Scorching Heat and Shrinking Horizons: The Impact of Rising Temperatures on Marriages and Migration in Rural India*

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Abstract

This study delves into the gendered impacts of rising temperatures from climate change on long-term female migration patterns in rural India. We utilize a panel fixed-effects model to investigate the relationship between temperature levels and migration trends by employing a district-level panel dataset that combines Census data for years 1991, 2001, and 2011, multiple rounds of household surveys, and local weather measurements. Our results showcase statistically significant declining effects of rising temperatures on female rural-rural and rural-urban migration in the country. Specifically, the findings suggest that a 1 °C temperature increase is associated with a 22% decline in rural-urban and a 13% decline in rural-rural female migration in an average district in India. This decline is primarily due to diminishing marriage-related migration among women in the northern districts of the country, which have a historically high prevalence of dowry. We identify decreasing agricultural yields from rising temperatures as an underlying mechanism that is reducing resources to finance dowry in northern India. We further note that the declines in female migration are driven by districts with poor access to credit, and more so in the northern districts.

JEL Classification: J12; O15; Q54

Keywords: Climate change; Migration; Marriages; Dowry; India

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I Introduction

Anthropogenic climate change is one of the most pressing issues of our time, with far-reaching impacts on human society. According to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), global warming of 1.1 degrees Celsius above pre-industrial levels is already profoundly affecting human systems (IPCC, 2021). These effects are felt most acutely in underdeveloped countries located in low-latitude regions and near the equator (Castells-Quintana et al., 2017; Cline, 2007; Dell et al., 2012). In this regard, Carleton and Hsiang (2016) argue that climate change, by variably affecting different sub-populations like women and the poor, can lead to substantial changes in demographic structures in the long run. These effects can potentially result in further distortion of existing social and economic inequalities in developing countries.

One such demographic effect of climate change is on migration patterns, which has garnered significant attention in recent studies (Adger et al., 2015; Black et al., 2011; Cattaneo et al., 2019; Hoffmann et al., 2021). However, while the literature has extensively discussed the impacts of climate change on migration rates in the global south, there continues to be limited evidence on the gendered impacts on migration. This is critical, given the prevalence of various gender-related norms surrounding women's migration in developing countries in South Asia and Africa (Bau, 2021; Khalil & Mookerjee, 2018). In light of this, in this study, we investigate the long-run impacts of climate change on internal female migration in India and explore the mediating role of marriage in shaping those impacts. To do this, we create a unique database combining information on intra-district rural-urban and rural-rural female migration for the years 1991, 2001, and 2011 from the Census of India and district-level data on temperature and precipitation from ERA5 reanalysis weather data (Berrisford et al., 2011). Additionally, we gather multiple waves of household-level surveys by the National Sample Survey (NSS) of India between 1987 and 2011 to further delve into the dynamics.

The gendered effects of climate change on migration are quite significant. We find that a 1°C increase in mean decadal temperature is associated with a 22% decline in female rural-urban migration and a 13% decline in female rural-rural migration in an average Indian district. Our results are also robust to multiple sensitivity tests. They remain robust to the inclusion of state-year trends and when the spatial correlation between the districts is taken into account using Conley standard errors (Conley, 1999). The findings are critical as India has a patrilocal structure where most women migrate to their in-laws' houses after marriage (Chatterjee & Desai, 2020). In fact, most migrants in India are women who migrate because of marriage and not for economic reasons, which is also due to the low participation of women in labor markets (Afridi et al., 2018; Mehrotra & Parida, 2017).

Moreover, the event of marriage in India includes the traditional custom of dowry, in which the bride's household transfers wealth and resources to the groom's household during marriage. Despite legal procedures, the custom continues to be highly pervasive in the country(Chiplunkar & Weaver, 2023) and plays a decisive role in a woman's marriage. In this study, we showcase that the declining effects on female migration are driven by reductions in female marriage migration, primarily in the northern part of the country where the dowry custom has been historically more rooted (Mitchell & Soni, 2021). We find that falling agricultural yields due to rising temperatures (Taraz, 2018) that are eroding agricultural incomes act as an underlying mechanism driving our results. Moreover, we also document that poor access to credit in rural areas is moderating the impacts of increasing temperatures on female migration. Besides, although we can only examine impacts on intra-district female migration due to data limitations, multiple sets of evidence indicate that most marriages occurred within the short distance of a woman's native place and within the same district during the time period of our study (Chiplunkar & Weaver, 2023; Fulford, 2013)[1], which upholds the findings of our study. The results of our study highlight a concerning trend as for many women in India, moving to the city through marriage is a means to broaden their horizons and improve their living standards (Kalpagam, 2008). Climate change, by interacting with traditional gender norm, is insidiously shrinking the prospects of women's movement to urban areas through marriage, trapping women in rural regions with potential negative consequences on their welfare.

Our study makes a significant contribution to multiple strands of literature. We supplement the literature on the demographic effects of climate change (Carleton & Hsiang, 2016). We provide evidence of how climate change is distorting demographic structure in the long run by disproportionately affecting the female sub-population in rural India. We also advance the growing literature on the effects of climate change on migration patterns in developing countries (Cattaneo et al., 2019; Hoffmann et al., 2021). Specifically, our study is related to works by Gray and Mueller (2012) and(Findley, 1994). Gray and Mueller (2012) examine the consequences of droughts on migration in rural Ethiopia, and note that drought events are associated with declines in female out-migration as households have fewer resources to bear wedding expenses as traditional norms dictate that the bride's household are responsible for spending on wedding expenses. Findley (1994) documents similar observations for Mali, where the occurrence of droughts is related to decreases in migration by women as resources to arrange weddings shrink. In our study, we show that rising temperature levels are associated with falling female marriage-related marriage migration in rural India. In this way, we also add to the literature on the broader economic implications of the increasing temperature levels in rural India. These studies include shrinking rural consumption levels (Aggarwal, 2020; Liu et al., 2023; Sedova et al., 2020), rising rural mortality rates (Burgess et al., 2014), and intensification of agricultural activities as demand for non-agricultural products shrivels due to falling agricultural incomes (Liu et al., 2023).

Moreover, our study augments the literature on how traditional gender-related norms shape gender outcomes in developing countries. For instance, Ashraf et al. (2019) document that in Indonesia and Zambia, groups that practice the custom of bride price tend to have more educated daughters. Lowes and Nunn (2017) note no associations between larger bride prices and earlier marriages and high fertility but even assert that bride price is linked to better quality marriages and high self-reported happiness from the wife. In contrast, in India, studies have recorded perverse gender outcomes due to dowry. For example, Bhalotra et al. (2020) detect that higher dowry costs, reflected in the high cost of gold, result in increased son preference behavior amongst the parents. Sekhri and Storeygard (2014) observe that dry rainfall shocks are linked to increases in the incidence of domestic violence against women and dowry deaths in India[2]. This is because dowry payments are used to smooth consumption in the event of dry shocks by the groom's households. Moreover, Calvi and Keskar (2021) conclude that women

[1] This is discussed further with evidence in Section II.II.

[2] According to Sekhri and Storeygard (2014) , in India, a dowry death is legally defined as the death of a woman that occurs within seven years of her marriage and is caused by any burns or other bodily injury that do not occur under normal circumstances.

who paid higher dowries in India are less likely to be poor than those who did not pay. They also possess high control over resources in the household and have better bargaining power within the household. Calvi and Keskar (2021) add that gender poverty gaps are much more pronounced in households with no or low dowry payments relative to those with high and moderate dowry payments.

In this regard, we also supplement the literature on the interaction of climate change, marriage markets, traditional gender norms, and gender-related economic outcomes. Our findings closely align with those of Corno et al. (2020) , who show that drought events increase the risk of early marriages in regions in Sub-Saharan Africa, where the bride price custom is common, in which the groom's household pays the bride during the event of marriage. They further show that droughts decrease the odds of early marriages in India as resources to finance dowry diminish. In congruence with our results, the declines in their study are driven by regions in northern India, where dowry custom is ubiquitous. Another related study by Trinh and Zhang (2021) contrasts Vietnam, which has a tradition of bride price, and India and records similar outcomes that rainfall shocks soar the likelihood of child marriage in Vietnam but have an opposite effect in India.

The rest of this article is organized as follows. Section II discusses the study context, and III provides information on data sources and the methodology. Section IV discusses results, and Section V delineates the underlying mechanism and contextual factor shaping our results. Section VI presents the discussion and policy implications. Lastly, Section VII provides the concluding remarks.

II Study Context

In this section, we provide some background on the agricultural sector and climate change, female marriage migration, and the dowry custom in India.

II.I Agricultural Sector and Climate Change in India

Despite the falling contribution of the agricultural sector to the national Gross Domestic Product (GDP) of India from 30% in 1981 to 16.5% in 2019 (Gulati & Juneja, 2022), the sector remains a crucial component of the economy. It is a major employer of the rural population (Chand et al., 2017) and employed 43% of the country's workforce and 62% of the rural population in 2019. It is also a principal source of employment for women in rural areas, with 76% of women working in this sector as of 2011-12 (Gulati & Juneja, 2022).

Given the strong dependence on the agricultural sector, climate change poses a significant threat to the Indian economy. Studies show a consistent rise in average temperature levels across the country (Kumar et al., 2006; van Oldenborgh et al., 2018), with rainfall trends remaining relatively unchanged on a national scale but exhibiting more region-specific variations (Dash & Hunt, 2007; Kumar et al., 2006; Mall et al., 2006). Multiple studies have highlighted the negative impact of rising temperatures on agricultural yields in India. Taraz (2018) finds that high temperatures are damaging agricultural yields in all districts of the country, particularly the historically colder districts. This is because hotter districts have relatively better accessibility to inter- and intra-crop adaptation methods that aid in adapting to moderate increases in temperature levels. Another study discusses how temperature spikes of 3-6 °C in the Indo-Gangetic plains in 2004 led to a decline in wheat production by over 4 million tonnes, also affecting other crops like mustard, peas, onion, and garlic (Kumar et al., 2011). Simulation models-based analyses have underscored the adverse impact of rising temperatures on crop yields in India. A review by Mall et al. (2006) outlines these models' consensus on the detrimental effects of climate change both on rice and wheat yields in the country.

The consequences of rising temperatures on agricultural yields are concerning as means of adaptation remain lacking, suggesting that these losses could be even more severe in the future. Adaptation strategies, such as changing crop patterns, high input delivery, and use efficiency, can help mitigate some of the losses caused by climate change (Kumar et al., 2011). However, there are several barriers to accessing these methods. Some of these methods also require complementary measures, such as investments in supportive infrastructure, to succeed. For instance, modifying crop varieties is successful mostly when complemented by water and soil conservation measures (Ponce, 2020). Access to irrigation remains a challenge, with only 48.7% of India's cultivated land being irrigated in 2017-18 (Gulati et al., 2020). The average farm size is small, at 1.3 hectares in 2015-16 (Lowder et al., 2016), which further discourages the adoption of new technologies and alternative cropping patterns (Bryan et al., 2014). Studies also indicate significant reductions in groundwater levels in the country, which can threaten agricultural irrigation in the coming years (Zaveri et al., 2016).

