

# CAN OPENNESS MITIGATE THE EFFECTS OF WEATHER SHOCKS? EVIDENCE FROM INDIA'S FAMINE ERA

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A weakening dependence on rain-fed agriculture has been a hallmark of the economic transformation of countries throughout history. Rural citizens in developing countries today, however, remain highly exposed to fluctuations in the weather. This exposure affects the incomes these citizens earn and the prices of the foods they eat. Recent work has documented the significant mortality and morbidity stress that rural households face in times of adverse weather (Rose 1999, Yang and Maccini 2009, Burgess, Deschenes, Donaldson, and Greenstone 2009, Kudamatsu, Persson, and Stromberg 2009). Famines—times of acutely low nominal agricultural income and acutely high food prices—are an extreme manifestation of this mapping from weather to death. Knowles (1924) describes these events as “agricultural lockouts” where both food supplies and agricultural employment, on which the bulk of the rural population depends, plummet. The result is catastrophic with widespread hunger and loss of life.

Though now constrained to the world's poorest countries food shortages and famines were features of most pre-industrial societies. Over time there has been intense debate over what role openness to trade in food might play in mitigating or exacerbating the mortality impacts of weather shocks. One group of thinkers dating back to at least Smith (1776) argues that: “...drought [in “rice countries”] is, perhaps, scarce ever so universal as necessarily to occasion a famine, if the government would allow a free trade.” (IV.5.45). This school of thought sees greater openness to trade as a key means of protecting human life by reducing volatility in real incomes. But others have argued along the lines of Gandhi (1938), that greater trade

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openness may “have...increased the frequency of famines, because, owing to facility of means of [movement], people sell out their grain, and it is sent to the dearest markets.” (p. 36) Indeed many see trade as having played a key role in converting mild food scarcities into full-blown famine.<sup>1</sup>

What role openness to trade plays in mediating the relationship between weather shocks and income and mortality outcomes remains an open and important question today. This is particularly so as a large fraction of humanity remains dependent on rain-fed agriculture and hence fully exposed to the vagaries of the weather. Results from the theoretical and empirical international trade (Newbery and Stiglitz 1981, Rodrik 1997, Anderson 2009, di Giovanni and Levchenko 2009) and famine literatures (Sen 1981, O Grada 2009, Ravallion 1987) are both ambiguous and inconclusive. Even at the aggregate level, without regard to the complexity of heterogeneous effects across the population, the fundamental ambiguity here is that openness makes nominal incomes more responsive to production shocks (due to both increased specialization and dampened offsetting price movements), but consumer prices less volatile, such that the net effect on real incomes is unclear.

The colonial era provides us with an opportunity to make some progress on this question. Prior to colonization countries were poorly integrated both domestically and internationally. Investments in new infrastructure such as railroads and roads radically changed the situation by slashing transport costs and enabling domestic and international trade. The gradual integration of different parts of a country via connection to these transportation infrastructures provides us with a window into the weather-trade-death relationship. It allows us to examine whether the weather-to-death relationship is an immutable, but unfortunate, fact of life in developing countries or whether investments which integrate regions of countries into the domestic and world economies can offer rural citizens some protection against the volatility of their environments.

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<sup>1</sup>Dreze and Sen (1989), for example, discuss (in Chapter 6) the role for trade openness to exacerbate famine intensity.

In this paper we construct an Indian district-level database for the period 1875 to 1919 to examine this issue. This time period contained one of the worst strings of famines in recorded history, with an estimated death toll of between 15 and 30 million people (Visaria and Visaria 1983, Davis 2001). It also covers the period when the bulk of the railroad network was built in British India. And just as railroads were, by 1919, reaching into every last corner of the country, India saw the end of peacetime famine (many decades before democracy came with independence in 1947).

Our district panel results estimated using specifications that include district and year fixed effects, largely confirm this aggregate picture. On average, before the arrival of railroads, local rainfall shortages led to a significant rise in our index of famine intensity (which is based on the cataloging and characterization of all famines in this time period by Srivastava (1968)). But after a district gained railroad access the effect of local rainfall shortages on famine intensity was significantly muted.<sup>2</sup>

These findings demonstrate that productivity shocks brought about by weather variation can have an alarming bearing on the lives of rural citizens—but equally, that policy can play a dramatic role in mitigating the risks that weather variation imposes on a large fraction of humanity. Interventions which enhance trade openness and market integration offer a way to shelter rural citizens from the productivity shocks brought about by a volatile climate. Equally, in this instance, openness due to railroads may have prevented famine through the increased mobility of labor, capital, or famine relief programs. In ongoing work we are using alternative data sources on excess mortality, as well as data on output, prices, trade flows, trade balances, passenger flows and records of famine relief to better understand the reduced-form relationship documented in this paper.

