Economic Factors Mediate the Impact of Drought on Farmer Suicides in India*

Yoav Rothler†, David Blakeslee‡, Ram Fishman§, Deepak Malghan¶

December 16, 2020

Abstract

We provide evidence that economic factors play a role in farmer suicides in India. Both temporal and spatial within-state variation in suicide occurrence reveal that droughts, which impact farmers' incomes, increase male farmer suicides by 19%, but have much smaller and insignificant impacts in other occupational or demographic groups. Moreover, whereas suicides by non-farmers are evenly distributed throughout the year, farmer suicides are concentrated during the agricultural season. Finally, the effect of drought on suicides is stronger where irrigation is less prevalent or farmer indebtedness is high. These results shed light on the mechanisms driving extreme social impacts of climatic variability and change.

Key words: Climate Change, Suicide, Smallholder Farmers, Agriculture.
JEL codes: O13; I12; Q56

*We are grateful for the support of the Boris Mints Institute for Strategic Policy Solutions to Global Challenges and the Manna Center Program for Food Security at Tel Aviv University. We thank the American Foundation for Suicide Prevention (AFSP) for supporting analysis of the Karnataka data reported here.

†Tel Aviv University. Email: yoavrothler@mail.tau.ac.il
‡New York University - Abu Dhabi. Email: davidsblakeslee@nyu.edu
§Tel Aviv University. Email: ramf@tauex.tau.ac.il
¶Indian Institute of Management Bangalore. Email: dmalghan@iimb.ac.in

1 Introduction

Nearly 80% of global suicides occur in developing countries (Stack, 2000; Rehkopf and Buka, 2005), but their primary drivers remain relatively little studied. While observational studies often find positive associations between suicidal behavior and various dimensions of economic hardship (Iemmi et al., 2016), causal evidence on this linkage remains limited (Christian et al., 2019).[1] Suicides by smallholder farmers have gathered particular attention in public discourse, especially in India, not least because such extreme acts likely reflect widespread distress affecting vast farmer populations. However, it remains imperfectly understood whether smallholder farmers commit suicide due to factors specific to farming or not; and whether they are income-related in nature.[2]

A new perspective on this question has recently been offered by investigations of the impact of climatic variability on suicide rates in developing countries. Elevated temperatures were found to increase suicide rates in India (Carleton, 2017) and Mexico (Burke et al., 2018), and low rainfall was shown to have similar impacts in Indonesia (Christian et al., 2019).[3] These studies add to a growing literature on the impacts of climatic variability on social behavior, including various forms of personal crime and conflict (see Hsiang et al., 2013 for a review). Like many other studies in this literature, they utilize a reduced form approach that establishes causality, but leaves the mechanisms driving these impacts, and particularly, whether they are income-related, unresolved (Blakeslee and Fishman, 2014). Both Carleton (2017) and Christian et al. (2019) hypothesize the impacts they observe to be driven by reduced crop yields and the ensuing economic duress for farmers (Guiteras, 2007; Auffhammer et al., 2012; Fishman, 2016; Carleton, 2018, 2017).[4] However, the observed impacts might also be driven by the well-established physiological impacts of climatic variability on human behavior and psychology (Anderson et al., 2000; Ranson, 2014). High temperatures, in particular, have been shown to increase mental illness and self-harm (Ding et al., 2015; Williams et al., 2016; Trang et al., 2016), leaving the attribution to an economic challenge inconclusive. In fact, Burke et al. (2018) attribute the impacts they find in Mexico and the U.S. to physiological, rather than income related channels, and find supporting evidence in

[1] A more robust body of evidence relates poverty to mental illness. See Ridley et al. (2020) for a recent review.

[2] Numerous studies, especially in India, including Mishra (2008, 2014); Vijayakumar et al. (2005); Vijayakumar (2007); Gruere and Sengupta (2011); Nagaraj et al. (2014); Kennedy and King (2014); Das (2011); Vijayakumar and Rajkumar (1999); Patel et al. (2012); Manoranjitham et al. (2010); Posani (2009) offer valuable qualitative or descriptive analyses of farmer suicides.

[3] In a related contribution in a high income setting, Hanigan et al. (2012) finds that the incidence of suicide among adult males in rural Australia increases during droughts.

[4] Carleton (2017) provides additional evidence in favor of this attribution by showing that only temperatures in the main growing season seem to affect suicides. These patterns, however, while suggestive, can also reflect other differences between seasons.

social media data.

In this paper, we provide evidence that economic channels play a significant role in the effect of climatic variability on suicide acts in agricultural households in India. We focus on the effect of drought on suicide rates between 1995–2014. Drought—i.e., a shortfall in the Monsoon rainfall—is known to be a strong determinant of crop production and farmers' economic fortunes in India (Guiteras, 2007; Auffhammer et al., 2012; Krishnamurthy, 2012; Fishman, 2016; Jayachandran, 2006).

If farmer suicides are indeed driven by economic stress, one would expect them to rise when incomes are driven down by drought. We present robust evidence for a drought-suicide relationship using both a panel of state level suicide data and high resolution cross-sectional data within one given state. A primary contribution that allows us to more conclusively test the role of agricultural income lies in our ability to observe suicide rates across different occupational groups. We show that the effects of drought on suicide rates are only observed among farming populations and no other occupational group, which is strongly suggestive of an agricultural income channel. Additional support for this hypothesis is obtained by studying the seasonal distribution of drought. Farmer suicides are concentrated in the agricultural season, whereas non-farmer suicides are more evenly spread throughout the year.

We also test several predictions of the agricultural channel hypothesis. If drought affects farmer suicide rates by affecting farmer incomes, this hypothesis would predict the impact on suicides to strengthen when: (1) crop yields are more vulnerable to drought and (2) farmers have fewer economic coping strategies. We test hypothesis (1) by examining whether the impacts of drought on farmer suicide rates weakens as greater portions of cultivable land are served with irrigation. Access to irrigation can buffer crop production from precipitation shortfalls by providing alternative sources of moisture (Duflo and Pande, 2007; Taraz, 2017; Fishman, 2018).[5] We test hypothesis (2) by examining whether the impacts of drought on suicide strengthen with the extent of outstanding farmer indebtedness. High levels of debt can also aggravate the negative effects of drought, as the inability to repay debts may cause debt burdens to grow, or existing debt may reduce the ability of farmers to obtain new loans in order to cope with the associated reduction in income (Sidhu and Gill, 2006; Mosse et al., 2002; Gruere and Sengupta, 2011; Plewis, 2014).

2 Empirical Strategy

Our analysis proceeds along two parallel tracks. The first makes use of aggregate, state-level panel data on suicides and drought occurrence; and the second makes use of more granular, and spatially precise, data on suicides and rainfall in the Indian state of Karnataka.

[5] Carleton (2017) conducts a similar test.

2.1 All India State-Level Data

Sample. We use a longitudinal data set consisting of state-year observations spanning India's 28 states between 1995-2014. Union territories are not included in the analysis, since they include far smaller populations making suicide rates much noisier. Data for the states of Chhattisgarh, Uttarakhand, and Jharkhand is unavailable between 1995–2000, as they were only founded in 2000; and the state of Telengana is excluded because it was only founded in 2014. Our main sample therefore consists of 496 observations.

Suicide Data. Suicide statistics are based on official data collected by the National Crime Records Bureau (NCRB), an agency within the Ministry of Home Affairs, between the years 1995 and 2014. The data reports the total number of suicide victims by state, year, gender, and occupation of the victim. From 2001 onward the data is further disaggregated into 5 different age groups, which allows us to conduct an age-wise analysis for a sub-sample of our sample consisting of 348 observations. Despite the under-reporting of farmer suicides due to social stigma and fear of prosecution, and despite errors in occupational classifications (Das, 2017; Plewis, 2014), the NCRB data has been shown to be reasonably reliable (Mayer, 2010), and demonstrates trends in suicide similar to those of other sources (Patel et al., 2012). Details on suicides disaggregated by occupation, age, and gender are reported in Figure A1.

To calculate suicide rates (defined as the number of cases per 100,000 population) within each state, year, and demographic/occupational group requires data on the total population of each respective category for each state and year. For this, we use data from the 2001 and 2011 demographic censuses and linearly interpolate the intermediate years, within each demographic category, to obtain annual data. The census provides a coarser occupational breakdown than NCRB data, so we restrict this interpolation to the farmers/non-farmers disaggregation. The size of the farmer population is defined as the sum of the number of land owning cultivators and landless agricultural laborers reported in the census, since the NCRB does not provide separate figures for these two sub-populations prior to 2014. Though the census data may not accurately depict the actual number of farmers (Plewis, 2014), discrepancies are minor among male farmers, who are the principal focus in this analysis.

The NCRB data for non-farmers is segregated by several occupational groups that are aggregated as a single category in the census data. For the purpose of analyzing the response of suicide rates by occupational category, we calculate suicide rates by dividing the number of suicides in each of these categories by the total population in that state, gender, and year. To test whether this somewhat imprecise approach may result in biased estimates, we apply it to the farmers/non-farmers disaggregation and find results that, though naturally of smaller magnitudes, display very similar statistical properties to those obtained using the more precise calculation.

The NCRB data indicates that the India-wide number of suicides have increased from 80,000 in 1995 to 132,000 in 2014. Adjusting for population growth reveals that suicide rates have increased to a lesser extent, from 8.6 to 10.4 per 100,000 people (Figure A2). The NCRB data also indicates that 14% of suicides occur among farmers (amongst which 85% are committed by males) making farmers second only to housewives in the share of overall cases (Figure A1). Nevertheless, accounting for the share of farmers in the overall population reveals that suicide rates among farmers are lower than those in the general population, and vary from 4.6 to 7.8 cases per 100,000 individuals between 1995 and 2014 (Figure A2).

Precipitation and Temperature Data. State-wise rainfall data was obtained from the Indian Meteorological Department (IMD).[6] In India, meteorological drought is generally defined by officials in terms of the percentage deficit of annual rainfall from the long-term mean in a given location, with threshold values varying between 75%–90% of long-term values. Here, we define drought occurrence using a binary indicator of annual rainfall falling below 80% of the long-term mean. We also test the robustness of our results to alternative definitions that: vary the threshold from 75% to 90%; use Monsoon rainfall instead of annual rainfall; and that normalize rainfall based onthe 30-year average rather than the longer-term value reported by the Indian Meteorological Department. Our regressions also control for seasonal average temperature and degree-days over the two main growing seasons (Kharif and Rabi), also obtained from the IMD.

Data on Irrigation. Longitudial and spatial data on irrigation was obtained by dividing annual gross irrigated area by the annual gross sown area, both from India's Ministry of Agriculture and Farmers Welfare. Gross area is calculated as the number of times the area is cropped and irrigated in a year times the area used in each cultivation cycle. Regression results are robust to an alternative definition that accounts for an agricultural area a single time regardless of the number of cultivation cycles (i.e., net irrigated area/net sown area).[7]

Data on Debt. Debt data is represented using state-wise outstanding credit to agriculture by scheduled commercial banks, as collected by the Reserve Bank of India (RBI) between 1995 and 2014.[8] Debt is normalized by dividing absolute debt by the number of cultivators in each state and year, which is derived from the 2001 and 2011 population censuses.[9]

Table A1 reports summary statistics of some of the important variables included in this

[6] https://data.gov.in/catalog/rainfall-india

[7] The area is assumed to be irrigated for cultivation through such sources as canals (Govt. & Private), tanks, tube-wells, other wells and other sources.
https://rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20States

[8] https://rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20States

[9] The percentage of small and marginal farmers in each state is based on India's 2011 Agricultural Census.
http://agcensus.dacnet.nic.in/statesummarytype.aspx

study.

2.2 Micro-Data from the State of Karnataka

We augment the inter-state analysis by further analyzing the effect of intra-state variation in drought occurrence on farmer and non-farmer suicides within the Indian state of Karnataka. Karnataka is one of India's largest and most populous states. Over 60% of its population resides in rural areas, and is exposed to severe and persistent droughts.