II.II Female Marriage Migration in India

As discussed, the majority of internal migrants in India are women who migrate to stay with their in-laws after marriage (see Figures 2 and 3). Along with patrilocal structure, which partly explains these patterns, the practice of village exogamy, in which a woman marries outside her village, is also responsible for high female out-migration in villages (Fulford, 2013). This practice was common in rural northern India but is becoming widespread in other parts of the country as well (Rao & Finnoff, 2015). However, though most marriages occur outside, they are usually within a short distance of the woman's native place (Fulford, 2013). Based on the Rural Economic Development Survey (REDS) 1999, Chiplunkar and Weaver (2023) document that almost 78.3% of marriages in India occurred within the same district. This trend is also confirmed by the National Sample Survey (NSS) Employment-Unemployment Survey (NSS-EUS) of 2007-08, which found that most migration among married working-age women was intra-district, predominantly from one rural area to another (see Figure A.3).

However, despite being a common phenomenon, marriage migration and the state of married female migrants remain remarkably understudied in the literature (Fulford, 2013). The most notable study is by Rosenzweig and Stark (1989) , who, based on a small panel of households in a few villages in South India, explore how female marriage migration can serve as a strategy for consumption smoothing in rural households. They delineate that families often marry their daughters into areas with weather patterns uncorrelated to their own, thereby far off from their own village, using this strategy as a form of insurance. These marriage networks enable the transfer of resources from the married daughter's in-laws to her natal family and vice versa during the years of poor harvest. These findings are challenged by empirical evidence, as discussed above, that shows that most marriages occur within shorter distances, thereby, in areas with weather correlated to the native places. Fulford (2013) further corroborates this by showcasing that transfer of resources is highly uncommon between households connected via marriage links.

Moreover, using measures capturing rainfall volatility, Fulford (2013) demonstrates that the fraction of women migrating for marriage is negatively associated with rainfall volatility and adds that parents in areas of high rainfall volatility tend to marry their daughters to closer locations.

The marriage of a woman in India typically involves the transfer of dowry, which we explain in detail in the following subsection.

II.III Dowry Custom and Preference for Urban Grooms

The custom of dowry involves the transfer of wealth from the bride's household to the groom's household during the event of the marriage. This practice is highly common in the country, and, although historically rooted amongst upper-caste Hindus in northern India (Dyson & Moore, 1983; Srinivasan & Lee, 2004), recent evidence indicates a widespread adoption of the custom across various castes, religions, and regions (Ifeka, 1989; Srinivasan & Bedi, 2007; Waheed, 2009). Traditionally, dowries comprised gold and silver jewelry, but modern dowries have expanded to include consumer goods like refrigerators and washing machines (Bhalotra et al., 2020). It is a considerable financial burden to households, and a typical dowry can be several times the annual household income (Anderson, 2007; Anukriti et al., 2022). Anukriti et al. (2022) discuss that parents in India start saving for dowry as soon as a daughter is born, and increase their current savings when they expect higher dowries in the future. The fathers of firstborn daughters even have a higher number of work days compared to the fathers of firstborn sons. However, the poorest families in rural areas face various income and behavioral constraints associated with poverty that hinder their ability to save for dowry in advance.

Looking at economic explanations of dowry, Becker (1973) regard dowries as pecuniary transfers necessary to clear the marriage market with relatively scarce grooms compared to brides. In contrast, Botticini and Siow (2003) considered it as a feature of virilocal societies- where married daughters move out of their paternal house, but married sons stay. Nevertheless, as Chiplunkar and Weaver (2023) highlight, the practice became widespread over the years in the country- from 38% of marriages involving dowry in the 1920s to 88% by 1975- with dowry amounts tripling from 1945 to 1975. Chiplunkar and Weaver (2023) argue that the expansion in dowry practices and size is linked to changes in groom characteristics. As the average educational level of potential grooms increased in the 20$^{\text{th}}$ century, so did the variation in educational attainment. This led to increased competition for the relatively limited number of "high-quality" grooms. In a two-sided matching market, the increase in the number of such grooms with white-collar jobs, who the parents perceived could provide high economic security to their daughters, amplified both the prevalence and size of dowry.

Some other studies, such as Anderson (2003) and Calvi and Keskar (2021) , have also highlighted the same. Additional evidence can be found in qualitative and ethnographic studies conducted in villages in India. Studies, such as by Kalpagam (2008) and Chorghade et al. (2006) record the universal practice of transfer of dowry during marriages in villages, and moreover, they find that parents often agree to pay exorbitant amounts of dowry to secure an urban groom. This is primarily because parents in the villages view urban life as less challenging than rural life and prefer for their daughters to marry men with service sector jobs in urban areas, which they believe would ensure a more comfortable and less arduous life for their daughters (Chorghade et al., 2006). These preferences and aspirations of rural parents for urban grooms and resorting to paying higher dowries to secure them are documented in earlier literature as well, such as in Caldwell et al. (1983) . Botticini and Siow (2003) quote Caldwell's observation as follows:

> Parents desire their daughters to marry educated men with urban jobs because such men have higher and more certain incomes, which are not subject to climatic cycles and which are paid monthly, and because the wives of such men will be freed from the drudgery of rural work and will usually live apart from their parents-in-law. In a sellers' market created by relative scarcity, there was no alternative but to offer a dowry with one's daughter (Caldwell et al., 1983, p. 347).

The practice of paying higher amounts of dowry to secure urban grooms has become common, and without sufficient dowry, women may have to settle for "low quality"grooms. In their study, Kalpagam (2008) describes a situation where a family's financial inability to provide a substantial dowry resulted in their daughter marrying a casual laborer in the village, who frequently faced unemployment, underlining the significant impact dowry can have on the marital prospects of women in rural regions. Besides, the preference for urban grooms not only stems from rural parents but also from the daughters, who associate urban life with modernity and freedom to lead their private lives, experience unrestricted mobility, freedom in style and clothing, and generally better quality of life. These differences in the rural and urban life of a woman are reflected in statistics based on the India Human Development Survey (IHDS) presented in Table A2 in the Appendix. Most women in both urban and rural regions need permission from their husbands to go outside, but those in urban areas are more likely to go alone once permission is granted, indicating greater freedom in mobility. Moreover, the practice of ghoonghat/purdah/veiling[3] is much more pervasive in rural areas. We also note that the norm of men eating before women is much more common in rural areas in northern India[4], which, as Sedlander et al. (2021) point out, leads to inequitable food allocation between men and women in the household.

These discussions highlight that rural parents and daughters prefer urban grooms, employed in the non-agricultural sector, for which parents agree to pay high amounts of dowry. As explained in subsequent sections, the increasing temperatures due to climate change, which is harming agricultural yields and incomes, can severely impact the wealth needed to finance these dowries. Coupled with limited access to credit in rural areas, increasing temperatures can further curb resources to finance dowry. In the long run, this can harm the prospects of rural women getting married to urban grooms, leading to significant changes in female marriage migration patterns in India.

III Data Sources and Methodology

This section details the main data sources employed in our study and describes the empirical strategy implemented to examine the effects of rising temperatures on female migration rates.

[3]Ghoonghat or purdah refers to the practice of covering the head and/or face amongst married women to seclude their contact with men outside the family and sometimes inside the family such as with relatives (Desai & Andrist, 2010).

[4]This is also highlighted by Sedlander et al. (2021) , who discuss how this traditional norm of men eating before women in rural India is linked to inequitable food allocation and lower health outcomes for women in the country.

III.I Data Sources

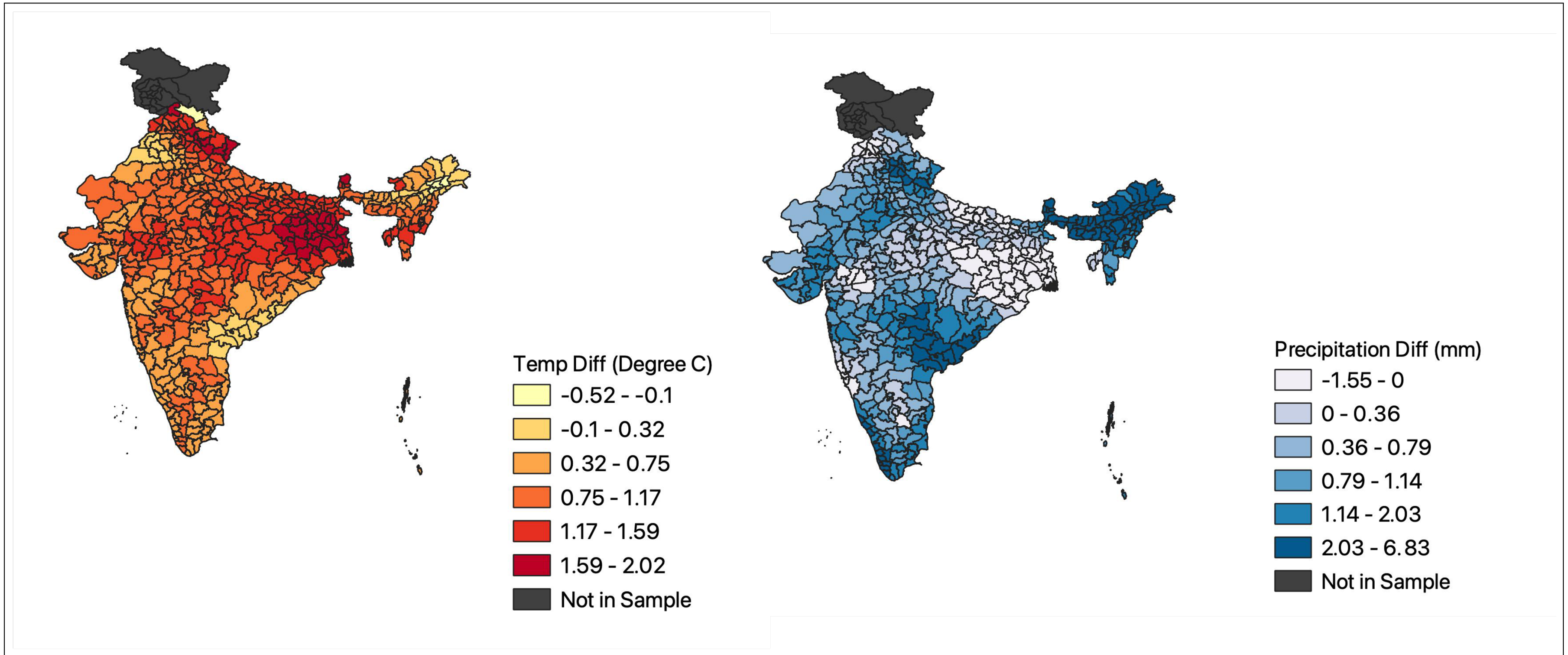
We use three main data sources in the study and assemble a district-level panel dataset by combining data on migration rates and weather variables. First, we formulate district-level measures of female rural-rural and rural-urban migration rates using the Indian Census data. Second, we aggregate the gridded monthly weather data published by the European Centre for Medium Range Weather Forecasts (ECMWF) (Berrisford et al., 2011) to construct district-level measures of temperature and precipitation. Third, we utilize micro-level household survey data from the National Sample Surveys (NSS) of India, conducted between 1987 and 2012. Using NSS, we extract district-level information on marriage migration by women. Together, these data sources allow us to construct a rich dataset to examine the impact of rising temperatures on female migration patterns in rural India and to test the effects on marriage-related migration.

