the instrumental variable approach. However, the test for weak instruments shows that the Cragg-Donald Wald F statistic (3.38) is below the 10 percent maximal IV relative bias critical value (9.08), indicating that the weather variables are weak instruments.

Table 7b reports the estimated coefficient of (log of) wheat yield for intra-district, inter-district and all migrants separately for total and male migrants. In all the cases the test for endogeneity suggests that the crop yield is endogenous in the migration equation and provides justification for use of instrumental variable approach. However, the test for weak instruments shows that Cragg-Donald Wald F statistic (3.38) is below the 10% maximal IV relative bias critical value (9.08), indicating that the weather variables are weak instruments.

The estimated coefficient of the wheat yield is significant across the 2SLS and LIML approaches. The LIML estimates are uniformly higher than those estimated through the 2SLS approach. The coefficients of the wheat yield in the models involving male migrants are slightly higher than in those involving total migrants. While the sign of the yield coefficient is as expected (i.e., positive) in the case of inter-district in-migration, it takes the opposite sign with regard to intra-district in-migration. However, it may be noted that inter- and intra-district in-migration is positively correlated in the data suggesting a similarity in the sign of the yield coefficient in both the models. The sign of the yield coefficient in the model with all migrants is also positive implying that as the wheat yield decreases, in-migration into that district also decreases.   The estimated semi-elasticity (based on LIML estimates) of the male (total) migration rate to the wheat yield change is 0.041 (0.034), which suggests that a 10 percent decrease in wheat yield in a district would

decrease the in-migration rate of male (total) migrants by about 0.41 percent (0.34 percent).

Table 7a: Estimated Coefficients for Wheat Yield Equation with Weather Variables (First Stage) (District Level)

Variable	Coefficient	p-value
June-September Temp.	0.284[**]	0.025
January-March Temp.	-0.344[**]	0.041
Annual Total Rainfall	0.0001	0.277
Intercept	0.384	0.900
Adjusted R^2	0.817	
F-statistic for Overall Significance of the Model	F(339, 331) =2802.66	0.000
F-statistic for Joint Significance of Weather Variables	F(3, 391) = 1.90	0.1282

Note: Same as in Table 4a.

Table 7b: Estimated Coefficients for In-Migration with Wheat Yield

(Second Stage) (District Level)

Variable	Intra-District Migrants		Inter-District Migrants		All Migrants	
	2SLS	LIML	2SLS	LIML	2SLS	LIML
Total Migrants						
Logarithm of Yield, lnY	0.022** (0.010)	0.032** (0.063)	0.012** (0.011)	0.014** (0.023)	0.034** (0.018)	0.053* (0.082)
Time Dummy	-0.006*** (0.000)	-0.007*** (0.000)	-0.003*** (0.000)	-0.003*** (0.000)	-0.011*** (0.000)	-0.013*** (0.000)
N; Adj. R^2	727; 0.62	727; 0.272	727; 0.68	727; 0.58	727; 0.39	727; 0.18
Test for Endogeneity	$F(1,391) =$ 9.794*** (0.0019)		$F(1,391) =$ 8.571*** (0.0036)		$F(1,391) =$ 7.271*** (0.0073)	
Male Migrants						
Logarithm of Yield, lnY	0.026*** (0.003)	0.030** (0.011)	0.013*** (0.008)	0.014** (0.012)	0.041*** (0.010)	0.057** (0.046)
Time Dummy	-0.008*** (0.000)	-0.008*** (0.000)	-0.003*** (0.000)	-0.003*** (0.000)	-0.013*** (0.000)	-0.015*** (0.000)
N; Adj. R^2	727; 0.43	727; 0.24	727; 0.30	727; 0.20	727; 0.36	727; 0.14
Test for Endogeneity	$F(1,391) =$ 19.253*** (0.000)		$F(1,391) =$ 10.915*** (0.001)		$F(1,391) =$ 11.077*** (0.001)	

Note: The numbers in brackets show p-values; *** denotes p-value ≤0.01, ** denotes p-value ≤ 0.05 and *denotes p-value ≤0.10; the Time Dummy represents the dummy variable for time period 1997-2001 with 1992-1997 as the reference period.

Rice Yield and In-Migration

In the model with rice yield as the relevant agricultural variable, four weather variables – three temperature variables and one rainfall variable – are identified as relevant instruments. The three temperature variables are June-September average temperature, January-March average temperature, and October-November average temperature; the rainfall variable is (the logarithm of) the June-September total rainfall. Table 8a

reports the estimated coefficients for this first-stage regression. While the increase in pre-sowing temperatures (January-March) is likely to positively influence rice yield, the increase in the south-west/north-east monsoon temperatures (June-September and October-November respectively) can adversely affect the yield. An increase in the monsoon rainfall also positively influences the rice yield.