Our sample consists of monthly counts of suicide cases among the general population and among farmers in the state of Karnataka between April 2015 to February 2016 (henceforth defined as year 2015/16), spatially distributed according to the police station in which the suicide was reported. There are 585 police stations in the state, as illustrated in Figure A3. Farmer suicide counts only include cases which were examined by the government as qualifying for special compensation, and thus are unlikely to include all cases of farmer suicide. Precipitation data is based on observations from a dense network of weather gauges operated by the Karnataka State Natural Disaster Monitoring Center (KSNDMC), aggregated to the police station level through area-weighted averaging.

2.3 Regression Analysis

The unit of observation in this study is the state-year. The empirical analysis follows the well-established methodology in the climate change impacts literature (Carleton and Hsiang, 2016) and estimates a difference-in-difference regression model of suicide rates on the occurrence of drought that also includes state- and year-specific intercepts (fixed effects):

$$y_{it} = \beta_1 D_{it} + \beta_2 T_{it} + \sigma_i + \omega_t + \varepsilon_{it} \tag{1}$$

Here, y_{it} is the suicide rate in state i at year t within a particular demographic segment. D_{it} is a binary variable that indicates whether a drought occurred in state i and year t, which is defined as annual rainfall being below 80% of the long-term mean in that state. Defining drought in this way helps avoid problems created by non-linearity in crop response to precipitation, and can improve statistical precision. We control for T, the average annual temperature in each of the two main cultivation seasons (Kharif and Rabi).[10] State-specific intercepts (state fixed effects) σ_i absorb all unobservable state characteristics that are time invariant, and temporal intercepts (year fixed effects) ω_t absorb all inter-annual variation in India-wide observable or unobservable confounders.

[10] By controlling for temperature, we account for the possible existence of an omitted variable bias that can arise from a correlation between temperature and precipitation.

We test the robustness of the results to variations in model specification that include the addition of state-specific linear time trends, and the omission of year fixed effects. We also test robustness to the inclusion of two (annual) lagged and leading observations of the drought indicator (i.e., $D_{i,t-2}...D_{i,t+2}$) and to alternative definitions of drought. Finally, we also report estimates allowing for arbitrary serial correlation in the errors across time in any given state in the supplementary information. Allowing for such correlation does not substantially change the results.

In addition to estimating the average impacts of drought on suicide rates, we also explore heterogeneity in impacts that can shed light on the underlying mechanisms. To do so we estimate regression models that include interactions between the drought indicator and various potential mediating factors, F, described in the results section:

$$y_{it} = \beta_1 D_{it} + \beta_2 F_{it} + \beta_3 D_{it} \times F_{it} + \beta_4 T_{it} + \sigma_i + \omega_t + \varepsilon_{it} \tag{2}$$

For the intra-state analysis in Karnataka, we cross-sectionally regress suicide count (by farmers and non-farmers separately) at the police-station level in 2015/16 (the only year for which we have this high-resolution data) on a drought indicator for that year. In comparison to the panel methods applied to the state level data, cross sectional correlations are more susceptible to bias from confounding variables. To partially ameliorate this concern, we focus on fine-scale within-district variation (using 31 district fixed effects), thus controlling for district-scale variation in potential confounders, and deriving our results from within-district high resolution variation in precipitation shortfalls. In addition, we use drought indicators based on local deviations of precipitations from the local long-term average (similar to Burke et al., 2015), which are less likely to be correlated with other spatial variables. To test for such correlations, we regress a wide range of 2001 census-data on this drought indicator at the police station level and find no evidence of an association. Since many of the police stations (298 of the 585) report zero farmer suicides, and numbers at such spatial resolution are generally low, we estimate a Poisson regression, while also controlling for each station's population size.

3 Results

We begin with results from the inter-state analysis and then move to describe results from the intra-state analysis in Karnataka. We present our main results graphically, and refer the reader to detailed regression tables in the Appendix.

3.1 Suicides by Farmers and Non-Farmers

We begin by using using a difference-in-difference analysis to estimate the impact of drought occurrence on the annual suicide rate, defined here as the number of suicides per 100,000 people, disaggregated into various population segments. Panel 1 of Figure 1 (and Table A2) reports estimates for suicide rates in the general population, as well as for the farming and non-farming populations separately. While the overall suicide rate does not display a statistically or substantively significant association with drought occurrence, disaggregating the response of the suicide rates between the farming and the non-farming populations reveals a striking divergence. During a drought year, the suicide rate in the farming population increases by a statistically significant 1.2 per 100,000 farmers, representing an increase of 19.1% in comparison to the annual mean of 6.35. The rate of suicides in the non-farming population, in contrast, shows a small and statistically insignificant decline during drought years (-0.50 cases, amounting to -4.3% of the mean rate).

The estimated impacts of an increase in average temperatures, reported in Table A2, do not paint as conclusive a picture. Elevated temperature during the main growing season (Kharif) have positive and statistically significant impacts on suicides among both the general population and among non-farmers. However, the effect of drought on farmer suicides is far smaller, and is generally statistically insignificant. Temperature effects during the secondary growing season (Rabi) are smaller and again generally statistically insignificant, consistent with Carleton (2017)'s findings. The ambiguity of these patterns stands in stark contrast to the patterns observed for the estimated impacts of drought, and do not provide clear support for an agricultural channel over a psychological one.

We find similar patterns when we modify the specification of temperatures in the regression model. In one modification, reported in Table A3, we use the concept of "degree days" (Dell et al., 2014), separately calculated above a 20°C cutoff, as in Carleton (2017). In a second modification, reported in Table A4, we use daily temperature data to estimate a non-linear model that utilizes the number of days falling in each of several temperature bins, as has become customary in the literature (Deschânes and Greenstone, 2007; Dell et al., 2014). Using this specification, we again find some evidence that hot days during the Kharif increase suicide rates, but the impact is found for non-farmers as well, for whom the effect is again of larger magnitude. Importantly, the estimated impact of drought is remarkably robust across these alternative specification of the temperature controls.

Impacts by Gender. Disaggregation of the farming population by gender reveals that the association is primarily driven by suicide amongst males (Figure 1, panel 2; Table A3). The male suicide rate increases by 1.9 per 100,000 in drought years (22.2% of the mean value), while the female rate displays a small and statistically insignificant decrease of -0.084 per 100,000 (-3.34% of the mean value).

Impacts by Occupation. A finer disaggregation of the male population by occupation reveals a similar pattern: farmers are the only profession to display a positive and significant impact between suicide and drought (Figure 2). There are many individuals who are not farmers, but whose incomes nonetheless heavily depend on agricultural output, such as: small business owners in rural areas, individuals whose secondary job is in farming, and urban consumers whose purchasing power is affected by crop production. The fact that none of the other occupations are affected suggests that the economic shock suffered by farmers during drought is far more severe than for other populations only indirectly dependent on agricultural production.[11] These findings give important insights for the role played by agricultural production on the incidence of suicide across different segements of society, and point the way towards designing carefully tailored policies for suicide prevention.

Impacts Across Age Groups. Among male farmers, a significant effect is separately detected across age groups above 30 years of age (panel 3 of Figure 1; Table A3). The effect of drought increases with age both in absolute terms as well as relative to the mean suicide rate within the respective age groups. For male farmers ages 15–29, there is a 0.93 per 100,000 (13.4% of the mean value) increase in suicide with drought, which rises to 4.14 per 100,000 (51.5% of the mean value) for farmers above 60 years of age. Because the age disaggregation is only available for the years 2001–2014, it is not possible to disentangle age effects from cohort effects, meaning we cannot rule out the possibility that the hetrogeneity by age is driven by unobserved characteristics that are common to the different age cohorts.

Robustness to Alternative Model Specifications. Estimates of the effect of drought on farmer suicides are robust to alternative specifications of the regression model, including: limiting the sample to individuals above the age of 15 (Figure A4); the addition of state-specific time trends (Figure A5); the use of alternative definitions of drought events (Figure A6); and the omission of any individual state from the sample (Figure A7). Furthermore, when the occurrence of drought in the two years preceding and the two years following the year of observation are controlled for, contemporaneous drought displays the largest and the only statistically significant impact (Figure 3), lending substantial confidence to our empirical approach. Allowing errors to display arbitrary serial correlation across time widens the confidence intervals but retains statistical significance (Table A3).

[11] The magnitude of the point estimate for farmers is smaller than that produced above due to the fact that suicides in the occupation-disaggregated regressions are calculated by dividing the occupation-specific number of suicides by the total population, rather than the farmer population, as explained in the methods section above.

3.2 Interactions

Numerous factors may affect the strength of the drought-suicide link. We test the effect of two factors that are often hypothesized to enhance male farmers' suicidal response, namely: irrigation cover and agricultural debt incidence. We do so by estimating regressions that include interactions between the occurrence of drought and the factors in question. Significant and positively signed estimates of the interaction terms between drought and these factors would indicate that the factor in question enhances the drought-suicide association. It is important to acknowledge that, because variation in the factors in question is not exogenous, these estimates should be interpreted with caution, as they may reflect unobservable factors that are correlated with the heterogeneity being examined. Figure 4 (and Table A5) reports estimates for the respective interaction terms, which are shown separately for male farmers and male non-farmers.

Irrigation. The first hypothesis we test is that access to irrigation may attenuate the impact of drought on suicide rates. If drought leads farmers to commit suicide through a decline in crop productivity, it is natural to hypothesize that access to irrigation weakens the impact by buffering crop yields from precipitation anomalies. Consistent with this hypothesis, we estimate a substantively negative and significant interaction term between access to irrigation (measured in percentage of cultivated area that is irrigated) and the occurrence of drought. The magnitude of the effect indicates that an additional 10 percentage points of irrigation cover (which amounts to 23% of the average value in the sample) reduces the impact of drought on suicide rates by 0.45 cases per 100,000 male farmers, from a baseline impact of 3.77 cases in completely un-irrigated circumstances. [12] The un-interacted, direct impact of irrigation on suicide rates, reported in Table A5, is also negative and significant, though only for farmers, suggesting that the expansion of irrigation may cause a decline in farmer suicide, perhaps through an increase in income.

Outstanding Debt. The second hypothesis we test is whether higher levels of outstanding agricultural debt increase the effect of drought on suicide. Agricultural debt by itself need not lead to adverse outcomes for farmers, as it may reflect greater access to credit and the ability to make productive investments in one's farm. However, agricultural debt may also exacerbate the economic consequences of crop failure, and thus the risk associated with drought. If drought leads farmers to commit suicide because of the associated income shock, then indebtedness may exacerbate the impact by, first, increasing sentiments of despair and hopelessness related to the ability of paying back loans (Kennedy and King, 2014; Udmale et al., 2014; Singh et al., 2016); and, second, by limiting the scope of other coping strategies, such as using additional loans to cope with the income shock.

[12]This effect is qualitatively similar to the results of Carleton (2017) irrigation-temperature interaction model, though the effects estimated in the latter are not statistically significant.

Consistent with this expectation, we estimate a sizable, and statistically significant, positive interaction effect between the level of outstanding agricultural debt to commercial banks (measured in terms of Rs./cultivator) and the occurrence of drought. The magnitude of the effect indicates that an additional 10,000 Rupees of outstanding debt per cultivator (40% of the mean value) increases the impact of drought on suicide rates by 0.256 per 100,000 farmers. Interestingly, we estimate the direct effect of debt on suicides to be negative but statistically insignificant, potentially indicating that the ability to invest in the farm, by itself, improves farmers welfare when weather conditions are favorable. We do not find evidence of any direct or interacted effect of farmer debt on non-farmer suicide rates, again increasing confidence in the hypothesized mechanism.

As noted above, caution must be exercised in interpreting the association between irrigation or debt levels and the strength of the drought-suicide linkage as causal. This is because there may be confounding factors that are correlated with irrigation and debt levels that affect the impact of drought on suicide. Nevertheless, the lack of evidence of similar effects on the suicide-drought relationship among non-farmers is reassuring in this regard.