III.I.1 Data on climate

For the climate data, we employ gridded monthly data on temperature and precipitation from the ERA5 high-quality reanalysis data produced by the European Centre for Medium Range Weather Forecasts (ECMWF) (Berrisford et al., 2011). Following the recent climate literature, we compute the average value of all grid points falling within a district boundary. Besides, as a robustness test in the later sections (Section IV.I), we also use an alternative aggregation method in which the grid-level data is aggregated to district-level weather outcomes, that is, mean temperature and mean precipitation by calculating the weighted average of all grid points within 100 kilometers of each district's geographic center using inverse-square weighting (Taraz, 2018).

The main variables are annual average temperature and average precipitation at the district level, and these variables are computed for each year between 1981 and 2010. The spatial distribution of the changes in the temperature and precipitation between the years 1981 and 2010 is presented in Figure 1. It is clear that almost all districts have experienced a rise in average temperature levels by at least 0.1 °C during the period of analysis. However, the figure shows a substantial spatial difference in temperature increases that can be utilized for our study. The descriptive statistics of these variables are presented in Table A1 in Appendix A.

Figure 1: Changes in the Temperature and Precipitation between 1981 and 2010



Note: The figure depicts long-run changes in temperature and precipitation. These changes are computed by subtracting the value of each variable in 1981 from the corresponding value in 2010. The changes in the annual temperature in °Celsius (Left) and the changes in annual precipitation in mm (Right).
Source: Authors' own illustration using the gridded ERA5 weather data. The figure is created using the district shapefile in QGIS.

III.I.2 Data on female rural-rural and rural-urban migration

To construct the main dependent variables capturing the female rural out-migration rates, we use the Census of India data for the years 1991, 2001, and 2011. We gather the district-wise population data using the Primary Census Abstract (PCA) data tables. The data on migration are compiled from the Migration (D-series) data tables from the Census digital library[5]. These tables provide district-level data on the total female population and female intra-district rural-urban and rural-rural migrants. For completeness and comparison, we have also collected information on the total and male population in the district and total and male intra-district rural-urban and rural-rural migrants.

To ensure consistency in district boundaries across the years, we harmonize the district boundaries using the district mapping file provided by Kumar and Somanathan (2017) . There were 466 districts in India in 1991. Figure A.1 in the Appendix depicts these 466 district boundaries that are consistent between 1991, 2001, and 2011. We could not include 14 districts from the state of Jammu and Kashmir[6] in the analysis due to the unavailability of census data in 1991. Additionally, due to the unavailability of weather data, we dropped 4 districts of union territory Pudducherry and 1 district of Lakshadweep, leading to a final sample of 447 districts.

The primary dependent variable is defined as the share of rural-urban (rural-rural) female intra-district migrants in the total female population of a district. Specifically, it is defined as:

$$Y_{j,t} = \frac{M_{j,t}}{P_{j,t}} \tag{1}$$

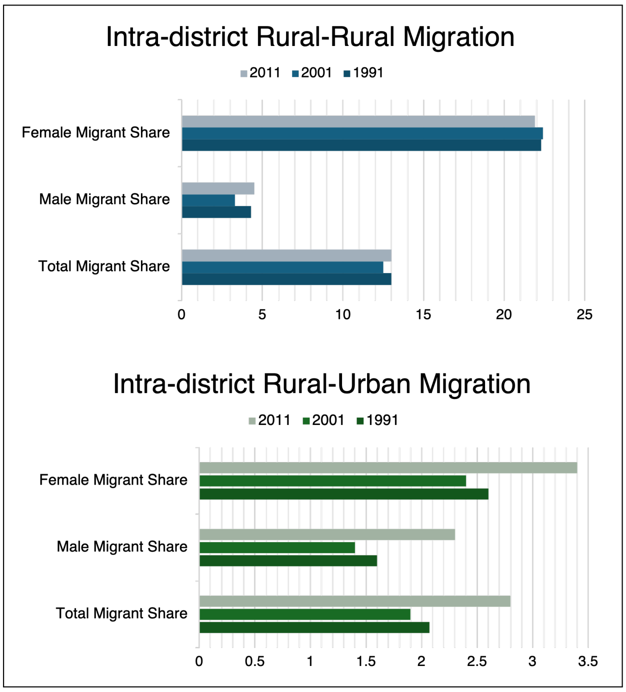
where $M_{j,t}$ is the number of rural-urban (rural-rural) female migrants and $P_{j,t}$ is the total female population in district j and in the decade beginning with year $t(= 1991, 2001, 2011)$. We construct this variable for female intra-district rural-urban (rural-rural) migrants as it is our primary outcome of interest. For comparison, we also construct similar variables measuring involving total and male intra-district rural-urban and rural-rural migrants.

We present these variables in Figure 2, which highlights two important aspects of internal migration in India: (1) Intra-district rural-rural migration by both men and women is more common than rural-urban migration; and, as previously discussed (2) Women make up the majority of internal migrants from rural areas in the country, irrespective of whether they move to other rural or urban destinations.

[5]https://censusindia.gov.in

[6]The state now is organized into two union territories: Jammu and Kashmir and Ladakh.

Figure 2: Intra-District Migration, Census of India, 1991-2011



Note: The chart above depicts the share (in percentages) of intra-district rural-rural female/male/total migrants in the female/male/total population of a district. The chart below illustrates the share in percentages) of intra-district rural-urban female/male/total migrants in female/male/total population of a district.
Source: Authors' own computation using Census of India 1991, 2001, and 2011.

We present spatial plots of intra-district rural-rural and rural-urban female migration based on Census 1991, 2001, and 2011 in Figure A.2 in Appendix A. The figure depicts that female rural-rural migration is much more common than rural-urban migration in the northern part of the country.

III.I.2.1 Data on female marriage migration

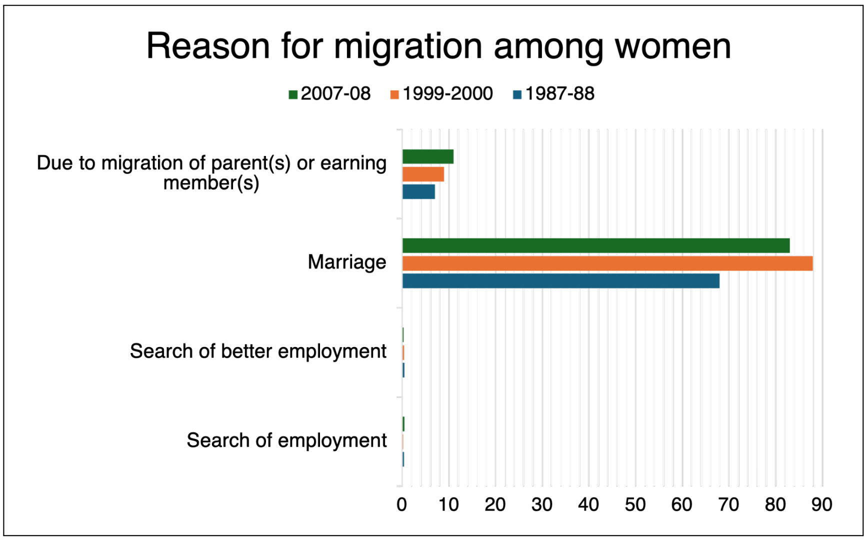
We augment our analysis with microdata from household surveys, specifically, the National Sample Survey (NSS) of India conducted between 1987 and 2012. The NSS surveys are nationally representative and cover around 100,000 sample households per round using a multi-stage sampling design.

To examine marriage-related migration among women, we draw on the NSS Employment-Unemployment Survey (NSS-EUS) data from the 43rd, 55th, and 64th rounds carried out in 1987-88, 1999-2000, and 2007-08, respectively. These surveys collected household-level information on migration, including whether the place of enumeration of a household member differs from their last usual place of residence and the reason for the move. The NSS data provides detailed insights into female migration patterns within districts, from rural to rural areas and rural to urban areas, and supplements our analysis with Census data. It should be noted that marriage migration may include disguised migration for economic purposes; however, it is not substantial enough to alter the results [7].

[7] Marriage migration in India has increased in the past three decades while the labor force participation rate

NSS-EUS provides additional evidence that most internal migration by working-age[8] married women are due to marriage. As shown in Figure 3, 68% of internal married working-age female migrants in India moved due to marriage in the 1987-88 round, which increased to over 80% in subsequent rounds. Additional descriptive statistics derived from NSS data are displayed in Figure A.3 in Appendix A.

Figure 3: Female Migration by Reason in India, NSS, 1987-2008



Note: The chart depicts the primary reason for migration among married working-age women in three NSS rounds: 1987-88, 1999-2000, and 2007-08. Source: Authors' own illustration using NSS-EUS data.

We establish a linkage between the NSS and Census data by utilizing the district codes available in the NSS surveys. To ensure that the districts are consistent with the Census data and to maintain the same district boundaries, we refer to Murthi et al. (2001) and Kumar and Somanathan (2017) .

III.I.3 Data on additional variables

The analysis is supplemented with data from several other sources. As we argue that reductions in agricultural yields due to rising temperatures act as an underlying mechanism explaining our results, we gather data on agricultural yields to test this mechanism. We collect agricultural data from the Village Dynamics in South Asia (VDSA), provided by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, 2015). This data set has annual measures of district-level agricultural yields for 15 crops between the years 1966 and 2010. These crops are rice, wheat, sugarcane, cotton, groundnut, sorghum, maize, pearl millet, finger millet, barley, chickpeas, pigeon pea, sesame, rapeseed and mustard, castor, and linseed. Following Taraz (2018) , we derive a price-weighted composite yield measure at the district level for each year

of women has fallen in the same time frame. Rao and Finnoff (2015) have conclusively shown that these trends are indeed due to rises in marriage migration and not increases in migration by women for economic purposes that are disguised as marriage migration. Mazumdar et al. (2013) also discuss this issue and using primary survey data and field studies conclude that labor migration by women in India is very low and most migration by women is for marriage.

[8]Following Rao and Finnoff (2015) , we consider working-age to be between 15 and 64 years old.

between 1981-2010. This is done through aggregating yields across the 15 crops, using average district-level crop prices between 1976 and 1980 as weights. Using base-year prices as crop weights removes the impact of climate shocks on prices, as discussed by Taraz (2018) and Duflo and Pande (2007) .

Furthermore, we examine the moderating role of access to credit at the baseline year as a contextual factor. For this, we focus on district-level access to bank branches in the baseline year of 1980. The data on the number of bank branches in each district in 1980 are obtained from the Basic Statistical Returns (BSR) reports published by the Reserve Bank of India[9]. Additionally, we source district-level population data from the Census 1981 (Vanneman & Barnes, 2000) and construct a baseline variable of bank branches per capita by dividing the total number of bank branches by the population.