Table 8b reports the estimated coefficients from the second-stage regression for rice. In the case of total migrants, the test for endogeneity indicates that the crop yield is endogenous in the migration equation. However, the test for endogeneity does not reject the null of yield being exogenous in the male migration rate equation. The test for weak instruments on the other hand shows that the Cragg-Donald Wald F statistic (17.75) is above the 10 percent maximal IV relative bias critical value (10.27), indicating that the weather variables are not weak instruments.

The estimated coefficient of the rice yield is significant across all models involving total migrants, whereas in the case of male migrants the rice yield coefficient is weakly significant only for inter-district-migrant and all-migrant streams. The sign of the yield coefficient is as expected (i.e., negative) in the case of intra-district in-migration but takes the opposite sign in the case of inter-district in-migration. This is the exact opposite of the result observed in the case of the wheat crop. Again, since both inter- and intra-district in-migrations are positively correlated in the data, one may expect a similarity of signs for the yield coefficient in the models involving inter- and intra-district migrants. Overall, the rice yield coefficient is negative in the migration equation suggesting that as the yield decreases the in-migration into that district increases, perhaps due to more intra-district than inter-district mobility. That is, as the yield of a district decreases there is a higher intra-district movement of people in search of livelihoods. Further, the estimated semi-elasticity of total migration is significantly higher than that of male migration indicating

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family movement in the case of households dependent on rice rather than exclusively male migration. The estimated (negative) semi-elasticity of male (total) migration rate to rice yield change is -0.004 (-0.011), which suggests that a 10 percent increase in rice yield in a district would lead to a decrease in the in-migration rate of male (total) migrants by about 0.04 percent (0.11 percent).

Table 8a: Estimated Coefficients for Rice Yield Equation with Weather Variables (First Stage) (District Level)

Variable	Coefficient	p-value
June-September Temp.	-0.638***	0.000
January-March Temp.	0.592***	0.000
October-November Temp.	-0.517***	0.000
(Log of) June-September Total Rainfall	0.252***	0.009
Intercept	15.42***	0.000
Adjusted R^2	0.819	
F-statistic for Overall Significance of the Model	$F(372,362) = 28963.75$	0.000
F-Statistic for Joint Significance of Weather Variables	$F(4,425) = 6.62$	0.000

Note: Same as in Table 4a.

Table 8b: Estimated Coefficients for Inter-State Out-Migration with Rice Yield (Second Stage) (District Level)

Variable	Intra-District Migrants		Inter-District Migrants		All Migrants	
	2SLS	LIML	2SLS	LIML	2SLS	LIML
Total Migrants						
Logarithm of Yield, lnY	-0.006*** (0.001)	-0.009*** (0.001)	-0.002*** (0.000)	-0.003*** (0.001)	-0.011*** (0.000)	-0.014*** (0.000)
Time Dummy	-0.004*** (0.000)	-0.004*** (0.000)	-0.002*** (0.000)	-0.002*** (0.000)	-0.008*** (0.000)	-0.008*** (0.000)
N; Adj. R^2	790; 0.842	790; 0.806	790; 0.885	790; 0.871	790; 0.751	790; 0.724
Test for Endogeneity	F(1,423) = 10.2961 (0.001)		F(1,423) = 5.687 (0.0175)		F(1,423) = 8.917 (0.003)	
Male Migrants						
Logarithm of Yield, lnY	0.0006 (0.662)	-0.016 (0.777)	-0.0013* (0.05)	-0.0025* (0.05)	-0.004 (0.114)	-0.0075 (0.10)
Time Dummy	-0.005*** (0.000)	-0.006*** (0.000)	-0.002*** (0.000)	-0.002*** (0.000)	-0.009*** (0.000)	-0.009*** (0.000)
N; Adj. R^2	790; 0.888	790; 0.548	790; 0.835	790; 0.810	790; 0.835	790; 0.816
Test for Endogeneity	F(1,423) = 0.224 (0.636)		F(1,423) = 2.065 (0.151)		F(1,423) = 1.672 (0.197)	

Note: The numbers in brackets show p-values; *** denotes p-value ≤0.01, ** denotes p-value ≤ 0.05 and *denotes p-value ≤0.10; the Time Dummy represents the dummy variable for time period 1997-2001 with 1992-1997 as the reference period.