3.3 Intra-State Analysis in Karnataka

As described above, granular data from the Indian state of Karnataka allows us to conduct additional tests of the economic channel hypothesis. First, we use information on the timing of suicide acts by farmers and non-farmers during 2015–6 to examine their sub-annual distributions. These distributions, displayed in Figure 5, provide strong indications of an agricultural income channel. Whereas suicides in the non-farmer population are approximately evenly distributed within the year, suicides by farmers are concentrated between July and November, when the main cultivation season occurs and during which farmers earn most of their annual incomes.

We repeat our regression analysis of the association between suicide rates and drought occurrence using the police station-level data available for Karnataka. This analysis has the advantage of allowing us to more precisely match the incidence suicide to the local occurrence of drought than is possible using state-level data. At the same time, however,it suffers from the important limitation of only being available for a single year of observation, which precludes the use of panel analysis and the isolation of location fixed effects. This problem is somewhat mitigated, however, by the fact that the drought indicator is defined in terms of the local inter-annual distribution of rainfall. Results presented in Table A6 indicate a positive and significant effect of drought occurrence on farmer suicide: wherever there was drought, farmer suicides were higher by 35%. Whereas the effect of drought on suicide rates among the non-farming population is small and statistically insignificant using the fixed effect model with state-level data, it is positive and significant in the single-year analysis for Karnataka. The magnitude of the effect for non-farmers (9.5%), however, is substantially smaller than the effect for farmers, and the difference between the two estimates is statistically significant. We recall that farmer suicide data in this analysis is derived from official enumeration of cases that were deemed applicable for government compensation, and thus constitute a subset of all actual suicides by farmers. Thus, counts of suicides in the remaining population (which are derived by subtracting farmer suicides from those in the general population) may also contain farmer suicide cases, potentially artificially increasing the magnitude of the general population estimate upwards.

Finally, we conduct a "balance test" by which we regress various indicators from India's 2011 demographic and 2013 economic census on drought at the police station level on the same drought variable, and using a similar specification. Results are reported in Table A7. We find no evidence of a correlation between these pre-treatment indicators and drought, lending the causal interpretation of our results with added confidence (but remaining acutely aware of the limitation of this approach).

4 Conclusion

The results of this analysis give compelling evidence that rainfall deficits increase farmer suicide rates in India, and that economic mechanisms related to agricultural income loss are, at least in part, driving this relationship. Our results give substantial empirical validation to the hypothesis that farmer suicides are driven by economic duress resulting from climatic variability.

The substantial effects of drought on suicide occurs only for farmers, with no other occupational group showing a similar response, consistent with an economic channel being at play. The effect is furthermore limited to male farmers, which may reflect the primary economic responsibility given to male income earners in rural Indian society. The effect of drought on suicide increases as farmers get older, which may reflect a reduced ability to seek alternative sources of income with age, or a more pessimistic view regarding future incomes.

Additional evidence for an income channel can be seen in the heterogeneity analysis, where we show that the impact of drought is stronger where irrigation is less prevalent, and where farmer indebtedness is higher. An intra-state analysis within the state of Karnataka also lends support to an economic channel, again showing that correlations between drought and suicide rates are much larger for farmers than for non-farmers.

Our findings have implications for the formation of policies that can avert some of underlying economic causes of suicides, and the widespread, but harder to observe distress that they likely reflect in the broader farmer population. First, we find evidence to suggest that an expansion of irrigation can help improve the resilience of Indian farmers to drought. Expanding access to irrigation has long been a central focus of Indian policy makers, and continues to motivate ambitious policy proposals for the creation of new dams and other irrigation infrastructure, particularly in semi-arid regions. This objective, however, faces numerous economic and hydrological obstacles, including growing water scarcity (Fishman, 2018).

We also find evidence to suggest that policies that can more carefully protect farmers exposed to debt may reduce resort to suicidal behavior in response to droughts. While debt itself is likely useful to farmers for the purpose of financing agricultural investments, it has the potential to amplify farmer distress in contexts where reliable insurance instruments are absent. Employment guarantee schemes (e.g., NREGA) may go some way towards insuring farmers from climatic shocks. Howeever, insurance schemes more directly targeting deeply indebted farmers are likely necessary for mitigating the the economic and psychic distress driving farmer suicide.

References

Anderson, C. A., Anderson, K. B., Dorr, N., DeNeve, K. M., and Flanagan, M. (2000). Temperature and aggression. In *Advances in Experimental Social Psychology*, volume 32, pages 63–133. Elsevier.

Auffhammer, M., Ramanathan, V., and Vincent, J. R. (2012). Climate change, the monsoon, and rice yield in india. *Climatic Change*, 111(2):411–424.

Blakeslee, D. and Fishman, R. (2014). Weather shocks, crime and agriculture: Evidence from india.

Burke, M., Gong, E., and Jones, K. (2015). Income shocks and hiv in africa. *The Economic Journal*, 125(585):1157–1189.

Burke, M., González, F., Baylis, P., Heft-Neal, S., Baysan, C., Basu, S., and Hsiang, S. (2018). Higher temperatures increase suicide rates in the united states and mexico. *Nature Climate Change*.

Carleton, T. A. (2017). Crop-damaging temperatures increase suicide rates in india. *Proceedings of the National Academy of Sciences*.

Carleton, T. A. (2018). Reply to plewis, murari et al., and das: The suicide–temperature link in india and the evidence of an agricultural channel are robust. *Proceedings of the National Academy of Sciences*, 115(2):E118–E121.

Carleton, T. A. and Hsiang, S. M. (2016). Social and economic impacts of climate. *Science*, 353(6304).

Christian, C., Hensel, L., and Roth, C. (2019). Income shocks and suicides: causal evidence from indonesia. *Review of Economics and Statistics*, 101(5):905–920.

Das, A. (2011). Farmers' suicide in india: Implications for public mental health. *International journal of social psychiatry*, 57(1):21–29.

Das, A. (2017). Farmers' suicide and agrarian crisis: Social policy and public mental health. 59:398.

Dell, M., Jones, B. F., and Olken, B. A. (2014). What do we learn from the weather? the new climate-economy literature. *Journal of Economic Literature*, 52(3):740–98.

Deschânes, O. and Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *American Economic Review*, 97(1):354–385.

Ding, N., BERRY, H., and O'Brien, L. (2015). The effect of extreme heat on mental health–evidence from australia. *International Journal of Epidemiology*, 44(supplement 1):i64.

Duflo, E. and Pande, R. (2007). Dams. *The Quarterly Journal of Economics*, 122(2):601–646.

Fishman, R. (2016). More uneven distributions overturn benefits of higher precipitation for crop yields. *Environmental Research Letters*, 11(2):024004.

Fishman, R. (2018). Groundwater depletion limits the scope for adaptation to increased rainfall variability in india. *Climatic Change*, 147.

Gruere, G. and Sengupta, D. (2011). Bt cotton and farmer suicides in india: An evidence-based assessment. *The Journal of Development Studies*, 47(2):316–337. PMID: 21506303.

Guiteras, R. (2007). Impact of climate change on indian agriculture. *Mimeo, University of Maryland*.

Hanigan, I. C., Butler, C. D., Kokic, P. N., and Hutchinson, M. F. (2012). Suicide and drought in new south wales, australia, 1970–2007. *Proceedings of the National Academy of Sciences*, 109(35):13950–13955.

Hsiang, S. M., Burke, M., and Miguel, E. (2013). Quantifying the influence of climate on human conflict. *Science*, 341(6151).

Iemmi, V., Bantjes, J., Coast, E., Channer, K., Leone, T., McDaid, D., Palfreyman, A., Stephens, B., and Lund, C. (2016). Suicide and poverty in low-income and middle-income countries: a systematic review. *The Lancet Psychiatry*, 3(8):774–783.

Jayachandran, S. (2006). Selling labor low: Wage responses to productivity shocks in developing countries. *Journal of Political Economy*, 114(3):538–575.

Kennedy, J. and King, L. (2014). The political economy of farmers' suicides in india: Indebted cash-crop farmers with marginal landholdings explain state-level variation in suicide rates. 10:16.

Krishnamurthy, C. K. B. (2012). The distributional impacts of climate change on indian agriculture: a quantile regression approach. *Madras School of Economics Working Paper No. 69/2012*.

Manoranjitham, S., Rajkumar, A., Thangadurai, P., Prasad, J., Jayakaran, R., and Jacob, K. (2010). Risk factors for suicide in rural south india. *The British Journal of Psychiatry*, 196(1):26–30.

Mayer, P. (2010). *Suicide and society in India*. Routledge.

Mishra, S. (2008). Risks, farmers' suicides and agrarian crisis in india: Is there a way out? *Ind. Jn. of Agri. Econ.*, 63(1):38–54.

Mishra, S. (2014). Farmers' suicides in india, 1995-2012: Measurement and interpretation. *LSE ARC Working Papers*.

Mosse, D., Gupta, S., Mehta, M., Shah, V., fnms Rees, J., and Team, K. P. (2002). Brokered livelihoods: Debt, labour migration and development in tribal western india. *The Journal of Development Studies*, 38(5):59–88.

Nagaraj, K., Sainath, P., Rukmani, R., and Gopinath, R. (2014). Farmers' suicides in india: Magnitudes, trends, and spatial patterns, 1997-2012. *Review of Agrarian Studies*, 4(2).

Patel, V., Ramasundarahettige, C., Vijayakumar, L., Thakur, J., Gajalakshmi, V., Gururaj, G., Suraweera, W., and Prabhat Jha, P. (2012). Suicide mortality in india: A nationally representative survey. *The Lancet*, 379(9834):2343–51.

Plewis, I. (2014). Gm cotton and suicide rates for indian farmers. *CCSR Working Paper*.

Posani, B. (2009). Farmer suicides and the political economy of agrarian distress in india. *Development Studies Institute Working Paper Series*, (09-95).

Ranson, M. (2014). Crime, weather, and climate change. *Journal of Environmental Economics and Management*, 67(3):274–302.

Rehkopf, D. H. and Buka, S. L. (2005). The association between suicide and the socio-economic characteristics of geographical areas: a systematic review. *Psychological Medicine*, 36(2):145.

Ridley, M. W., Rao, G., Schilbach, F., and Patel, V. H. (2020). Poverty, depression, and anxiety: Causal evidence and mechanisms. Technical report, National Bureau of Economic Research.

Sidhu, R. and Gill, S. (2006). Agricultural credit and indebtedness in india: Some issues. 61(1):11–35.

Singh, L., Bhangoo, K., and Sharma, R. (2016). *Agrarian Distress and Farmer Suicides in North India*. New York: Routledge.

Stack, S. (2000). Suicide: A 15-year review of the sociological literature part i: Cultural and economic factors. *Suicide and Life-Threatening Behavior*, 30:145–62.

Taraz, V. (2017). Adaptation to climate change: historical evidence from the indian monsoon. 22(5):1–29.

Trang, P. M., Rocklöv, J., Giang, K. B., Kullgren, G., and Nilsson, M. (2016). Heatwaves and hospital admissions for mental disorders in northern vietnam. *PloS one*, 11(5):e0155609.

Udmale, P., Ichikawa, Y., Manandhar, S., Ishidaira, H., and Kiem, A. S. (2014). Farmer perception of drought impacts, local adaptation and administrative mitigation measures in maharashtra state, india. *International Journal of Disaster Risk Reduction*, 10:250.

Vijayakumar, L. (2007). Suicide and its prevention: The urgent need in india. 49:81–4.

Vijayakumar, L., Nagaraj, K., Pirkis, J., and Whiteford, H. (2005). Suicide in developing countries: Frequency, distribution, and association with socioeconomic indicators. *The Journal of Crisis Intervention and Suicide Prevention*, 26(3):104–111.

Vijayakumar, L. and Rajkumar, S. (1999). Are risk factors for suicide universal? a case-control study in india. *Acta psychiatrica scandinavica*, 99(6):407–411.