Lastly, to explore the changes in dowry values, we utilize the most common data source on dowries in India, the Rural Economic and Demographic Survey (REDS). REDS collected data on economic and demographic variables of rural households across 17 major states in India, which encompass 96% of the total population of the country. It additionally recorded information on the marriages of the household heads, their brothers, sisters, sons, and daughters. We employ the 1999 round of REDS and consider marriages that occurred during the period of our analysis, that is, from 1981 onwards. REDS includes data on the nominal value of the dowry paid from the bride to the groom's household and the dowry received from the groom to the bride's household during the marriage. It also has information on the year of marriage. We follow the methodology adopted by Chiplunkar and Weaver (2023) to compute the net real values of dowry paid. We create the net dowry paid variable as the difference between the value of the dowry paid by the bride's household and the value of the dowry paid by the groom's household. Thereafter, we convert the net nominal value of dowry paid to the real values using the Wholesale Price Index (WPI)[10].

III.II Empirical Strategy

We conduct a panel fixed-effects estimation, and the main econometric specification is as follows:

$$Y_{j,t} = \beta_0 T_{j,t} + \beta_1 P_{j,t} + \phi_j + \gamma_t + \epsilon_{j,t} \tag{2}$$

The variable $Y_{j,t}$ is the outcome of interest in district j and in decade beginning with year t $(= 1991, 2001, 2011)$. It is the share of rural-urban (rural-rural) intra-district female migrants in the total female population of the district. This is our primary outcome of interest. For comparison and completeness, we also consider the share of rural-urban (rural-rural) intra-district male/total migrants in the total male/total population of the district. $T_{j,t}$ represents the average annual temperature in °Celsius of district j in the past decade ending in year t. $P_{j,t}$ is the average annual precipitation in millimetres of district j in the past decade ending in year t.

We follow the literature discussing the estimation of impacts of climate change on economic outcomes and include both temperature and precipitation in the specification (Auffhammer et al., 2013; Cattaneo & Peri, 2016) so that we obtain unbiased estimates of the effects of rising temperatures on female migration rates. However, as discussed in Section II.I, following the

[9]https://dbie.rbi.org.in/DBIE/dbie.rbi?site=publications Accessed 12 May 2024.
[10]The WPI data for the years 1981 to 1998 is gathered from the Reserve Bank of India.

climate change literature on India, which documents consistent rises in average temperatures across the country but region-specific changes in precipitation, we only interpret the coefficients associated with the temperature levels throughout this study. Thus, β_0 is the main coefficient of interest in this study and captures the effect of rising temperatures on migration rates, and $\beta_0 < 0$ signifies that migration rates are declining with rising temperatures.

Furthermore, we also include fixed effects, ϕ_j, capturing fixed district characteristics. γ_t is the year effects that control for changes over time that are consistent across districts. We only include fixed effects as controls to ensure that the model stays parsimonious and to avoid overcontrolling. This is because including other controls, such as socioeconomic characteristics that might be correlated to agricultural productivity, may introduce bias in the estimation due to over-controlling (Cattaneo & Peri, 2016). The standard errors are clustered at the district level and are provided in parentheses in the regression tables.

Specification (2) is a reduced-form linear relationship between rural-urban and rural-rural female migration rates and climate variables. In the upcoming sections, we discuss the possible channels through which climate change may shape migration rates, such as changes in agricultural productivity and contextual factors like access to credit.

IV Results

Table 1 illustrates the estimated effects of annual temperatures on intra-district female rural-rural and rural-urban migration rates in India. They indicate a statistically significant negative effect of increasing temperatures on rural-rural and rural-urban female migration rates. Specifically, the results show that a 1 °Celsius increase in temperature in an average Indian district is associated with a 22% decrease in the share of female rural-urban migrants and a 13% reduction in the share of female rural-rural migrants. The effects on male migration rates are not statistically significant, aligning with the findings of Liu et al. (2023) .

Table 1: Effect of Rising Temperatures on Migration, 1991-2011

	Rural-Urban			Rural-Rural		
	Total	Male	Female	Total	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature	−0.004	−0.002	−0.007	−0.018	−0.006	−0.030
	(0.003)	(0.003)	(0.003)**	(0.008)**	(0.006)	(0.012)**
Precipitation	0.004	0.003	0.004	−0.001	0.008	−0.010
	(0.003)	(0.002)	(0.003)	(0.005)	(0.003)**	(0.007)
District FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	1,341	1,341	1,341	1,341	1,341	1,341

Note: The dependent variable in (1) is the share of total intra-district rural-urban migrants, in (2) is the share of male intra-district rural-urban migrants, in (3) is the share of female intra-district rural-urban migrants, in (4) is the share of total intra-district rural-rural migrants, in (5) is the share of male intra-district rural-rural migrants, and in (6) is the share of female intra-district rural-rural migrations, in years 1991, 2001, and 2011. The independent variables are the decadal averages of annual temperature (°C) and annual precipitation (mm). The standard errors are clustered by district in parentheses.

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

We argue that the declines in female migration are primarily due to the decreases in marriage-related migration. Furthermore, these declines could be driven by the districts in northern India, where the custom of dowry, as previously discussed, has been historically widespread. To check for this, we categorize the districts as northern districts that are located in the northern states[11]. We exploit this heterogeneity in the historical prevalence of dowry between the northern districts and the rest of India by re-running the previous analysis and allowing the coefficients of temperature and precipitation to vary depending on whether the district is in a northern state. The results are reported in Table 2 and match our expectations. In the northern districts, rising temperatures have a pronounced negative effect on female migration rates[12].

Table 2: Effect of Rising Temperatures on Female Migration in Northern Districts, 1991-2011

	Rural-Urban	Rural-Rural
	Female	Female
	(1)	(2)
Temperature	0.010	0.029
	$(0.005)^{**}$	$(0.016)^{*}$
Temperature x North	-0.022	-0.075
	$(0.004)^{***}$	$(0.012)^{***}$
Precipitation	0.006	-0.007
	$(0.003)^{*}$	(0.006)
Precipitation x North	-0.017	-0.040
	$(0.004)^{***}$	$(0.015)^{***}$
District FE	Y	Y
Year FE	Y	Y
Observations	1,341	1,341

Note: The dependent variable in (1) is the share of female intra-district rural-urban migrants in the years 1991, 2001, and 2011. The dependent variable in (2) is the share of female intra-district rural-rural migrants in the years 1991, 2001, and 2011. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C) and decadal averages of annual temperature interacted with "North" dummy denoting 1 if the district lies in a major northern state such as Punjab, Uttarakhand, Uttar Pradesh, Haryana, Bihar, Jharkhand, Rajasthan, Madhya Pradesh, and Chhattisgarh, and 0 otherwise. It also includes the decadal averages of annual precipitation (in mm) and decadal averages of annual precipitation interacted with the "North" dummy. The standard errors are clustered by district in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

It might still be the case that these changes observed through Census data are not due to

[11] We follow the Government of India's categorization of the north and north-central cultural zone (Ministry of Culture, Govt. of India, n.d.) to identify the northern states and classify the states Punjab, Haryana, Uttar Pradesh, Rajasthan, Bihar, Rajasthan, Uttarakhand, Chhattisgarh, Jharkhand, and Madhya Pradesh as northern states. We exclude the erstwhile state of Jammu & Kashmir due to the unavailability of Census data in 1991. The state of Himachal Pradesh is also omitted as it has a smaller population and area, and we only consider the major northern states. The state of Uttarakhand is also small but has been considered as it was part of the state of Uttar Pradesh until 2000. Similarly, the states Jharkhand and Chhattisgarh are also considered as they belonged to the states of Bihar and Madhya Pradesh, respectively, until the year 2000.

[12] In an additional analysis, we allow the temperature coefficients to vary based on whether the district is in southern states of India, where the custom historically has not been prevalent. The results are reported in Appendix C, highlighting no negative effects for southern districts. These results complement the findings of Corno et al. (2020) .

changes in marriage-related female migration. Therefore, we further corroborate our analysis by providing more evidence on the marriage channel using the NSS-EUS survey for the years 1987-88, 1999-2000, and 2006-07. These waves of EUS had modules on migration where the survey respondents, that is, the members of the household, were asked if their current place of enumeration was different from their last usual place of residence. If so, the primary reason for this migration is recorded. Thus, using this data and the survey weights provided by NSS, for each of these waves of EUS, we construct an outcome variable that is the share of the total married working-age female migrants in the district who have undergone intra-district rural-urban migration due to marriage in last ten years. We compute similar measures for intra-district rural-rural migration. The approach is aligned with the measurement of migration variables using the Census data, but here, the variables are refined further to capture only the marriage-related migration by women.

The computation of climate variables stays the same. We then carry out a panel fixed effects regression in a similar manner as before with district-fixed and year effects. The results are presented in Table 3, and findings from regression (3) indicate a negative association between increases in temperature and female rural-urban marriage migration in the northern regions. These findings lend further support to the initial results, suggesting that the declines in female migration observed previously are driven by decreases in marriage-related migration in northern India.

Table 3: Effects of Rising Temperatures on Marriage Migration, NSS Survey, 1987-2007

	Rural-Urban	Rural-Rural	Rural-Urban	Rural-Rural
	Female	Female	Female	Female
	(1)	(2)	(3)	(4)
Temperature	0.009	0.0005	0.030	−0.001
	(0.016)	(0.044)	(0.017)*	(0.053)
Temperature x North			−0.049	−0.007
			(0.023)**	(0.069)
Precipitation	0.001	−0.023	0.022	−0.013
	(0.015)	(0.033)	(0.015)	(0.034)
Precipitation x North			−0.026	−0.070
			(0.023)	(0.059)
District FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	881	881	881	881

Note: The dependent variables in (1) and (3) are the share of married female intra-district rural-urban migrants of working age who have migrated due to marriage in NSS rounds 1987-88, 1999-00, and 2007-08, respectively. The dependent variables in (2) and (4) are the share of married female intra-district rural-rural migrants of working age who have migrated due to marriage in NSS rounds 1987-88, 1999-00, and 2007-08, respectively. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C) and precipitation (in mm). The independent variables in (3) and (4) are the decadal averages of annual temperature (°C) and decadal averages of annual temperature interacted with "North" dummy denoting 1 if the district lies in a major northern state such as Punjab, Uttarakhand, Uttar Pradesh, Haryana, Bihar, Jharkhand, Rajasthan, Madhya Pradesh, and Chhattisgarh, and 0 otherwise. The regression also controls for the decadal average of precipitation (in mm) and decadal average of precipitation interacted with "North" dummy. The standard errors are clustered by district and are in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Moreover, we posit that these declines in marriage migration by women are due to the diminishing agricultural income and wealth from soaring temperatures in rural areas, which, in turn, is dwindling the resources for dowry in northern areas. We provide suggestive evidence of shrinking dowry amounts in rural northern India in figure 4 below. The figure displays a negative relationship between net dowry paid by brides' households and rising temperatures.

IV.I Robustness Tests

In this section, we discuss the robustness tests we implement to further validate our main results regarding female migration rates in Table 1. These tests include adding state-year trends to the regression equation, re-running the analysis using alternative climate variables, and accounting for spatial autocorrelation. The results of robustness tests are attached in Appendix B.