In what follows we begin in Section 1 by describing the colonial Indian environment between 1875 and 1919, and the data on famine intensity, rainfall and railroad penetration

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<sup>2</sup>This finding is echoed, if less precisely estimated, in Keniston (2007) who uses decadal census data on population to attempt to estimate decadal death rates.

that we have constructed. Section 2 then presents our results of the rainfall-to-famine relationship, and how railroads mitigated this exposure of local famine severity to local rainfall shortage. Finally, Section 3 offers conclusions and directions for future work.

## 1. RAIN, RAILROADS AND FAMINE

Table 1 presents descriptive statistics for the main district level variables that we collected for this project. Throughout the period that we consider (1875-1919), India's economy was overwhelmingly agricultural—even in 1921 almost two-thirds of the employed worked in the agricultural sector (Census Commissioner of India 1922). Very little of this agriculture was irrigated, so agricultural production was heavily dependent on rainfall. And the annual amount of rainfall with which farmers and farm workers had to make do was extremely volatile—Figure 1 illustrates that even when district-level rainfall is averaged at the provincial level the resulting rainfall series are remarkably volatile.<sup>3</sup> As a result the Indian population was continuously buffeted by rainfall shocks leading agriculture in this period to be described innumerably as ‘a gamble in monsoons.’

This rainfall volatility took place against the backdrop of extremely low—essentially subsistence—average rural income levels (Heston 1983) and rudimentary health infrastructure (Arnold 1993). Subsistence living in average years meant a public health crisis in years of scanty rainfall and correspondingly meager agricultural incomes. Reflecting this, India's annual *Sanitary Reports*, the reports of the public health administration, collected and published just three forms of data: death rates, rainfall amounts, and prices of staple foods. The rainfall-to-death relationship, working as it did through food production, was a cornerstone of public health in this period.

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<sup>3</sup>Our rainfall data comes from meteorological stations in each district. The sources of these data are detailed in Donaldson (2008).

Years with particularly inadequate rainfall often gave rise to such wide-spread death that they were referred to, officially and unofficially, as ‘famines’.<sup>4</sup> Unfortunately, there was no consistent official system for declaring famine in this period.

To characterize the changing incidence of famine in India, we therefore draw on the work of Srivastava (1968) to construct a measure of famine intensity at the district level, annually from 1875-1919.<sup>5</sup> Based on extensive analysis of reports from British colonial administrators, Srivastava (1968) catalogs twenty-five food shortages and famines during our sample period, in each case documenting both the geographical area affected and the relative severity of the shortage across this area.

We have used Srivastava’s famine descriptions to assign each Indian district a famine severity score for each year from 1875 to 1919: 0 if a district was not discussed in the year in question, 1 if the district was affected by food scarcity (a condition less severe than famine), 2 if it experienced a mild famine or 3 if it experienced a severe famine.<sup>6</sup> Crucially the result is only an ordinal index of famine intensity so our empirical approach to using this data (described in the next section) reflects this feature.

Figure 2 illustrates the cumulative famine index for each district for each of the three fifteen-year periods between 1875 and 1919.<sup>7</sup> Two features of India’s famines are clear from this figure. First, food scarcities and famines tended to be local events affecting individual districts or groups of districts with the spatial pattern changing over time. At no point of time was the whole of British India affected by famine. This spatial concentration of famine

<sup>4</sup>While famines can arise from multiple fundamental and proximate causes (Sen 1981, Lin and Yang 2000, Meng, Qian, and Yared 2009), writing about colonial Indian famines McAlpin (1979) argues: “There is not much dispute that India has been subject to periodic crop failures for centuries, nor that the proximate cause of these crop failures is the lack of adequate timely rainfall.” (p. 143)

<sup>5</sup>Srivastava (1968) covers the period from 1861-1919. However, our rainfall data are too sporadic in the period from 1861-1874 so we begin our analysis in 1875.

<sup>6</sup>Srivastava (1968) was not concerned with the areas of modern-day Pakistan, Bangladesh or Myanmar, so we exclude these areas from our analysis.

<sup>7</sup>These figures include all regions of modern-day India—areas that were both ‘British districts’ under direct British rule and ‘Native States’ that were under indirect British rule. Our analysis focuses entirely on the British districts (referred to throughout as simply districts) because rainfall records from meteorological stations in the Native State areas are unavailable.

would of course be more apparent in plots at an annual rather than fifteen-year frequency. Second, there is a decline in the incidence and severity of famines pattern—a decline that would appear particularly stark in the period post-1919 (which was deliberately not covered by Srivastava (1968) due to the lack of famines to catalog in this period).