Williams, M. N., Hill, S. R., and Spicer, J. (2016). Do hotter temperatures increase the incidence of self-harm hospitalisations? *Psychology, health & medicine*, 21(2):226–235.

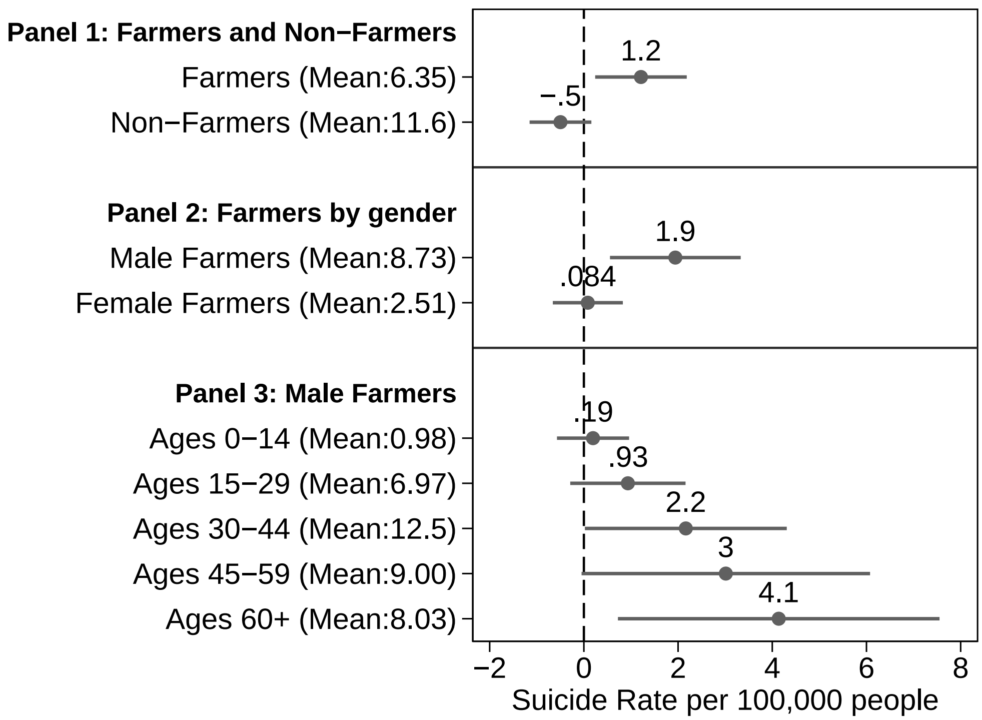

Figure 1: **The Effect of Drought on Suicide Rates.** Points represent estimated coefficients of the impact of drought (from regression 1) on suicide rates (cases per 100,000 people) in various demographic and occupational groups. Error bars indicate 95% confidence intervals. Each coefficient represents a separate regression. All regressions include controls for mean temperature in the two main growing seasons as well as state and year fixed effects. The sample size for panel 1 and 2 is n=496, and for panel 3 is n=348 (age specific data is only available after the year 2000). see Table A3 for detailed regression output.

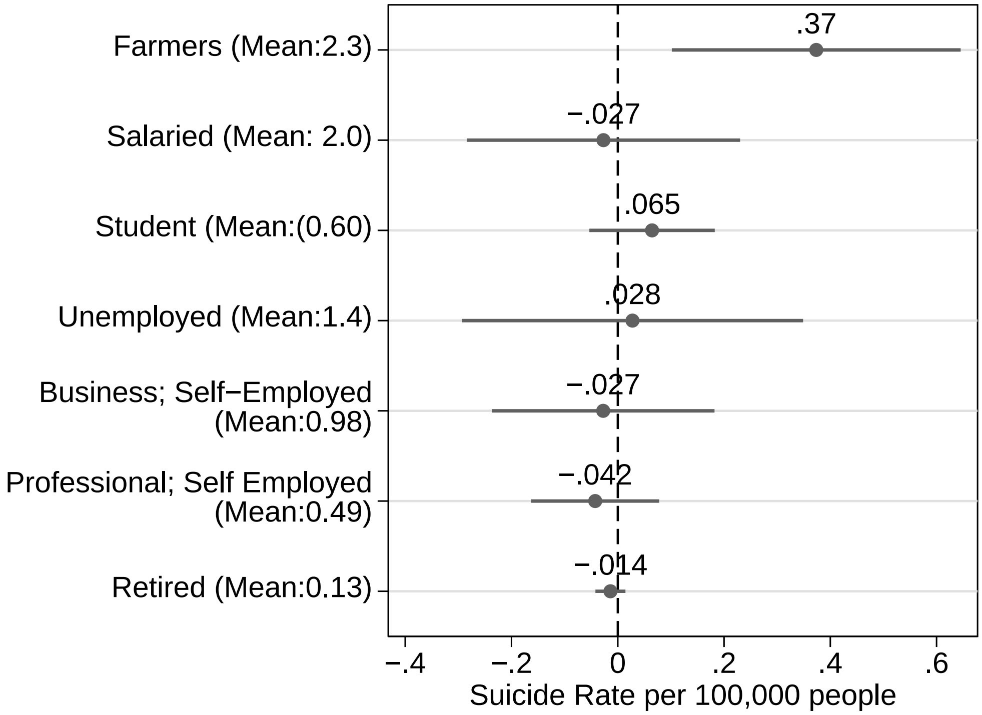

Figure 2: **Impact by Occupational Groups.** Points represent estimated coefficients of the impact of drought occurrence (from regression 1) on male suicide rates (cases per 100,000 people) in various occupational groups. Error bars indicate 95% confidence intervals. Each coefficient represents a separate regression. All regressions include controls for mean temperature in the two main growing seasons as well as state and year fixed effects

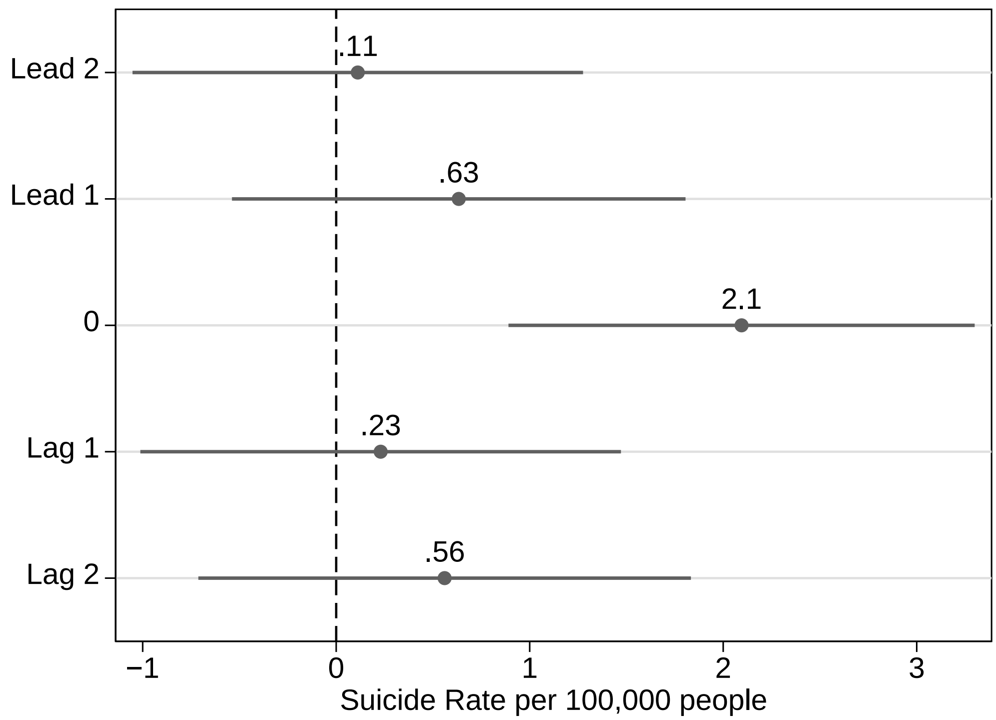

Figure 3: **Distributed Lag Model.** Point estimates and 95% confidence intervals of the impact of a variant of regression (1) that includes two annual lags and leads of drought occurrence (5 drought indicators in total). All estimates are derived from a single regression that includes state and year fixed effects as well as controls for mean temperature in the two main growing seasons.

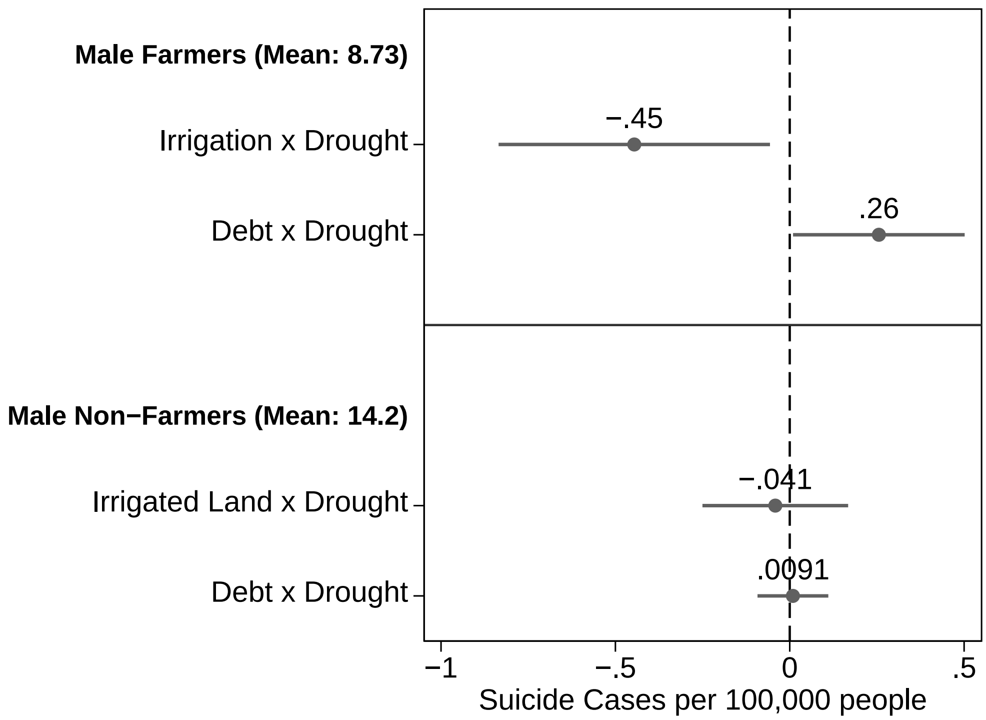

Figure 4: **Mediating Factor and Interaction Effects.** Points represent estimated coefficients for the interaction term (regression 2) between drought and the indicated mediating factors:(1) irrigation; measured as the percentage of gross irrigated land (mean: 44%; units: 10%) and (2) debt; measured as the per capita outstanding agricultural credit by scheduled banks (mean: 24,890 Rs/Cultivator; units: 10,000 Rs/Cultivator). Error bars indicate 95% confidence intervals. Each coefficient represents a separate regression. All regressions include controls for mean temperature in the two main growing seasons as well as state and year fixed effects and state specific linear time trends. see Table A5 for detailed regression output.