State-year trends. In the first robustness test, we add state-year trends to our regression equation to capture state-specific time trends. The findings, presented in Table A3, show a slight increase in the magnitude of the estimates. Importantly, the direction and statistical significance of the results stay consistent with the initial findings.

Alternative climate variables. We explore the sensitivity of our main results to different measures of temperature and precipitation. For this, we aggregate grid-level weather data to district-level outcomes by calculating the weighted average of all grid points within 100 kilometers of each district's geographic center, using an inverse-square weighting of the distances, as suggested by Taraz (2018) . These results, which are displayed in Table A4, affirm the robustness of the initial findings. The estimates remain statistically significant and consistent with the main results. The magnitudes of the estimated coefficients have increased slightly, indicating that the effects of rising temperature on female migration rates might be even higher than previously estimated.

Conley standard errors. In the third robustness test, we adjust the standard errors to consider possible spatial auto-correlation (Conley, 1999; Hsiang, 2010). We follow Sekhri and Storeygard (2014) and set the distance cutoffs at 100, 150, and 200 kilometers. The results, detailed in Table A5, demonstrate that the estimates remain robust when applying Conley standard error adjustments for these distance cutoffs.

V Mechanisms and contextual factors

In this section, we first investigate the underlying mechanism driving our results. We explain that declines in agricultural yields due to rising temperatures are eroding the wealth of rural households. This, in turn, harms their ability to finance the dowry payments. In addition, we test whether the effects of rising temperatures on female migration rates vary with a contextual factor, such as poor access to credit.

V.I Agricultural Yields and Dowries

As we discussed before, evidence supported by simulation models and observational data shows the detrimental effects of temperature rises on agricultural yields in India. We replicate these findings for the time period of our study and, specifically, carry out an analysis to dissect the effects for the northern districts. We follow Taraz (2018) and Liu et al. (2023) to measure the yearly aggregate agricultural yield at the district level. As detailed in Section III, we use the VDSA data on agricultural yields and compute the aggregate agricultural yield at the district level for the time period of our analysis, 1981-2010. Thereafter, we conduct a panel fixed-effects estimation with the natural logarithm of the aggregate agricultural yields as the dependent variable[13].

As expected, the results in Table 4 show a marked decline in agricultural yields due to rising temperatures.

Table 4: Effects of Rising Temperatures on Agricultural Yields, 1981-2010

	Log Agr. Yield
	(1)
Temperature	-0.065
	$(0.019)^{***}$
Precipitation	0.044
	$(0.010)^{***}$
District FE	Y
Year FE	Y
Observations	8,693

Note: The dependent variables in (1) is the natural logarithm of the aggregate agricultural yields, between the years 1981 and 2010. The independent variables in (1) are the average annual temperature (°C) and precipitation (in mm). The standard errors are clustered by district and are in parentheses.
*p $<$ 0.10, **p $<$ 0.05, ***p $<$ 0.01.

How do these declines in agricultural yields translate into lower resources for dowry? The gradual declines in agricultural yields from rising temperatures over the years are decreasing income for agricultural households. However, rural households in India exhibit consumption patterns characterized by habit formation, meaning they slowly adjust their consumption in response to income volatility (Khanal et al., 2019), often delving into their savings to finance consumption. As the agricultural households gradually and disproportionately adjust their consumption to the decreases in agricultural incomes, far fewer resources are left for savings for dowry[14].

The social and economic costs of not being able to get a daughter married are high (Anukriti et al., 2022), which can compel a few agricultural households to possibly overcome these losses in savings by adapting to rising temperatures and finding ways to save enough for dowry. However, this could be specifically more difficult for relatively poorer households[15], who are unable to adapt and fail to save enough. As the cost of an unmarried daughter is high, these households

[13] We execute the following econometric analysis:

$$lnY_{j,t} = \eta_0 T_{j,t} + \eta_1 P_{j,t} + \phi_j + \gamma_t + \epsilon_{j,t}$$

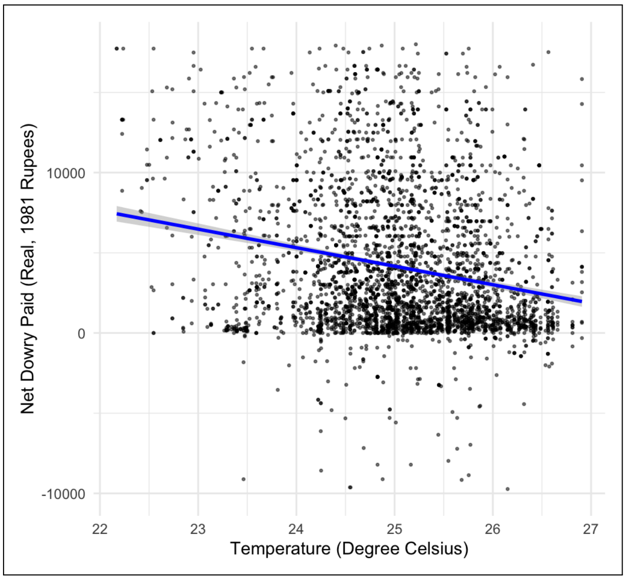
Here, $Y_{j,t}$ is the aggregate agricultural yield in district j and year t. $T_{j,t}$ is the annual average temperature in °C and $P_{j,t}$ is the annual average precipitation in mm in district j and year t. We control for district fixed effects using ϕ_j and year effects through γ_t.

[14] We cannot completely discount that consumption levels are not changing. Studies have discussed the negative effects of rising temperatures on the consumption of rural households (Liu et al., 2023). More likely, both consumption and savings are drying up.

[15] Approximately 70% of the rural population in India has zero to little landholdings (Asher et al., 2022). Research shows considerable linkages between the size of landholdings and access to adaptation to climate change (Baland & Robinson, 2008; Bryan et al., 2009; Deressa et al., 2009; Dustmann & Okatenko, 2014).

also need to get their daughters married, and they do so by resorting to paying lower amounts of dowry. We provide suggestive evidence of this in Figure 4 below. It displays a negative relationship between the net dowry amounts paid by the brides' households and the increasing temperature levels in the northern rural regions[16]. With lower amounts of dowry, these households are settling for "low" quality grooms residing in the rural regions rather than "high" quality grooms in urban areas for their daughters.

Figure 4: Net Dowry Paid by Brides and Temperature Levels in Northern Districts, 1981-1998



Note: The plot exhibits the real value of the net dowry paid by the bride's household in rural areas in the northern districts for marriages between 1981 and 1998 in 1981 Rupees in the vertical axis. The nominal values are converted to real values using WPI. On the horizontal axis are the average temperature levels in °C in the corresponding marriage year in the district. Each point in the scatter plot represents the surveyed household with a bride in marriage years between 1981 and 1998.
Source: Authors' own illustration using the REDS 1999 and ERA5 data.

In this regard, access to credit that can enable these households to borrow for dowries during the marriage years can play a critical role and considerably shape our initial results. We explore this issue in the following subsection.

V.II Access to Credit: Heterogeneity Analysis

In this subsection, we examine how access to credit in a district at the baseline year can influence the effects of rising temperatures on the female migration rate. Access to credit can moderate the impacts in two broad ways. It can enhance adaptation to climate change by agricultural households by facilitating investment in agricultural technologies or encouraging diversification into the non-agricultural sector[17]. Moreover, better access to credit can increase the ability to

[16] This is similar to Chowdhury et al. (2020) , who discuss how income shocks in rural Bangladesh impact marriage payments. A positive income shock increases the bride price and dowry amounts, but a negative income shock reduces them.

[17] We run similar heterogeneity analysis based on access to irrigation at the baseline in the district, as better access to irrigation can also aid in adaptation to climate change. The results are provided in Appendix D and do not show any discernible effects.

save in advance and enable borrowing during the marriage year to finance dowry and wedding expenses (Anukriti et al., 2022).

For this analysis, we identify districts with low access to banks in the baseline year 1980. We determine whether the per capita number of bank branches was below the national median and create a binary variable to represent this condition: it equals 1 when the per capita number of bank branches in a district in 1980 is below the national median and 0 otherwise. The spatial plot in Figure A.4 in the Appendix shows significant variation in access to bank branches across districts in 1980. To assess how it moderates the effect of rising temperatures on female migration rates, we carry out a variation of the regression equation (2). We allow the coefficients attached to temperature to change based on whether the district had poor access to credit at the baseline.

The findings in Table 5 outline that limited access to banks significantly shapes the impact of temperature increases on female migration, both rural-rural and rural-urban, with a more substantial effect on the latter. Our results confirm that the access to credit constraints faced by poor agricultural households prevent them from saving for dowry in advance, challenge securing loans during the marriage years, and perhaps even constrain their ability to adapt to rising temperatures. This, in turn, is intensifying the effect of climate change on the marriage prospects of rural women and the marriage-related migration by them. In magnitude terms, these results show that a 1 °Celsius increase in temperature is associated with a 25% decline in female rural-urban migration in districts with low access to banks and a 19% decrease in female rural-rural migration. The lower magnitude of the declining effect associated with rural-rural female migration hints that rural households in districts with poor access to credit are perhaps resorting to marrying their daughters to other rural areas rather than to urban areas by offering lower dowry amounts.

Additionally, we adjust the analysis to examine the effects specifically in the northern districts. The findings are depicted as results of regressions (3) and (4) in Table 5. Unsurprisingly, we observe that the diminishing effects are driven by northern districts and, more so, by northern districts with limited access to credit at the baseline.

Table 5: Effect of Rising Temperatures on Female Migration and Heterogeneous Effects by Access to Banks, 1991-2011

	Rural-Urban	Rural-Rural	Rural-Urban	Rural-Rural
	Female	Female	Female	Female
	(1)	(2)	(3)	(4)
T	0.005	−0.019	0.010	0.028
	(0.004)	(0.013)	$(0.005)^{*}$	$(0.016)^{*}$
T x Low Bank Access	−0.011	−0.037		
	$(0.003)^{***}$	$(0.012)^{***}$		
T x North			−0.018	−0.057
			$(0.005)^{***}$	$(0.013)^{***}$
T x North x Low Bank Access			−0.006	−0.034
			$(0.002)^{***}$	$(0.013)^{***}$
P	0.016	−0.016	0.006	−0.006
	$(0.005)^{***}$	$(0.007)^{**}$	$(0.003)^{*}$	(0.006)
P x Low Bank Access	-0.020	0.008		
	$(0.005)^{***}$	(0.011)		
P x North			−0.012	−0.021
			$(0.004)^{***}$	(0.022)
P x North x Low Bank Access			−0.004	−0.010
			(0.004)	(0.028)
District FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	1,326	1,326	1,326	1,326

Note: The dependent variables in (1) and (3) are the share female intra-district rural-urban migrants, respectively, in years 1991, 2001, and 2011. The dependent variables in (2) and (4) are the share female intra-district rural-rural migrants, respectively, in years 1991, 2001, and 2011. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C), decadal averages of annual temperatureinteracted with "Low Bank Access" dummy denoting 1 if the per capita Bank branches at the baseline was lower than the national median and 0 otherwise, decadal average of annual precipitation (in mm), and decadal average of annual precipitation (in mm) interacted with the "Low Bank Access" dummy. The independent variables in (3) and (4) are the decadal averages of annual temperature (°C), decadal averages of annual temperature interacted with "North" dummy denoting 1 if the district lies in a major in a major northern state such as Punjab, Uttarakhand, Uttar Pradesh, Haryana, Bihar, Jharkhand, Rajasthan, Madhya Pradesh, and Chattisgarh, and 0 otherwise, and decadal averages of annual temperature interacted with "North" dummy and "Low Bank Access" dummy. The regressions also control for the decadal average of annual precipitation (in mm), and decadal average of annual interacted with the "North" dummy, and decadal average of annual interacted with the "Low Bank Access" dummy. The standard errors are clustered by district in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

VI Discussion & Policy Implications

In this study, we discuss the gender-specific impacts of climate change, particularly the effects of rising temperatures, on long-term female migration patterns in rural India. We provide evidence of temperature increases substantially affecting female rural-rural and rural-urban migration rates. These reductions in female migration rates are mainly driven by declines in marriage-related female migration in northern districts where the custom of dowry is ubiquitous.