SUMMARY OF RESULTS

Based on the state- and district-level analyses, we summarize the estimated semi-elasticity of migration to crop yield change in Table 9 and arrive at the following observations based on these results:

(a) In case of inter-state out-migration, the semi-elasticity is similar irrespective of the choice of crop. This estimate is also close to the estimated semi-elasticity from the reduced-form single equation using the per-capita net state domestic product from agriculture;

(b) The semi-elasticity based on district-level estimations is on average higher than those estimated from the state-level analysis, particularly for wheat (Table 9). This perhaps reflects the higher rates of intra-state movement compared to inter-state movements;

(c) From the district-level analysis, it can be inferred that, (i) if inter-district movement dominates over intra-district movement, there will be less 'in' migration into a district that fares poorly on the agricultural front; and (ii) if intra-district movement dominates over inter-district movement, there will be more within-district movement of people searching for livelihood in periods when there is poor performance on the agricultural front.

(d) Since the estimated semi-elasticity of the migration rate with respect to wheat yield is positive in the district-level analysis, perhaps inter-district movement dominates over intra-district movement because of the geographically sparser cultivation of wheat than of rice. In contrast, the migration semi-elasticity for rice is negative, indicating the dominance of intra-district movement over inter-district movement in the case of rice because of the cultivation of rice in geographically contiguous areas in almost all states. Though the dominance of the inter-district migration rate over the intra-district migration rate (and *vice-versa*) is not quite evident from the estimated coefficients, two additional factors could be influencing the overall sign of the yield coefficient in the migration equation. These, as mentioned previously, are: (i) the observation that both inter- and intra-district migration rates are positively correlated; and (ii) the specific nature of the crop under consideration and its relative labor intensity.

(e) In the case of wheat, the estimated semi-elasticity of the migration rate is nearly the same for both male and total migrants in the district-level analysis, whereas for rice, the

estimated semi-elasticity of migration rate for total migrants is higher than that for male migrants. This could be because, in the case of rice, as explained above, the possible domination of intra-district migration may have to do with short-distance (and short-duration) migration in lean times involving the movement of entire families as against the movement of male members alone in the case of wheat.

Table 9: Estimates of Semi-Elasticity (Elasticity) of Migration Rate to Agricultural Performance – Summary

Variables	Inter-State Out-Migration	Intra/Inter-District In-Migration
Total Migration Rate to NSDPAg	-0.034 (-0.75)	-
Male Migration Rate to Wheat Yield	-	0.046 (2.78)
Total Migration Rate to Wheat Yield	-0.004 (-0.90)	0.037 (0.90)
Male Migration Rate to Rice Yield	-	-0.004 (-0.22)
Total Migration Rate to Rice	-0.007 (-1.85)	-0.011 (-0.27)

(f) Notes: (1) In case of out-migration, the total migrant population excludes marriage migration and place-of-birth migrants; (2) District-level in-migration includes all migrants from rural areas as the reason for migration is not available from the Census; (3) Values in brackets are elasticity of migration rates to Agricultural Performance.

Hind-Casting Migration Rate

From the estimated model used for migration analysis one can either forecast or hind cast the migration rate under various hypothetical changes in the weather variables. The present study prefers to hind-cast given the likely uncertainties in forecasting based on coefficient estimates sourced from a historical data analysis.

Using the estimations based on the state-level analysis reported above, the change in migration rate associated with a one-degree Celsius annual temperature change is estimated[10] as 0.000413. Since the state-level average annual out-migration rate in the period between 1971 and 2001 was 0.4 percent, we may conclude that the migration rate during the period would have been 0.44 percent had the annual temperature been 1°C higher during this period than what it purportedly was according to available records. Similarly, in the case of the wheat crop, the migration rate would have been 0.46 percent had the October-November temperature been 1°C higher during the 1971-2001 period than what it was.

CONCLUSIONS

This study sought to explore the linkages between weather variability, agricultural performance and migration in India using state-level data for the 1981-2001 period and district-level data for the 1991-2000 period. Such a three-way nexus based on a secondary database has not been investigated rigorously in the Indian context and this study fills that gap in the literature. Studies based on migration data in India often focus on the push and pull factors determining migration and are based on single cross-sectional data (for e.g., Joe *et al.,* 2009; Mitra and Murayama, 2008; Ozden and Sewadeh, 2010). Our study, on the other hand, is based on several years of Census data and the durations of stay reported in each Census, which facilitate a rigorous econometric analysis.