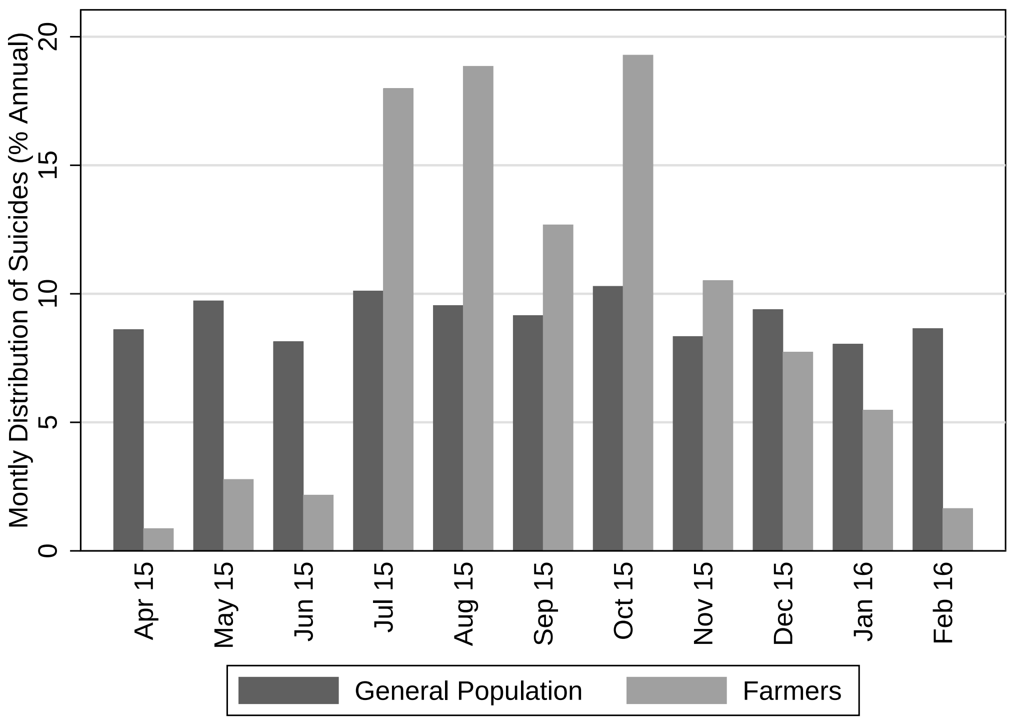

Figure 5: **Monthly Distribution of Suicides in Karnataka.** The dark and bright bars, respectively, represent the 2015/16 average monthly distribution (% annual) of suicides among the general population and among farmers in the State of Karnataka.

5 Appendix Figures and Tables

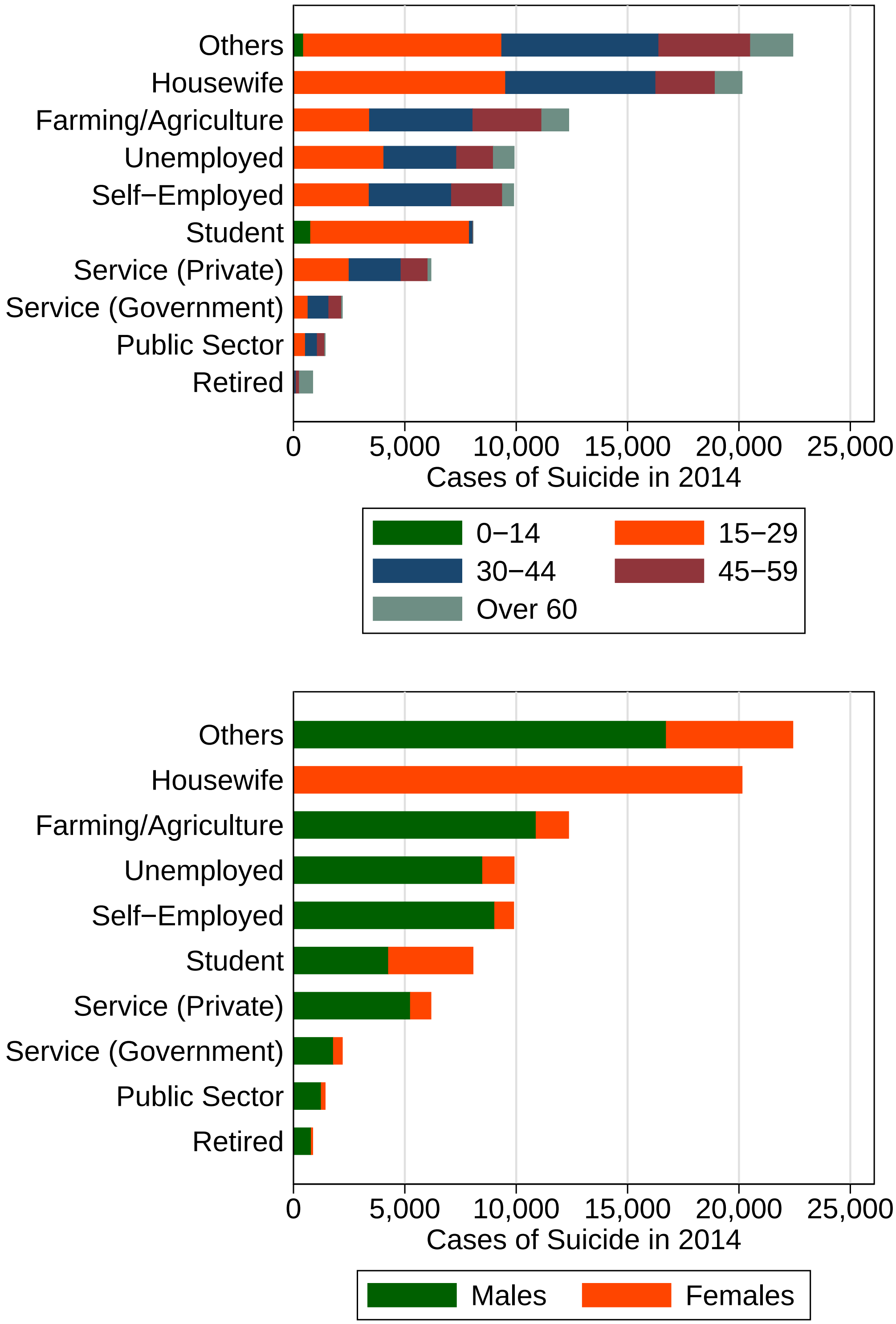

Figure A1: **NCRB Suicide Data.** Number of suicide cases in all of India in the year 2014 by occupation and age (top) and by occupation and gender (bottom). The NCRB data used in our analysis is categorized by year, state, age, gender and occupation.

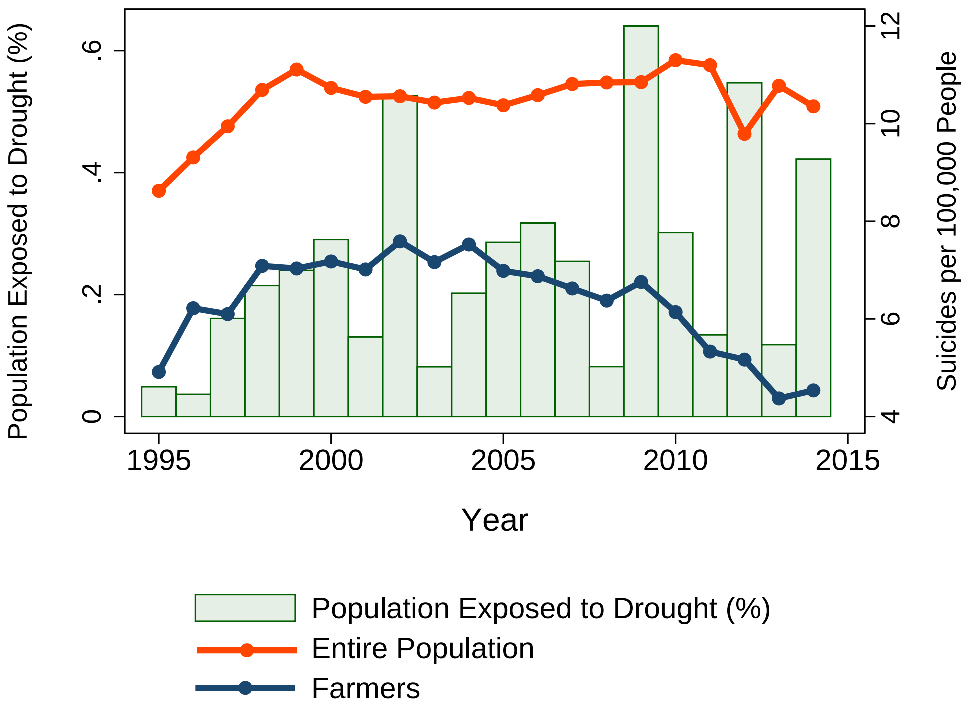

Figure A2: **Suicide Rates Among Farmers and the Total Population Over Time.** A time series of the all-India farmer (blue line) and total population (red line) suicide rates (right y-axis); and the percent of the Indian population exposed to drought in each year (bars; left y-axis). Source: author calculations based on the Indian Meteorological Department, NCRB and Census data.

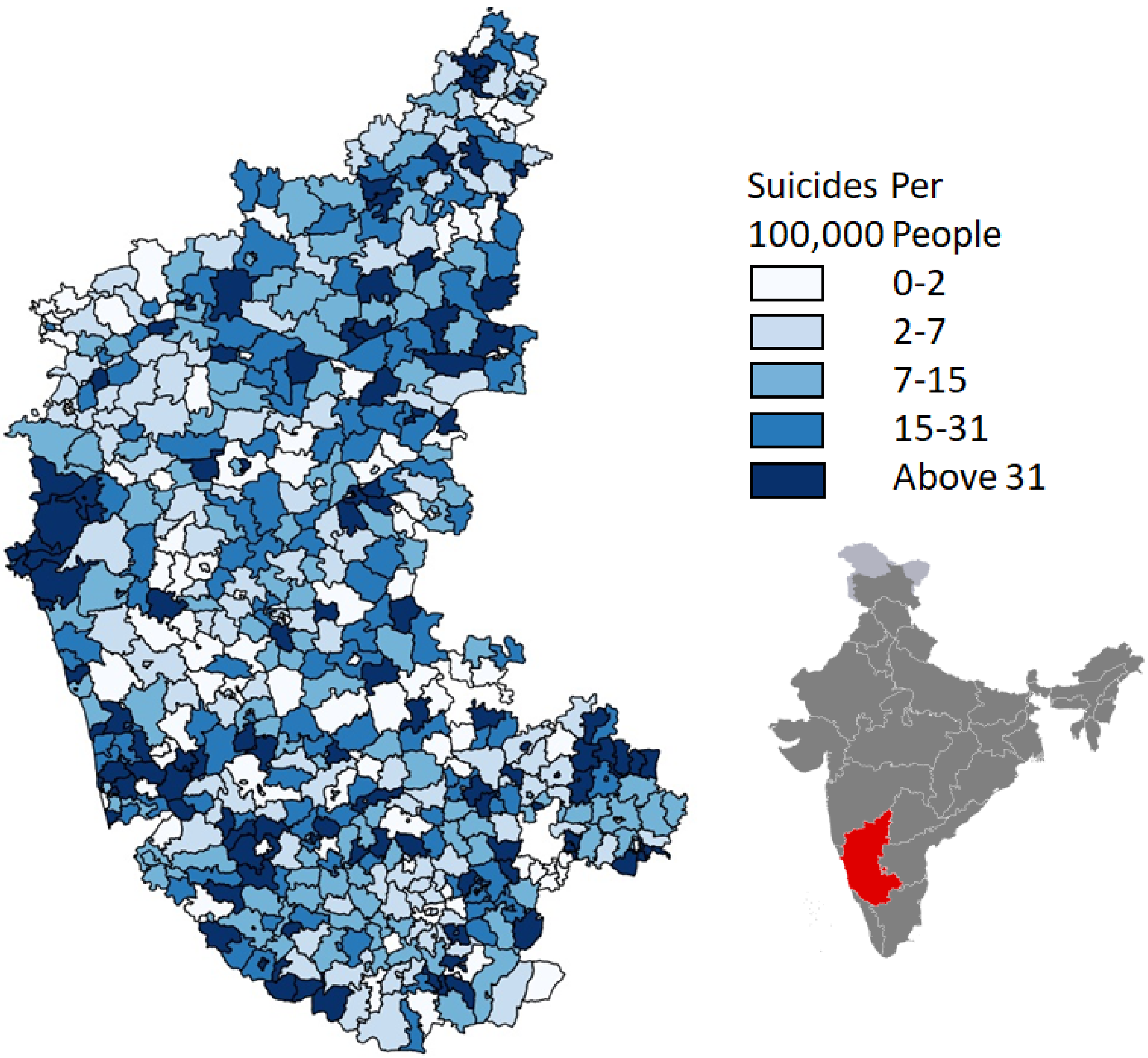

Figure A3: **Suicide Incidence by Police Station in Karnataka.** The map illustrates suicide incidence according to police station jurisdiction in Karnataka in the year 2015.