The policy implications of this study, particularly concerning the traditional custom of dowry, are multifaceted and complex. Various studies have highlighted the ineffectiveness of the Dowry Prohibition Act of India, with some suggesting legal procedures can inadvertently exacerbate women's welfare (Calvi & Keskar, 2021, 2023). On a different note, Chiplunkar and Weaver (2023) 's recent study suggests that, as India's literacy rate is rising sharply, the dowry custom might contract in the future as women's literacy improves and the supply of educated grooms increases. However, other studies present a contrasting view, arguing that dowry custom would continue to play a fundamental role in marriages in India in the coming years (Beauchamp et al., 2017). This is because grooms increasingly seek educated women as brides but not highly educated. Thus, highly educated women may face challenges in finding suitable grooms and might need to offer substantial dowries for marriage.

Nonetheless, an important policy recommendation based on the findings is improving access to credit in rural areas. Burgess et al. (2014) have demonstrated how access to banks can reduce mortality in rural areas during summers in India. Banks facilitate consumption smoothing and provide loans at manageable interest rates, which can be crucial for financing dowry resources and adapting to climate change. For instance, farmers can obtain credit to invest in adaptation strategies such as irrigation, crop diversification, mechanization, and purchasing seeds. Additionally, banking access also offers resources for migration to cities. This has been highlighted by Bryan et al. (2014) , who found that offering small loans to subsistence-based farmers and job matching can reduce their aversion to migration. However, it is critical that financial inclusion policies are gender-sensitive. This ensures that women have equal opportunities to migrate for education or work, in addition to traditional marriage-related migration. Mehrotra and Parida (2017) argue that women's labor force participation is likely to increase as more women attain education. Yet, this progression depends on women's mobility and sense of safety when moving out. Therefore, policy interventions are required to first encourage the acceptance of women migrating for reasons other than marriage, such as education or employment opportunities, and make destination places safer. Furthermore, as suggested by Anukriti et al. (2022) , policies that liquidate dowry, such as financial inclusion policies that mitigate barriers to savings and induce savings behavior in poor rural households, can evade distress borrowing at exorbitant rates from informal sources during the time of marriage.

Finally, our study highlights the urgent need for state interventions to transform rural economies to be more resilient to climate change. Infrastructure programs, like road construction and electrification that connect rural areas to cities, can enhance access to agricultural markets, reduce information costs, and bolster the uptake of adaptation means by agricultural households.

VII Conclusion

The literature on climate change and migration in developing countries has expanded significantly in recent years. However, there remains a notable gap in understanding the specific impacts on women, who often constitute a major share of internal migrants due to the patrilocal structure prevalent in these regions. Although female migration appears non-economic, there are often various economic channels underlying the marriage of a woman in these countries. In our study, we demonstrate that rising temperatures are decreasing female migration rates in India, specifically female marriage-related migration in northern regions. We contend that this is due to the historical prevalence of dowry in northern India and identify decreasing agricultural yields from soaring temperatures as an underlying mechanism. In particular, we show that the reductions in agricultural yields are shrinking resources to finance dowry. We further note the declining effects are much more pronounced in regions with limited access to credit.

It should be noted that various norms surrounding marriages, other than dowry, in the country remained largely unchanged during the time period of our analysis, which upholds the validity of our results. For instance, marriages continue to be arranged by parents with little say from the daughters in rural areas, a trend that persisted despite societal modernization and contrasts with predictions of theories of family change (Allendorf & Pandian, 2016; Banerji & Deshpande, 2021). Additionally, marriages continue to occur within the same caste and religion (Allendorf & Pandian, 2016; Banerjee et al., 2013). Comparing 1984 and 2009, Kamble et al. (2014) show that despite massive cultural shifts, mate preferences in India have persisted, including the preference for grooms with higher perceived economic security by women. These factors further support the results of our study.

Nevertheless, our study has important limitations. Firstly, although we have provided ample evidence showing that most marriages occur within short distances of native places during the time period of our study and within districts, we cannot completely discount the possibility that climate change might be inducing rural households to marry off their daughters to far-off places with different weather as a risk diversification mechanism (Rosenzweig & Stark, 1989). This is an issue that could not be explored in our study due to the unavailability of data from the Census of India and NSS, but it is a useful avenue for future research. Secondly, it might be the case that village endogamy, or marrying within one's own village, became more common during our analysis period, which could not be captured through migration rates. In this context, we rely on evidence provided by Mazumdar et al. (2013) , who, based on their primary survey between 2009 and 2011, highlight a contrasting trend of increasing exogamous marriages in previously endogamous regions and note an overall rise in exogamous marriages among younger cohorts.

Our study makes a crucial contribution to the literature on the gendered economic effects of climate change and underlines how climate change can potentially increase economic inequalities by disproportionately affecting women. The findings of our study can be utilized in future studies to investigate further the broader dynamics of climate change impacts on marriages, female migration, and gender outcomes in other developing countries where marriage-related payments such as dowry and bride price are widespread. Moreover, future research should also examine how such traditional gender norms in interaction with climate change are shaping other economic outcomes, such as educational attainment, and social outcomes, such as domestic violence, for women in developing countries.

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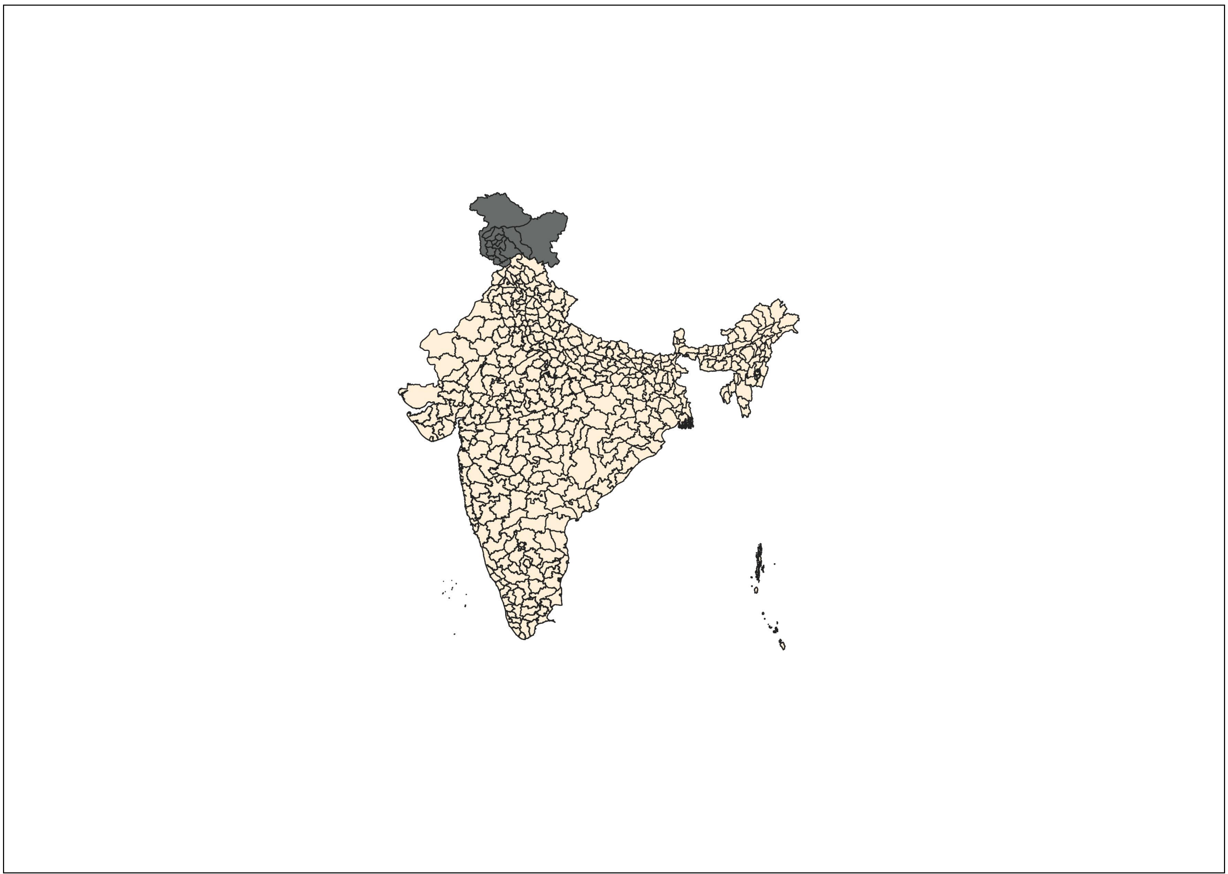
Appendices