The results suggest that while weather-variability-led agricultural distress could lead to migration from rural to urban areas in India, the

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[10] The modelling analysis adopted in this study can be summarized through the following two equation systems:

$M_i = \alpha + \beta \, lnY_i + \varepsilon_i$

$Y_i = \gamma + \delta T_i + \lambda T_i^2 + v_i$

From this specification, we may estimate the marginal change in the migration rate (M_{it}) as:

$\Delta M_{it} = \beta *(\delta + 2\lambda T_i)* \Delta T_i$

magnitude of the response is relatively small compared to those reported for other countries in the literature. Further, the rate and type of migration vary across crop types and level of (geographical) disaggregation used in the analysis. The elasticity of inter-state out-migration to wheat (rice) yield is estimated as -0.90 (-1.85). In the absence of other livelihood opportunities in rural as well as urban areas, weather-induced migration operating through the agriculture channel may not lead to significant migration. The low semi-elasticity values reported in this study substantiate this observation. Further, as noted in the beginning of the paper, the rural to urban migrants have registered a larger growth between 1991 and 2001 compared to the previous decade and this is more so in the inter-district and inter-state streams of migration. Thus, one could surmise that given the current level of development in India, migration is largely explained by the development angle. An even clearer picture would emerge if longitudinal data regarding individual migrants was available at the regional level.

From a climate change perspective, the study findings have important policy implications as migration is often seen as an effective adaptation option by the policy makers. Despite the low magnitude of the impact of crop yield changes on migration rates that this study reports, the presence of linkages between weather variability, agriculture and migration that it elicits and conclusively establishes here suggests that migration could still be an important adaptation option in India. This is more likely to be the case in the long run given the long time-lags that are typically associated with the manifestation of climate change impacts on people's livelihood options and responses and the likely upward movement of India along the development ladder by that time. The economic growth and development are known to facilitate rapid urbanization resulting in release of agricultural laborers from rural areas.

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Appendix A

Figure A.1: Out Migration Rates

Inter-State Out Migration Rate
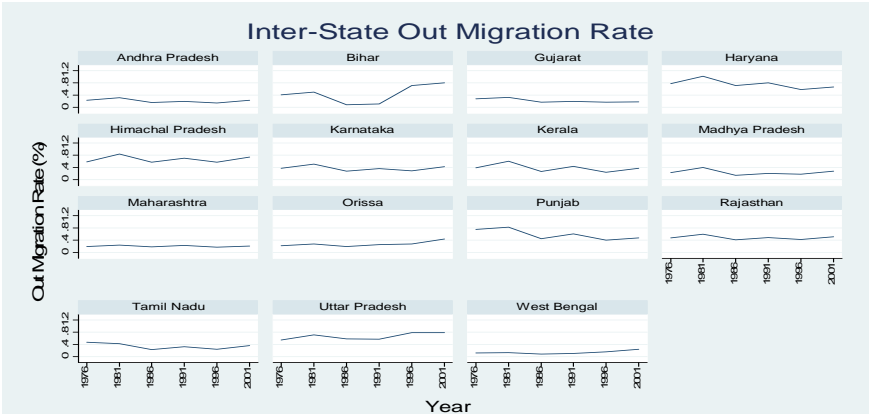
Figure A.2: Per Capita Net State Domestic Product in Agriculture

Per Capita NSDP Agriculture (Rs. '00)

42
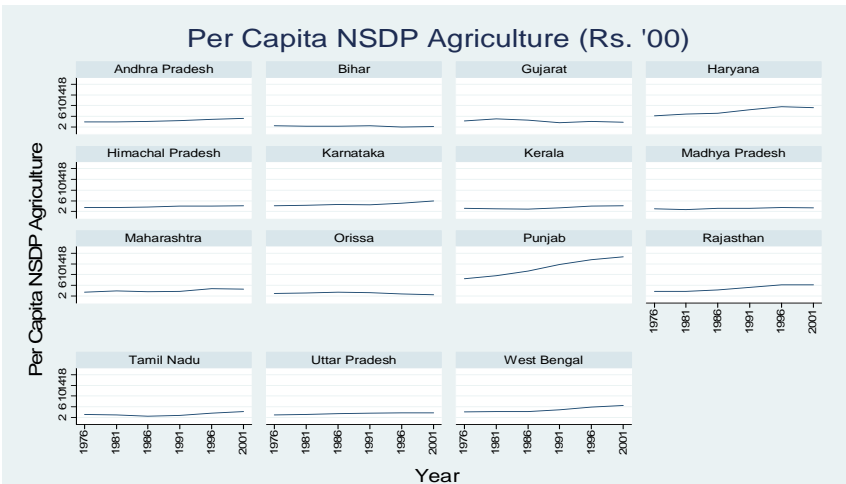
Figure A.3: Rice and Wheat Yields

Rice and Wheat Yields(tons/ha)