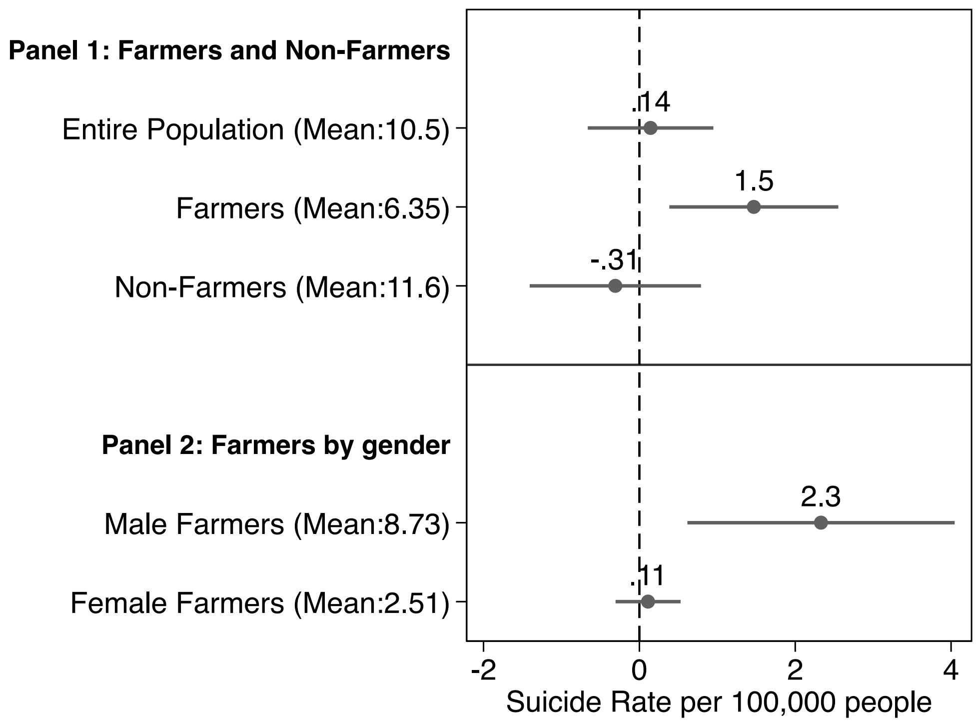

Figure A4: **Effects of Drought on Suicide Rates Among People Over the Age of 15.** Points represent estimated coefficients of the impact of drought on suicide rates for people aged 15 and above . Error bars indicate 95% confidence intervals. Each coefficient represents a separate regression. All regressions include controls for mean temperature in the two main growing seasons as well as state and year fixed effects. The sample size is n=348 (age specific data is only available after the year 2000).

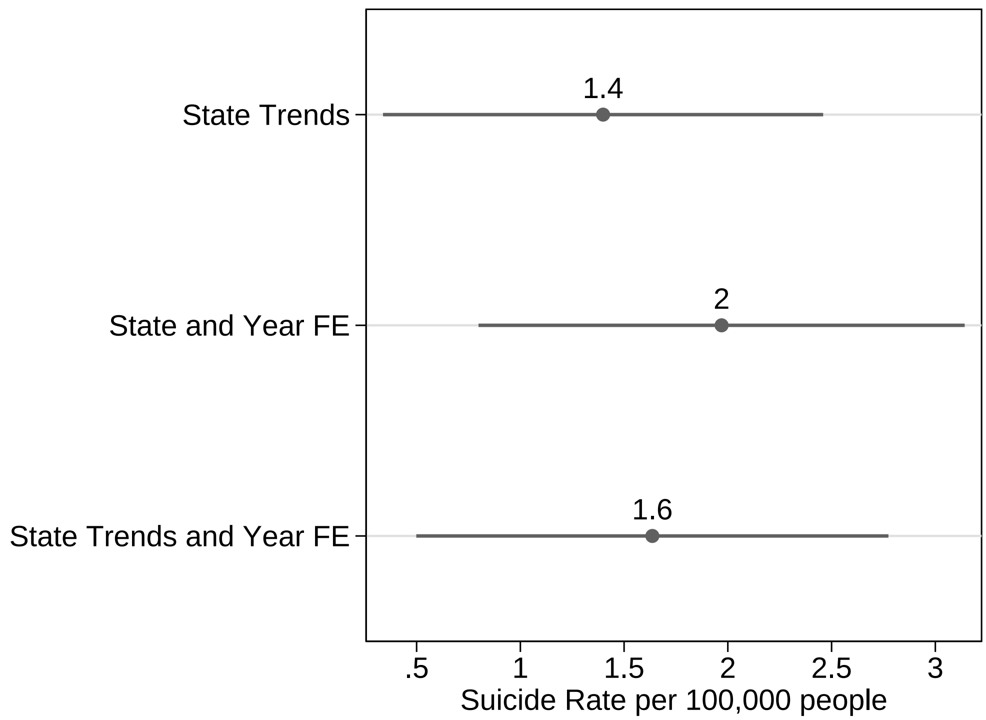

Figure A5: **Alternative Regression Models.** Points represent estimated coefficients of the impact of drought occurrence on suicide rates (cases per 100,000 people) obtained from regression models similar to regression (1) but that control for state specific linear time trends but not year fixed effects (top); include state and year fixed effects (middle); and both year fixed effects and state specific time trends (bottom). All regressions include controls for mean temperature in the two main growing seasons. Error bars indicate 95% confidence intervals.

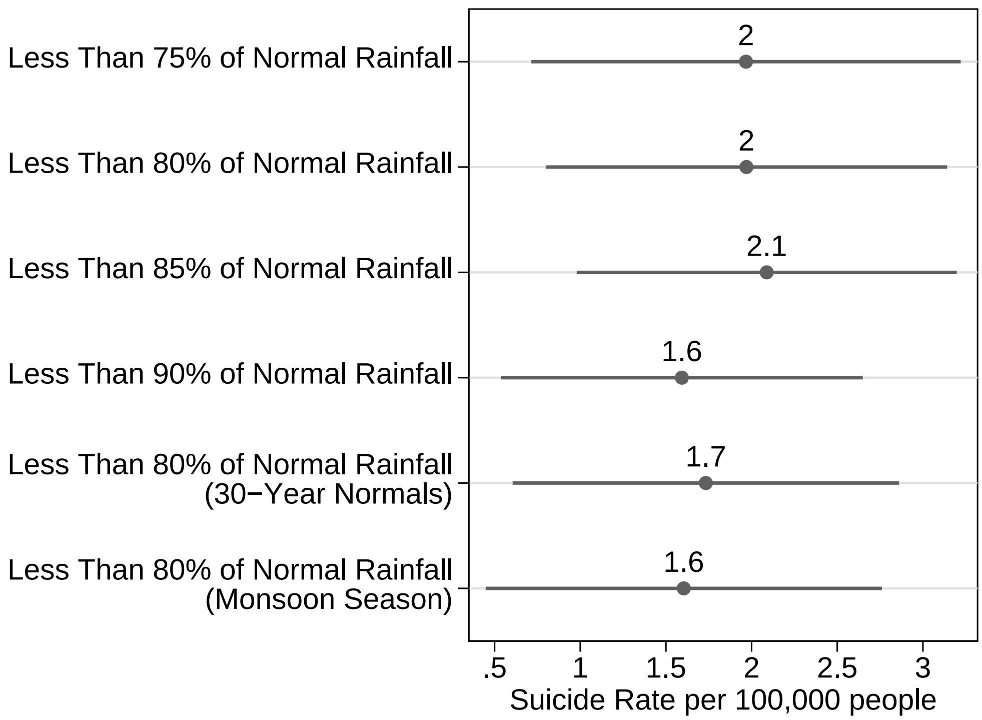

Figure A6: **Alternative Drought Definitions.** Points represent estimated coefficients of the impact of drought occurrence on male farmer suicide rates (cases per 100,000 people) obtained from regression (1), by using various alternative definitions of drought: annual rainfall falling below 75%, 80%, 85% and 90% of the long-term mean mean (reported by Indian Meteorological Department); 80% below the 30-year mean; and Monsoon rainfall falling below 80% of the long-term Monsoon rainfall mean. Error bars indicate 95% confidence intervals. All regressions include controls for mean temperature in the two main growing seasons as well as state and year fixed effects

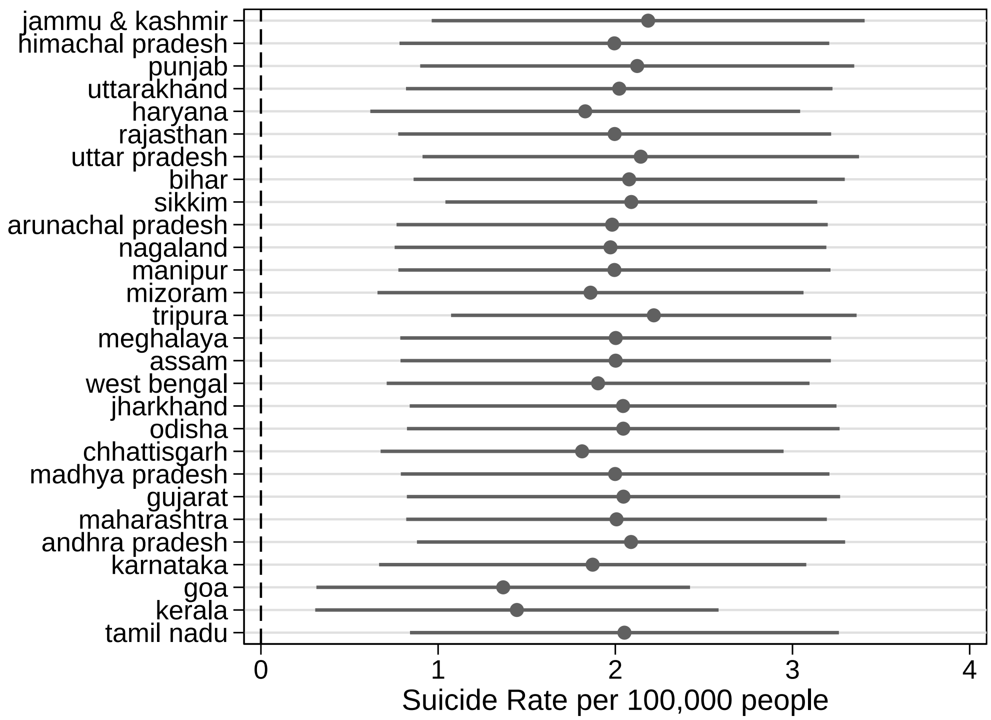

Figure A7: **Omitting Various States from the Sample.** Point estimates and 95% confidence intervals of regression (1), estimated repeatedly by dropping each state in-turn from the sample. Each coefficient represents a separate regression in which a single state has been omitted. All regressions include controls for mean temperature in the two main growing seasons as well as state and year fixed effects