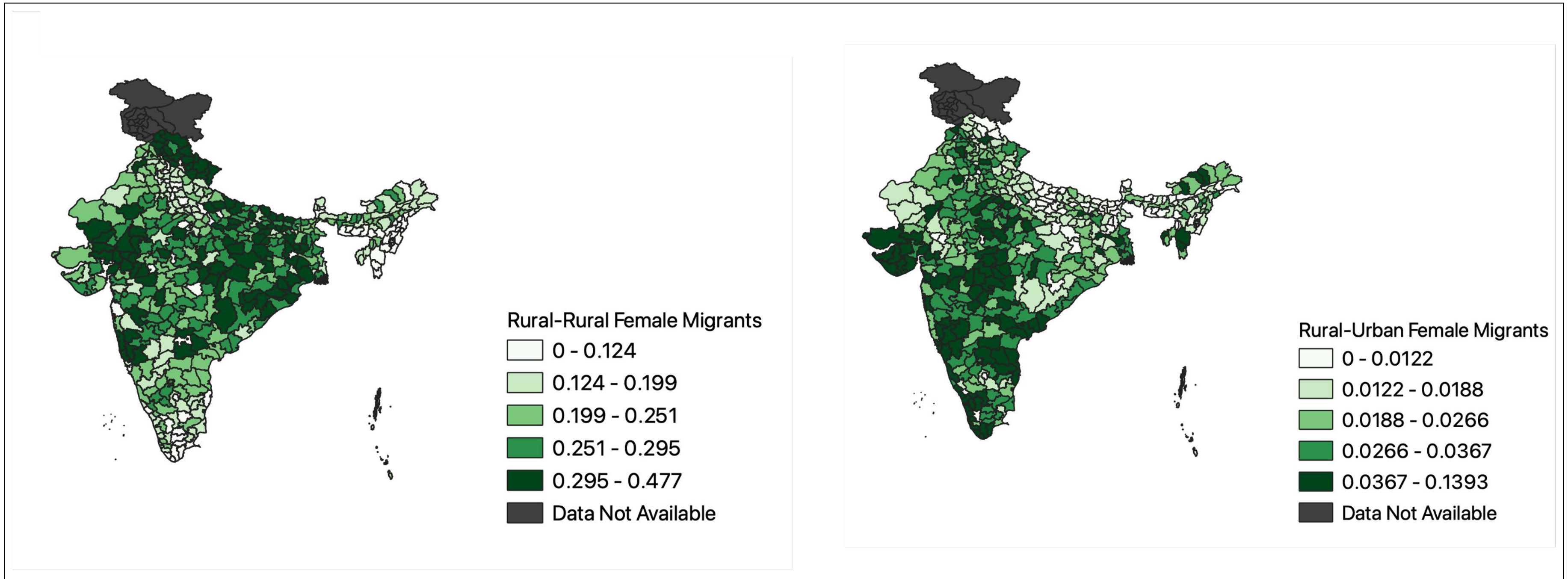
A Figures & Tables

Figure A.1: Districts in India, 1991



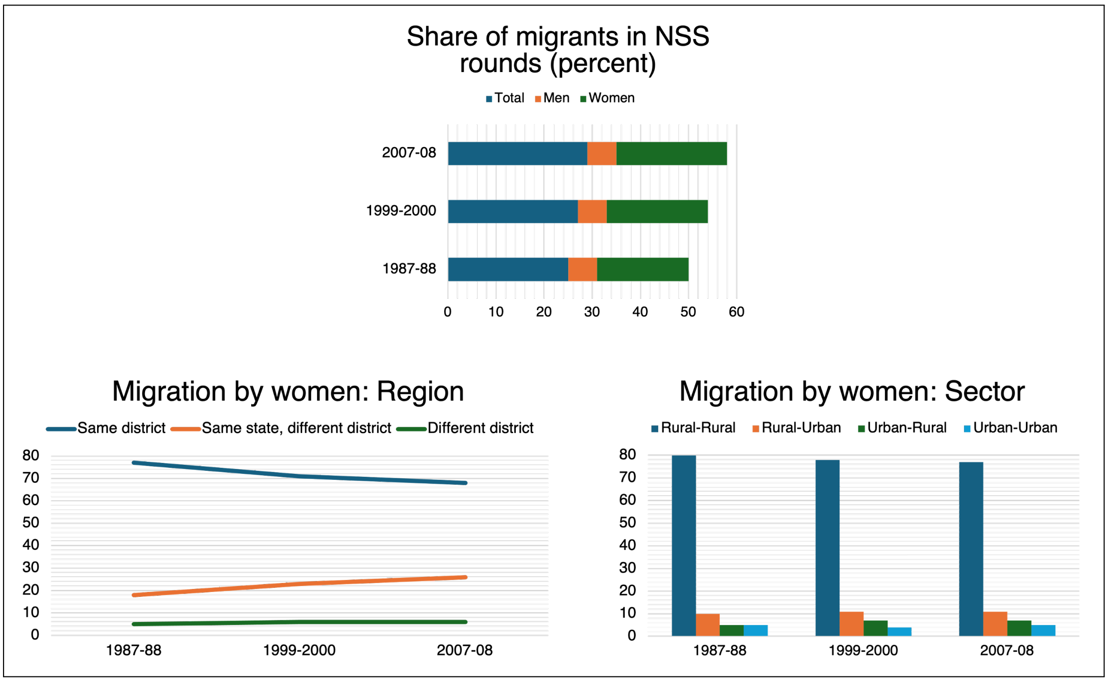
Note: The figure depicts 466 districts in 1991 in India. We excluded the northern union territories of Jammu & Kashmir and Ladakh (erstwhile northern state of Jammu & Kashmir) due to the unavailability of migration data in 1991. We also dropped the union territories Pudducherry and Lakshadweep because of the lack of availability of weather data. The excluded regions are marked in grey. The figure is processed using the district shapefile in QGIS.

Figure A.2: Female Migration in India, Census of India, 1991-2011



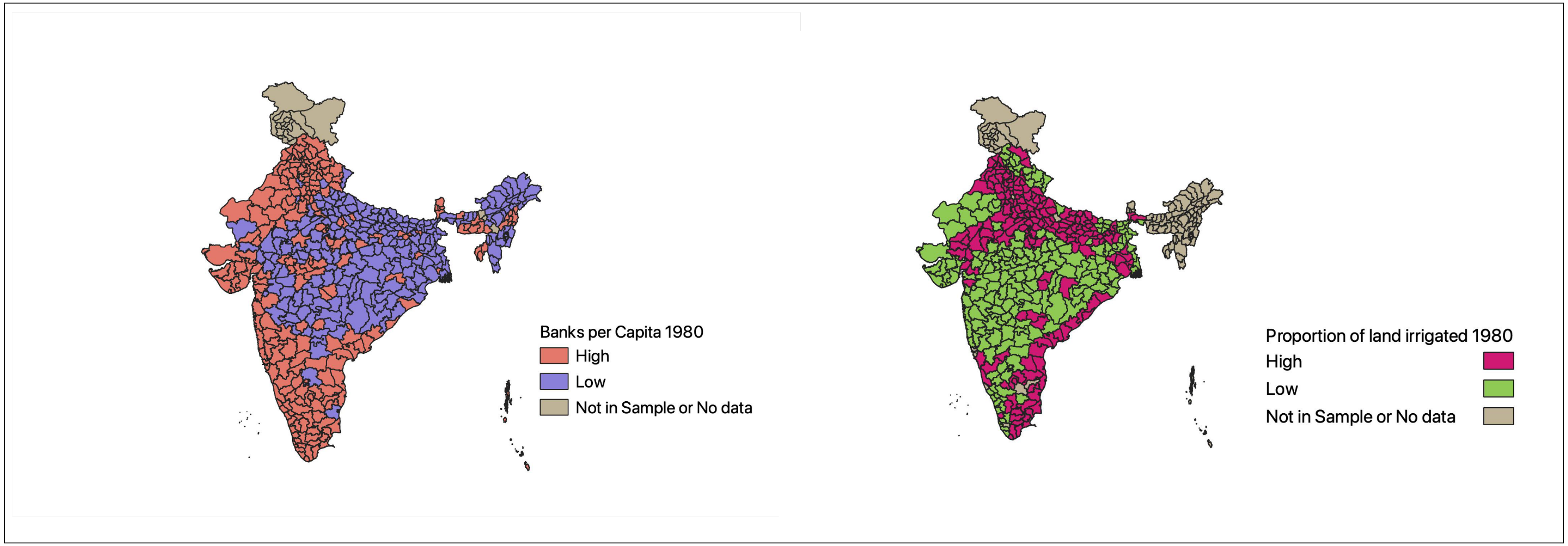
Note: The figure depicts the average female rural-rural migration in the years 1991, 2001, and 2011 (Left) and average female rural-urban migration in the years 1991, 2001, and 2011 (Right).
Source: Authors' own illustration using Census of India data. The figure is processed using the district shapefile in QGIS.

Figure A.3: Female Migration in India, NSS, 1987-2008



Note: (Clock-wise)The first chart shows the share of migrants (Total/men/women) in India in three NSS rounds 1987-88, 1999-2000, and 2007-08. The second plot illustrates the migration of working-age married women by sector. The third plot presents the migration of working-age married women by region.
Source: Authors' own calculations using NSS-EUS data.

Figure A.4: Irrigation and Banks per capita at baseline (1980)



Note: The figure depicts the distribution of banks per capita (left) and proportion of land irrigated (right) at the baseline year of 1980. The districts are categorized into high banks per capita and low banks per capita based on the national median banks per capita in 1980, which is approximately 4 for every 100,000 people. Similarly, the districts are categorized into high irrigated and low irrigated based on the national median proportion of land irrigated in 1980, which is equal to 0.17.
Source: Authors' own compilation using the Reserve Bank of India (RBI) data and data from ICRISAT (2015) . The maps are processed using the district shapefile in QGIS.

Table A1: Temperature and Precipitation, 1981-2010

Year	Mean	SD
Annual Temperature (°C)		
1981-1990	24.0	4.51
1991-2000	24.1	4.44
2001-2010	24.4	4.43
Annual Precipitation (m)		
1981-1990	0.00377	0.00251
1991-2000	0.00391	0.00254
2001-2010	0.00393	0.00238

Source: Authors' own calculation using ERA5 data

Table A2: Marriage and gender norms, IHDS, 2011-12

	North India		**South India**		**Rest of India**	
	Rural	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
Ask permission to visit health centre	0.87	0.82	0.82	0.84	0.72	0.71
If yes, can you go alone?	0.57	0.71	0.61	0.62	0.70	0.70
Ask permission to visit friend or relative in the neighborhood	0.73	0.73	0.85	0.85	0.60	0.63
If yes, can you go alone?	0.64	0.73	0.63	0.59	0.75	0.74
Ask permission to visit kirana shop	0.42	0.50	0.60	0.62	0.42	0.46
If yes, can you go alone?	0.75	0.84	0.75	0.75	0.81	0.83
Do you practice ghoonghat/ purdah/ pallu?	0.84	0.72	0.11	0.18	0.73	0.50
Family meal eating: men eating first	0.48	0.28	0.14	0.11	0.22	0.14
Does anybody in the family have a bank account?	0.70	0.74	0.65	0.71	0.60	0.75
If yes, is the respondent's name on the bank account?	0.47	0.55	0.67	0.65	0.46	0.56

Note: The data is gathered from the India Human Development Survey-II, 2011-12. The module with data on ever-married women aged 15-49 is used. The measures are calculated using the survey weights. The large northern states are Punjab, Uttarakhand, Uttar Pradesh, Haryana, Bihar, Jharkhand, Rajasthan, Madhya Pradesh, and Chhattisgarh. The large southern states are Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh. Rest of the states are Jammu & Kashmir, Himachal Pradesh, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, Assam, West Bengal, Odisha, Gujarat, Maharashtra, and Goa.
Source: Authors' own calculation using India Human Development Survey, 2011-12.