Figure A.4: Temperature

Temperatures (Deg. Celsius)
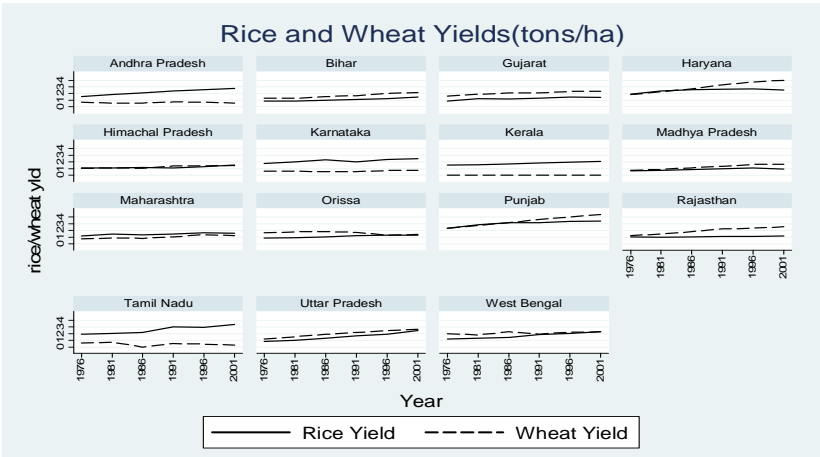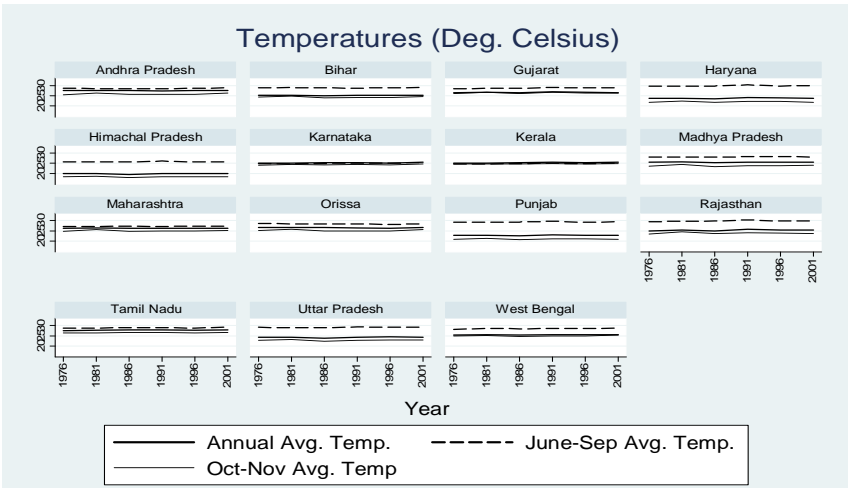
Figure A.5: Rainfall

Rainfall (cms)
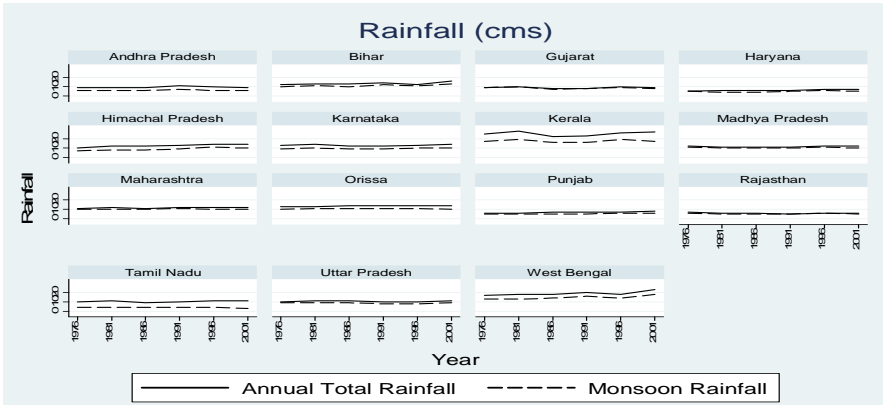
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