	Suicide Rates Per 100,000 People					Irrigated	Agricultural	Rabi	Kharif
	General Polulation	Non Farmers	Farmers Farmers	Male Farmers	Female Farmers	Land (%)	Debt (K Rs/Capita)	Temp. (Deg. C)	Temp. (Deg. C)
Jammu & Kashmir	1.74	1.93	0.73	0.97	0.29	41.19	6.97	11.25	24.5
	(0.76)	(0.84)	(0.71)	(0.95)	(0.33)	(0.66)	(9.6)	(0.64)	(0.39)
Himachal Pradesh	4.75	7.42	1.87	3.8	0.34	19.53	5.67	14.04	25.55
	(1.02)	(1.38)	(1.7)	(3.01)	(0.7)	(1)	(5.77)	(0.55)	(0.39)
Punjab	1.6	1.68	2.23	2.69	0.18	97.06	69.02	16.63	29.47
	(0.38)	(0.4)	(0.74)	(0.95)	(0.26)	(1.06)	(75.1)	(0.56)	(0.41)
Uttarakhand	2.6	3.15	1.39	2.25	0.54	46.5	14.21	15.48	25.86
	(0.71)	(0.91)	(0.67)	(1.12)	(0.49)	(2.1)	(11.9)	(0.49)	(0.41)
Haryana	6.09	7.06	4.79	6.87	0.98	83.94	37.16	17.72	30.1
	(0.82)	(1.08)	(2.18)	(2.6)	(0.99)	(3.49)	(41.82)	(0.55)	(0.45)
Rajasthan	4.6	6.03	3.18	5.35	0.85	34.09	9.95	20.11	30.06
	(0.5)	(0.63)	(1.43)	(2.33)	(0.65)	(3.15)	(10.62)	(0.63)	(0.48)
Uttar Pradesh	2.32	2.5	1.6	1.82	0.99	72.61	12.13	19.32	29.9
	(0.54)	(0.62)	(0.45)	(0.52)	(0.38)	(4.38)	(12.97)	(0.49)	(0.5)
Bihar	0.98	1.13	0.34	0.41	0.16	56.56	8.99	20.33	29.39
	(0.53)	(0.61)	(0.17)	(0.19)	(0.14)	(7.62)	(10.4)	(0.47)	(0.41)
Sikkim	17.86	20.99	16.4	23.22	8.65	11.67	3.46	17.98	25.62
	(8.6)	(10.47)	(10.38)	(15.36)	(7.56)	(2.41)	(3.55)	(0.51)	(0.29)
Arunachal Pradesh	5.56	7.25	3.96	6.77	1.15	18.55	1.87	20.31	28.28
	(1.51)	(1.92)	(2.96)	(4.86)	(1.49)	(1.86)	(1.4)	(0.38)	(0.28)
Nagaland	0.73	1.04	0.31	0.56	0.07	24.38	1.63	20.13	27.97
	(0.33)	(0.49)	(0.46)	(0.88)	(0.14)	(4.17)	(1.9)	(0.45)	(0.35)
Manipur	0.85	1.06	0.19	0.28	0.08	24.79	2.56	19.84	27.1
	(0.33)	(0.43)	(0.24)	(0.42)	(0.3)	(7.49)	(2.69)	(0.43)	(0.26)
Mizoram	1.95	2.64	1.68	2.8	0.33	13.13	4.68	19.7	26.91
	(0.96)	(1.48)	(3.2)	(5.08)	(0.93)	(3.95)	(5.16)	(0.37)	(0.25)
Tripura	19.18	20.37	10.77	11.01	9.9	28.72	7.51	19.75	26.93
	(3.6)	(5.65)	(14.13)	(10.75)	(21.63)	(9.23)	(7.86)	(0.37)	(0.26)
Meghalaya	1.83	2.26	1.3	2.01	0.45	24.94	2.99	19.79	27.21
	(0.58)	(0.64)	(0.94)	(1.34)	(0.63)	(5.19)	(3.2)	(0.41)	(0.28)
Assam	6.55	7.28	4.25	5.62	1	6.13	3.73	19.71	27.39
	(0.55)	(0.63)	(1.67)	(2.25)	(0.69)	(3.25)	(4.3)	(0.4)	(0.37)
West Bengal	14.73	15.48	7.69	8.18	6.15	54.18	14.49	21.31	28.62
	(3.9)	(4.03)	(4)	(4.15)	(4.19)	(8.85)	(15.84)	(0.42)	(0.29)
Jharkhand	2.06	2.6	1.09	1.79	0.17	10.75	4.89	20.88	28.9
	(0.77)	(0.95)	(0.71)	(1.16)	(0.24)	(1.66)	(4.29)	(0.47)	(0.42)
Odisha	9.26	11.16	2.63	3.57	0.94	29.44	10.21	23.06	28.43
	(0.67)	(0.85)	(1.1)	(1.43)	(0.7)	(3.49)	(10.6)	(0.39)	(0.4)
Chhattisgarh	14.06	18.85	13.15	20.95	4.92	25.33	9.37	21.78	28.13
	(1.45)	(2.65)	(7.9)	(12.77)	(3.16)	(3.59)	(8.89)	(0.41)	(0.49)
Madhya Pradesh	11.45	14.27	8.23	11.53	3.87	29.97	11.79	20.78	28.45
	(2.05)	(2.3)	(3.31)	(4.28)	(2.31)	(4.97)	(11.93)	(0.54)	(0.52)
Gujarat	8.54	9.93	4.88	6.77	2.02	39.22	20.67	23.63	28.79
	(0.71)	(0.9)	(0.74)	(1.23)	(0.54)	(6.11)	(20.57)	(0.47)	(0.4)
Maharashtra	10.21	12.39	13.47	22.79	2.95	18.04	16.95	23.75	27.17
	(1.43)	(1.82)	(3.37)	(5.89)	(1.28)	(1.3)	(16.25)	(0.43)	(0.44)
Andhra Pradesh	10.56	13.13	8.62	13.15	3.39	44.44	46.33	24.82	28.55
	(1.71)	(2.14)	(2.32)	(3.64)	(1.2)	(3.46)	(57.07)	(0.36)	(0.37)
Karnataka	14.69	16.85	15.51	22.23	6.45	27.99	30.69	23.88	25.16
	(1.99)	(2.24)	(3.64)	(5.18)	(2.9)	(3.74)	(31.26)	(0.33)	(0.29)
Goa	14.26	15.13	10.43	20.25	0.8	22.4	76.03	25.72	26.08
	(4.2)	(4.81)	(8.25)	(16.6)	(1.48)	(1.31)	(114.1)	(0.32)	(0.26)
Kerala	14.78	14.85	50.58	65.5	13.5	16.07	177.47	24.71	25.08
	(2.05)	(2.17)	(8.95)	(11.95)	(5.8)	(1.58)	(214.73)	(0.25)	(0.26)
Tamil Nadu	14.81	17.66	6.11	9.03	2.58	54.71	68.2	25.95	28.95
	(1.18)	(1.46)	(2.72)	(4.16)	(1.12)	(3.27)	(85.9)	(0.26)	(0.31)

Table A1: **Summary Statistics.** Inter-annual means and standard deviations of selected variables, disaggregated by state.

	(1) General Population	(2) Non Farmers	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			Farmers							
Gender	All	All	All	Females	Males					
Ages	All	All	All	All	All	0-14	15-29	30-44	45-59	60+
Drought	0.168	-0.497	1.212**	-0.0838	1.942***	0.194	0.934	2.164**	3.014*	4.137**
	(0.291)	(0.334)	(0.495)	(0.378)	(0.706)	(0.389)	(0.622)	(1.090)	(1.557)	(1.736)
	[0.513]	[0.546]	[0.638]	[0.314]	[0.929]	[0.291]	[0.859]	[1.100]	[1.600]	[2.134]
Temperature Kharif	0.957*	1.199**	-0.0547	-0.609	0.588	-0.0756	0.409	0.734	3.421**	-0.243
	(0.508)	(0.565)	(0.799)	(0.780)	(1.084)	(0.615)	(1.001)	(1.644)	(1.647)	(2.221)
	[0.875]	[0.886]	[1.179]	[1.182]	[1.650]	[0.667]	[1.266]	[2.503]	[1.739]	[1.481]
Temperature Rabi	-0.184	-0.361	0.444	0.403	0.416	-0.0334	1.981	3.238*	2.744	1.189
	(0.320)	(0.386)	(0.599)	(0.666)	(0.728)	(0.544)	(1.243)	(1.905)	(1.690)	(3.144)
	[0.265]	[0.357]	[0.684]	[0.828]	[0.918]	[0.399]	[1.402]	[3.096]	[2.337]	[4.034]
$MeanSuicide$	10.5	11.6	6.35	2.51	8.73	0.98	6.97	12.5	9.00	8.03
$\%ofMean$	1.60%	-4.25%	19.1%	-3.34%	22.2%	19.8%	13.4%	17.3%	33.5%	51.5%
Obs.	496	496	496	496	496	348	348	348	348	348
R^2	0.89	0.86	0.83	0.38	0.83	0.23	0.76	0.78	0.73	0.58

Table A2: **The Effect of Drought Occurrence on Suicide Rates.** Estimated impacts of drought occurrence on suicide rates (suicide cases per 100,000 people) in various occupational, gender and age groups (each column reports a separate regression conducted over the appropriate sub-sample). Coefficients are compared to the average suicide rates within the respective population. All regressions include controls mean temperature (°C) in the two main growing seasons. All regressions include state and year fixed effects (not shown). Robust standard errors in parenthesis; clustered standard errors by state in square brackets. Stars indicate statistical significance of the regressions with unclustered errors: * p<0.1, ** p<0.05, *** p<0.01.

	(1) General Population	(2) Non Farmers	(3)	(4)	(5)	(6) Farmers	(7)	(8)	(9)	(10)
Gender	All	All	All	Females	Males					
Ages	All	All	All	All	All	0-14	15-29	30-44	45-59	60+
Drought	-0.228	-0.483	0.876*	-0.191	1.539**	0.791	0.836	2.007*	2.867*	3.975**
	(0.261)	(0.311)	(0.466)	(0.386)	(0.659)	(0.711)	(0.620)	(1.045)	(1.509)	(1.788)
	[0.451]	[0.471]	[0.648]	[0.464]	[0.892]	[0.593]	[0.881]	[1.029]	[1.488]	[2.123]
Kharif Season										
Degree-Days	-0.00869	-0.00452	-0.0301	0.0501	-0.0762	-0.175	-0.132	-0.250	-0.110	-0.232
Below 20^oC	(0.0617)	(0.0708)	(0.102)	(0.0780)	(0.154)	(0.138)	(0.145)	(0.292)	(0.353)	(0.451)
	[0.0592]	[0.0590]	[0.0882]	[0.0573]	[0.136]	[0.101]	[0.124]	[0.277]	[0.268]	[0.353]
Degree-Days	0.00895**	0.0104**	0.00345	-0.00149	0.00977	-0.0104	0.00126	-0.00242	0.0288**	0.00105
Above 20^oC	(0.00392)	(0.00427)	(0.00537)	(0.00435)	(0.00812)	(0.00868)	(0.00756)	(0.0140)	(0.0120)	(0.0178)
	[0.00569]	[0.00569]	[0.00748]	[0.00528]	[0.0122]	[0.00704]	[0.0104]	[0.0206]	[0.0134]	[0.0109]
Rabi Season										
Degree-Days	-0.00421	-0.00468	-0.00499	-0.000549	-0.0103	-0.00702	-0.0109	-0.0186	-0.0400*	-0.0422
Below 20^oC	(0.00613)	(0.00667)	(0.00768)	(0.00507)	(0.0122)	(0.00601)	(0.0140)	(0.0295)	(0.0240)	(0.0390)
	[0.00446]	[0.00518]	[0.0107]	[0.00300]	[0.0188]	[0.00722]	[0.0174]	[0.0421]	[0.0419]	[0.0478]
Degree-Days	-0.00390	-0.00694	0.00481	0.00593	0.00238	-0.00836	0.0176*	0.0222	0.00836	-0.00315
Above 20^oC	(0.00426)	(0.00484)	(0.00623)	(0.00660)	(0.00867)	(0.00869)	(0.0102)	(0.0181)	(0.0157)	(0.0252)
	[0.00463]	[0.00568]	[0.00982]	[0.0110]	[0.0132]	[0.00907]	[0.0148]	[0.0230]	[0.0146]	[0.0274]
Obs.	513	513	513	513	513	364	364	364	364	364
R^2	0.90	0.86	0.83	0.37	0.84	0.24	0.76	0.78	0.74	0.59