B Robustness Tests

Table A3: Effect of Rising Temperatures on Migration with State-Year Trends, 1991-2011

	Rural-Urban	Rural-Rural
	Female	Female
	(1)	(2)
Temperature	-0.007	-0.033
	$(0.003)^{**}$	$(0.013)^{***}$
Precipitation	0.005	-0.010
	(0.003)	(0.007)
District FE	Y	Y
Year FE	Y	Y
State Year Trends	Y	Y
Observations	1,341	1,341

Note: The dependent variables in (1) and (2) are the share of female intra-district rural-urban and rural-rural migrants, respectively, in the years 1991, 2001, and 2011. The independent variables are the decadal averages of annual temperature (°C) and decadal averages of annual precipitation (mm). The standard errors are clustered by district in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A4: Effect of Rising Annual Temperatures on Migration with Alternative Climate Variables, 1991-2011

	Rural-Urban	Rural-Rural
	Female	Female
	(1)	(2)
Temperature	-0.008	-0.033
	$(0.003)^{***}$	$(0.013)^{**}$
Precipitation	0.003	-0.010
	(0.003)	(0.007)
District FE	Y	Y
Year FE	Y	Y
Observations	1,341	1,341

Note: The dependent variables in (1) and (2) are the share of female intra-district rural-urban and rural-rural migrants, respectively, in years 1991, 2001, and 2011. The independent variables are the decadal averages of annual temperature (°C) and decadal averages of annual precipitation (mm). The standard errors are clustered by district in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A5: Effect of Rising Annual Temperatures on Female Migration with Conley Standard Errors, 1991-2011

Variable	Standard error	Distance cut-off	Temperature		Precipitation	
			Coefficient	SE	Coefficient	SE
Rural-urban						
	Conley standard error	100	−0.007	(0.003)**	0.004	(0.003)
	Conley standard error	150	−0.007	(0.003)*	0.004	(0.004)
	Conley standard error	200	−0.007	(0.004)*	0.004	(0.004)
	Clustering District		−0.007	(0.003)**	0.004	(0.003)
Rural-rural						
	Conley standard error	100	−0.031	(0.011)***	−0.010	(0.006)*
	Conley standard error	150	−0.031	(0.012)**	−0.010	(0.006)
	Conley standard error	200	−0.031	(0.012)**	−0.010	(0.007)
	Clustering District		−0.030	(0.012)**	−0.010	(0.007)
Observations			1,341		1,341	

Note: The coefficients are estimated based on the same model as in equation (2). These regressions control for district fixed effects and year effects. The Conley standard errors are computed using the conleyreg() function under the package conleyreg in statistical software R with time lag equal to 0. The distance cut-off are in kilometres. The Conley standard errors are in the parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

C Additional Analysis: Southern States

C.I Impacts on Female Migration Rates in the Southern States

To check for the effects on female migration rates in the southern states, we run a similar analysis as in equation (2) and allow the temperature coefficients to vary based on whether the district is in the southern states [18].

The results are shown in Table A6, and we observe a positive effect of rising temperatures on female migration rates. This positive effect matches with the results documented by Corno et al. (2020) . The authors find that overall, droughts decrease the incidence of early marriages in India as resources to afford dowry reduce following a drought. However, the effects are mainly observed for early-born cohorts in South India by Corno et al. (2020) . As previously discussed, the dowry custom was historically much less prevalent in southern India but is recently becoming common. It could be the case that our model is unable to capture the recent rises in dowry demands in southern India as the data in this study is relatively old. We find suggestive evidence of this when we vary the coefficients based on the year 2011 in Table. The effects on female rural-urban migration in southern India are similar to that in the northern region, albeit statistically significant only at 10%.

[18]The southern states are identified as those categorized in the southern cultural zone by the Government of India (Ministry of Culture, Govt. of India, n.d.). These states are Karnataka, Andhra Pradesh, Kerala, and Tamil Nadu.

Table A6: Effect of Rising Temperatures on Female Migration in Southern States, 1991-2011

	Rural-Urban	Rural-Rural	Rural-Urban	Rural-Rural
	Female	Female	Female	Female
	(1)	(2)	(3)	(4)
T	0.002	−0.025	0.001	−0.002
	(0.004)	(0.012)**	(0.002)	(0.012)
T x South	0.045	0.125	0.018	0.102
	(0.019)**	(0.036)***	(0.029)	(0.060)*
T x Year 2011			0.00008	−0.001
			(0.00006)	(0.0006)*
T x South x Year 2011			−0.001	0.0004
			(0.0003)**	(0.001)
P	−0.003	−0.014	−0.009	0.006
	(0.002)	(0.007)*	(0.002)	(0.007)
P x South	0.022	−0.011	0.009	−0.022
	(0.007)***	(0.011)	(0.006)	(0.013)
P x Year 2011			0.002	0.005
			(0.0003)***	(0.001)***
P x South x Year 2011			0.007	−0.001
			(0.003)***	(0.005)
District FE	Y	Y	Y	Y
Year FE	Y	Y	N	N
Observations	1,341	1,341	1,341	1,341

Note: The dependent variables in (1) and (3) are the share of female intra-district rural-urban migrants in the years 1991, 2001, and 2011, respectively. The dependent variables in (2) and (4) are the share of female intra-district rural-rural migrants in the years 1991, 2001, and 2011, respectively. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C), decadal averages of annual temperature interacted with "South" dummy denoting 1 if the district lies in a major southern state such as Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, and 0 otherwise. It also includes decadal averages of annual precipitation (in mm) and decadal averages of annual precipitation interacted with the "South" dummy. The independent variables in (3) and (4) are the decadal averages of annual temperature (°C), decadal averages of annual temperature interacted with "South" dummy denoting 1 if the district lies in a major southern state and 0 otherwise, decadal averages of annual temperature (°C) interacted with "Year 2011" dummy denoting 1 if the year is 2011 and 0 otherwise, and lastly interaction of decadal averages of annual temperature (°C), "South" dummy, and "Year 2011" dummy. It also includes annual precipitation (in mm), and precipitation interacted with the "South" dummy, precipitation interacted with "Year 2011" dummy, and precipitation interacted with "South" dummy and "Year 2011" dummy. In (3) and (4), year effects are removed to specifically analyze the changes for the year 2011 and maintain the model as parsimonious. The estimated coefficients of relevant variables are largely unchanged in terms of magnitude and signs even when the year effects are included. The standard errors are clustered by district in parentheses.
*p $<$ 0.10, **p $<$ 0.05, ***p $<$ 0.01.

Besides, we repeat the analysis using the NSS-EUS data, where we refine the dependent variable to include only the married working-age women who have migrated due to marriage in the last ten years. We illustrate the results in Table A7, and we find no statistically significant impact of rising temperature levels on the female marriage migration rates.

Table A7: Effects of Rising Temperatures on Marriage Migration in the Southern States, NSS Survey, 1987-2007

	Rural-Urban	Rural-Rural
	Female	Female
	(1)	(2)
Temperature	0.006	−0.008
	(0.016)	(0.046)
Temperature x South	0.035	0.081
	(0.042)	(0.115)
Precipitation	−0.003	−0.035
	(0.011)	(0.039)
Precipitation x South	0.016	0.047
	(0.031)	(0.050)
District FE	Y	Y
Year FE	Y	Y
Observations	881	881

Note: The dependent variable in (1) is the share of married working-age female intra-district rural-urban migrants who have migrated due to marriage in NSS rounds 1987-88, 1999-00, and 2007-08, respectively. The dependent variable in (2) is the share of married working-age female intra-district rural-rural migrants who have migrated due to marriage in NSS rounds 1987-88, 1999-00, and 2007-08, respectively. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C) and decadal averages of annual temperature interacted with "South" dummy denoting 1 if the district lies in a major southern state such as Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, and 0 otherwise. The regression also controls for precipitation (in mm) and precipitation interacted with "South" dummy. The standard errors are clustered by district and are in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

C.II Access to Credit and Female Migration Rates in the Southern States

Table A8: Effect of Rising Temperatures on Female Migration and Heterogeneous Effects by Access to Banks, 1991-2011

	Rural-Urban	Rural-Rural
	Female	Female
	(1)	(2)
T	0.001	−0.026
	(0.003)	(0.013)**
T x South	0.047	0.136
	(0.021)**	(0.0037)***
T x South x Low Bank Access	−0.019	−0.105
	(0.023)	(0.147)
P	−0.002	−0.014
	(0.001)	(0.007)*
P x South	0.023	−0.011
	(0.007)**	(0.011)
P x South x Low Bank Access	−0.017	−0.020
	(0.010)*	(0.049)
District FE	Y	Y
Year FE	Y	Y
Observations	1,326	1,326

Note: The dependent variable in (1) is the share of female intra-district rural-urban migrants in the years 1991, 2001, and 2011. The dependent variable in (2) is the share of female intra-district rural-rural migrants in the years 1991, 2001, and 2011. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C), decadal averages of annual temperature interacted with "South" dummy denoting 1 if the district lies in a major southern state such as Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, and 0 otherwise, and annual temperature (°C) interacted with "South" dummy and "Low Bank Access" dummy. The regressions also control for the decadal average of annual precipitation (in mm), decadal average of annual precipitation interacted with the "South" dummy, and decadal average of annual precipitation interacted with the "Low Bank Access" dummy. The standard errors are clustered by district in parentheses. *p $<$ 0.10, **p $<$ 0.05, ***p $<$ 0.01.

D Additional Analysis: Access to Irrigation

Given that decent access to irrigation can moderately address the effects of temperature increases on agricultural yields and incomes (Porter et al., 2014), in this analysis, we examine how differential access to agricultural irrigation at baseline might influence the impact of temperature rises on female migration. We categorize districts with low access to irrigation in the baseline year of 1980, depending on whether the proportion of agricultural land irrigated in the district was lower than the national median. The spatial plot in Figure A.4 in Appendix A shows districts situated chiefly in the north along the Ganges river and in the northwestern region in Punjab are the ones with relatively high access to irrigation.

We vary the coefficients associated with temperature in equation (2) based on whether the district had the proportion of irrigated land lower than the national median at the baseline. The results, outlined in Table A9, show no statistically significant impact from districts with limited access to irrigation. Although we expected that rural households in districts with enhanced access to irrigation could potentially better adapt to rising temperatures—thereby lessening the impact on agricultural yields and income—these results underscore the broader issue of unequal irrigation access in India. Asher et al. (2022) underscore this while illustrating how districts with historic access to canal irrigation did not witness significant consumption gains in comparison to the other districts. The benefits from canal irrigation are concentrated only amongst the households with large enough landholdings and remained elusive to approximately 70% of the rural population with no to little landholdings.

Table A9: Effect of Rising Temperatures on Female Migration and Heterogeneous Effects by Access to Irrigation Proportion, 1991-2011

	Rural-Urban	Rural-Rural
	Female	Female
	(1)	(2)
T	0.004	−0.032
	(0.006)	(0.014)**
T x Low Irrigation	0.00004	0.007
	(0.003)	(0.012)
P	0.012	−0.008
	(0.007)*	(0.012)
P x Low Irrigation	0.006	−0.001
	(0.009)	(0.012)
District FE	Y	Y
Year FE	Y	Y
Observations	1,095	1,095

Note: The dependent variables in (1) and (2) are the share of female intra-district rural-urban migrants and female intra-district rural-urban migrants, respectively, in 1991, 2001, and 2011. The independent variables in (1) and (2) are the decadal averages of annual temperature (°C), decadal averages of annual temperature interacted with "Low Irrigation" dummy denoting 1 if the proportion of agricultural land irrigated at the baseline was lower than the national median and 0 otherwise, decadal averages of annual precipitation (in mm), and decadal averages of annual precipitation interacted with the "Low Irrigation" dummy. The standard errors are clustered by district in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.