Table A3: **Alternative Model #1 for The Effect of Drought Occurrence on Suicide Rates.** Estimated impacts of drought occurrence on suicide rates (suicide cases per 100,000 people) in various occupational, gender and age groups (each column reports a separate regression conducted over the appropriate sub-sample). All regressions include controls for degree-days (the effect of 1 day becoming 1°C warmer) in the two main growing seasons, where the degree day threshold is 20°C. All regressions include state and year fixed effects (not shown). Robust standard errors in parenthesis; clustered standard errors by state in square brackets. Stars indicate statistical significance of the regressions with unclustered errors: * p<0.1, ** p<0.05, *** p<0.01.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	General Population	Non Farmers	Farmers							
Gender	All	All	All	Females	Males					
Ages	All	All	All	All	All	0-14	15-29	30-44	45-59	60+
Drought	-0.110	-0.305	0.906*	-0.150	1.537**	0.381	0.579	1.085	2.251	3.518*
	(0.294)	(0.356)	(0.495)	(0.389)	(0.720)	(0.375)	(0.659)	(1.225)	(1.574)	(1.952)
	[0.411]	[0.459]	[0.581]	[0.380]	[0.798]	[0.292]	[0.812]	[1.218]	[1.324]	[2.274]
Kharif Season Degree Days										
6°C to 10°C	-1.995	6.924	-28.65	-18.13	-38.97	-13.13	-45.40	-26.12	-49.22	-121.1
	(9.085)	(11.49)	(17.83)	(13.60)	(25.34)	(17.25)	(36.91)	(56.55)	(81.28)	(114.6)
11°C to 15°C	-0.0771	-0.341	0.769*	0.656*	0.847	0.232	1.061	0.0596	0.901	3.193
	(0.211)	(0.281)	(0.433)	(0.387)	(0.613)	(0.382)	(0.770)	(1.217)	(1.803)	(2.604)
16°C to 20°C	0.206	0.360*	-0.158	-0.225	-0.0585	-0.228	-0.306	-0.631	0.389	-1.826
	(0.166)	(0.198)	(0.324)	(0.233)	(0.466)	(0.373)	(0.471)	(0.710)	(0.817)	(1.828)
21°C to 25°C	0.0294	0.0322	0.0424	-0.0135	0.0919	-0.129	-0.00142	-0.141	0.0517	-0.305
	(0.0356)	(0.0413)	(0.0560)	(0.0530)	(0.0752)	(0.110)	(0.119)	(0.142)	(0.107)	(0.295)
26°C to 30°C	0.0361**	0.0431**	0.0314	-0.00531	0.0616**	-0.0326	0.0372	-0.000888	0.0942**	-0.0965
	(0.0164)	(0.0198)	(0.0220)	(0.0188)	(0.0303)	(0.0426)	(0.0441)	(0.0526)	(0.0451)	(0.160)
31°C to 35°C	0.0205**	0.0230*	0.0202	-0.00340	0.0417**	-0.0252	0.0237	-0.0126	0.0646**	-0.0535
	(0.0102)	(0.0121)	(0.0140)	(0.0113)	(0.0196)	(0.0285)	(0.0303)	(0.0361)	(0.0277)	(0.100)
36°C to 40°C	0.0153*	0.0202**	0.00619	-0.00713	0.0188	-0.0235	-0.00614	-0.0142	0.0416*	-0.0606
	(0.00837)	(0.00967)	(0.0117)	(0.00997)	(0.0162)	(0.0203)	(0.0214)	(0.0294)	(0.0235)	(0.0696)
41°C to 45°C	0.0113	0.0106	0.0113	0.000583	0.0213	-0.0108	0.0225	0.0240	0.0628**	-0.0222
	(0.00727)	(0.00947)	(0.0118)	(0.00899)	(0.0172)	(0.0180)	(0.0198)	(0.0307)	(0.0258)	(0.0453)
46°C to 50°C	0.0816	0.157**	-0.156	-0.249	-0.0733	-0.237	-0.427	-0.632	-0.642	-1.219*
	(0.0583)	(0.0721)	(0.131)	(0.162)	(0.156)	(0.282)	(0.323)	(0.641)	(0.733)	(0.690)
Rabi Season Degree Days										
-9°C to −5°C	-0.140	-0.450	0.930	1.088	0.876	0.217	2.183**	1.073	-0.219	2.739
	(0.377)	(0.498)	(0.759)	(0.795)	(0.940)	(0.575)	(0.906)	(1.741)	(1.971)	(2.027)
-4°C to 0°C	0.000484	0.0150	-0.0525	-0.0590	-0.0522	0.000965	-0.122	-0.146	-0.0239	-0.0759
	(0.0299)	(0.0362)	(0.0446)	(0.0455)	(0.0583)	(0.0443)	(0.0789)	(0.159)	(0.136)	(0.146)
1°C to 5°C	-0.0111	-0.0263	0.0376	0.0381	0.0359	-0.0393	0.0375	0.0869	0.00519	0.130
	(0.0195)	(0.0226)	(0.0270)	(0.0255)	(0.0366)	(0.0260)	(0.0371)	(0.0794)	(0.0646)	(0.107)
6°C to 10°C	-0.0155	-0.00751	-0.0538**	-0.0268	-0.0768**	0.00400	-0.0737	-0.180	-0.136*	-0.0770
	(0.0216)	(0.0243)	(0.0260)	(0.0200)	(0.0380)	(0.0235)	(0.0498)	(0.111)	(0.0810)	(0.0923)
11°C to 15°C	-0.00997	-0.0223	0.0255	0.0436	0.0125	-0.0368	0.0120	0.0609	-0.0446	0.0540
	(0.0136)	(0.0166)	(0.0249)	(0.0265)	(0.0302)	(0.0248)	(0.0367)	(0.0513)	(0.0514)	(0.108)
16°C to 20°C	-0.103	-0.125	-0.115	-0.00886	-0.209	-0.154	-0.186	-0.412	-0.536**	0.557
	(0.0811)	(0.101)	(0.0946)	(0.0793)	(0.133)	(0.0973)	(0.269)	(0.306)	(0.244)	(0.691)
21°C to 25°C	-0.0528	-0.0699	-0.0232	0.0616	-0.0913	-0.0840	-0.0796	-0.209	-0.233**	0.199
	(0.0348)	(0.0463)	(0.0503)	(0.0499)	(0.0645)	(0.0570)	(0.116)	(0.131)	(0.108)	(0.446)
26°C to 30°C	-0.0136	-0.0208	-0.000588	0.00660	-0.00414	-0.0167	0.0202	0.0435	0.0142	0.0868
	(0.0135)	(0.0164)	(0.0184)	(0.0183)	(0.0248)	(0.0204)	(0.0410)	(0.0460)	(0.0436)	(0.104)
31°C to 35°C	-0.0173	-0.0245*	-0.00392	0.0152	-0.0223	-0.0234*	-0.00379	-0.0102	-0.0537*	0.0544
	(0.0106)	(0.0128)	(0.0128)	(0.0121)	(0.0179)	(0.0142)	(0.0298)	(0.0407)	(0.0312)	(0.112)
36°C to 40°C	-0.00258	-0.00424	-0.00309	0.0107	-0.0129	-0.0145	-0.0194	-0.0498	-0.0638*	0.0367
	(0.00977)	(0.0120)	(0.0125)	(0.00997)	(0.0187)	(0.0117)	(0.0221)	(0.0387)	(0.0339)	(0.0625)
Obs.	513	513	513	513	513	364	364	364	364	364
R^2	0.90	0.87	0.84	0.39	0.84	0.32	0.77	0.80	0.76	0.59

Table A4: **Alternative Model #2 for The Effect of Drought Occurrence on Suicide Rates.** Estimated impacts of drought occurrence on suicide rates (suicide cases per 100,000 people) in various occupational, gender and age groups (each column reports a separate regression conducted over the appropriate sub-sample). All regressions include controls for degree-days (the effect of 1 day becoming 1°C warmer) in the two main growing seasons, where the degree day threshold is 20°C. at 5°C Intervals. All regressions include state and year fixed effects (not shown). Robust standard errors in parenthesis; clustered standard errors of the drought variable by state in square brackets. Stars indicate statistical significance of the regressions with unclustered errors: * p<0.1, ** p<0.05, *** p<0.01.

	(1)	(2)
Mediating factor:	**Irrigation**	**Debt**
Panel 1: Male Farmers (Mean Suicide Rate: 8.73 per 100,000)		
Interaction Term	-0.446**	0.256**
	(0.198)	(0.125)
Drought	3.766***	1.465**
	(1.305)	(0.665)
Direct Effect	-2.123**	-0.305**
	(0.871)	(0.0979)
Observations	496	496
R^2	0.88	0.88
Panel 2: Male Non-Farmers (Mean Suicide Rate: 14.2 per 100,000)		
Interaction Term	-0.0414	0.00909
	(0.106)	(0.0517)
Drought	0.362	0.184
	(0.699)	(0.410)
Direct Effect	1.471**	-0.0976
	(0.733)	(0.0825)
Observations	496	496
R^2	0.88	0.88
Coefficient Units	10%	10,000 Rs/Capita
Mean Values	44%	24,890 Rs/Capita

Table A5: **Interaction Effects.** The Table reports estimated coefficients of the interaction terms (from regression 2) between drought occurrence and (column 1) irrigation; measured as the percentage of gross irrigated land and (column 2) debt; measured as the per capita outstanding formal agricultural credit. Panel 1 reports estimates for farmers and panel 2 for non-farmers. All regressions include controls for mean temperature in the two main growing seasons. All regressions include state and year fixed effects as well as state specific linear time trends. Standard errors in parenthesis. Stars indicate statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

	(1) Non-Farmers 2015/16	(2) Farmers 2015/16
Drought Dummy	0.0946***	0.352***
	(0.0254)	(0.0653)
Observations	556	556
Pseudo R^2	0.0022	0.0108

Table A6: **The effect of Drought Occurrence on Suicides in Karnataka.** The Table reports estimated coefficients of drought occurrence on absolute number of suicides. Each column reports a separate Poisson regression conducted over the appropriate sub-sample. All regressions include a control for population size. Stars indicate statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

		Mean	Drought		Constant		Obs.
			Coef.	SE	Coef.	SE	
(1)	Scheduled Castes (% Total Population)	0.2074	0.0117	(0.0201)	0.204***	(0.00585)	554
(2)	Literate (% Total Population)	0.614	-0.0134	(0.0122)	0.618***	(0.00355)	554
(3)	Workers (% Total Population)	0.493	0.0109	(0.00846)	0.489***	(0.00246)	554
(4)	Cultivators (% Total Population)	0.150	0.0168	(0.0151)	0.145***	(0.00439)	554
(5)	Good Condition of HH (% Total Households)	0.518	0.00851	(0.0130)	0.521***	(0.000378)	554
(6)	Treated Tapwater (% Total Households)	0.229	0.0156	(0.0163)	0.225***	(0.00475)	554
(7)	Electricity (% Total Households)	0.868	0.00970	(0.0100)	0.865***	(0.00291)	554
(8)	Permanent Household (% Total Households)	0.559	-0.00804	(0.0229)	0.563***	(0.00665)	554
(9)	Private Enterprise (% Total Enterprises)	0.849	0.00224	(0.0111)	0.849***	(0.00137)	553
(10)	Public Sector Enterprise (% Total Enterprises)	0.0885	0.0115	(0.0162)	0.0871***	(0.00199)	553

Table A7: **Effect of Drought on Economic and Demographic Variables in Karnataka.** The table reports estimated coefficients of drought occurrence on various variables extracted from India's 2011 Demographic Census and 2013 Economic Census in the State of Karnataka. Each row reports a seperate regression. All regressions include district FE. Standard errors are clustered by district. * p<0.05 ** p<0.01 *** p<0.001 .