Despite the enormous human tragedy posed by famine, the British colonial government was reluctant to intervene. They instead believed that allowing free inter-regional trade would prevent famine and that it was the responsibility of the state only to enable these trades to occur (Stokes 1959). It was obvious to many observers that India’s new and expanding railroad network—also illustrated in Figure 2—held significant promise in this endeavor (Johnson 1963, Government of India 1880).<sup>8</sup> The fact that India’s famines were regional calamities, rather than national ones, reinforced this belief that lower trade costs brought about by rail transport could allow surplus regions to feed deficit regions. Under this view, railroads would limit the effect of local rainfall variation on local famine intensity. However, others argued that railroads could exacerbate local exposure to the local vagaries of the monsoon by allowing food to be shipped out of a famine-stricken district (food “counter-movements” in the language of Dreze and Sen (1989)). We now turn to empirical findings that are designed to shed light on the truth of these opposing views regarding the role of openness to trade, brought about by railroad expansion, in preventing or exacerbating famines in colonial India.

## 2. METHOD AND RESULTS

This section presents empirical results on whether local rainfall shortages caused local famines in colonial India, and the extent to which India’s expanding railroad network intervened in this rainfall-to-famine relationship. As discussed above we have codified the work of Srivastava (1968) to construct an index of famine intensity in India, by district and year

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<sup>8</sup>The sources of these maps of railroads by year, which underpin the railroad penetration dummy variable that we use below, are detailed in Donaldson (2008).

(1875-1919). We model latent (unobserved) famine intensity,  $F_{dt}^*$ , in district  $d$  and year  $t$  as

$$(1) \quad F_{dt}^* = \alpha_d + \beta_t + \gamma_1 RAIN_{dt} + \gamma_2 RAIL_{dt} + \gamma_3 RAIN_{dt} \times RAIL_{dt} + \varepsilon_{dt},$$

where  $\alpha_d$  is a district fixed-effect,  $\beta_t$  is a year fixed-effect,  $RAIN_{dt}$  is the amount of local rainfall enjoyed by district  $d$  in year  $t$  and  $RAIL_{dt}$  is a dummy variable indicating whether district  $d$  has a railroad line in the district in year  $t$  or not. We do not observe  $F_{dt}^*$ , but instead an ordered, qualitative index based on the true famine intensity,  $F_{dt}^*$ . (The qualitative index takes on one of four values: 0 for ‘normal’ (no mention of famine or scarcity), 1 for a ‘food scarcity’, 2 for a ‘mild famine’, or 3 for a ‘severe famine’). For this reason we estimate equation (1) using a fixed-effects ordered logit model.<sup>9</sup>

One would expect to see  $\gamma_1 < 0$  if rainfall shortages do contribute to famine. This is likely, as Donaldson (2008) found that rainfall shortages significantly damaged agricultural productivity in this time period in India, and the resultant effects of rainfall shortages on agricultural incomes may have been so acute as to lead to food scarcity and, in extreme cases, famine. The coefficient on railroad access,  $\gamma_2$ , captures the extent to which the expansion of railroads was associated with declining famine intensity. And finally the coefficient on the rainfall-railroad interaction term,  $\gamma_3$ , attempts to answer the key question we have posed in this paper – did railroads mitigate ( $\gamma_3 > 0$ ) or exacerbate ( $\gamma_3 < 0$ ) the ill-effects of rainfall shortages on famine intensity?

The results from our estimation of equation (1), via ordered logit with district and year fixed effects, are contained in Table 2. Column (1) begins by establishing that, on average over our sample period, a local rainfall shortage in a district would increase the probability of observing a famine in that district. However, as demonstrated in column (2), this mapping from rainfall shortages to famine was not an immutable fact of life throughout the entire sample period. In particular, prior to obtaining railroad access, rainfall shortages had a large

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<sup>9</sup>Ferrer-i-Carbonel and Frijters (2004) develop this estimator based on the insight of the Chamberlain (1980) conditional logit model.

(ie, statistically and economically significant) effect on famine intensity. But after a district obtained railroad access, famine intensity fell significantly (ie,  $\gamma_2 < 0$ ) and the responsiveness of famine intensity to rainfall fell significantly (ie,  $\gamma_3 > 0$ ) to a level that is precisely estimated yet economically insignificant. (That is, the estimated effect of rainfall on famine intensity post-railroads is  $\hat{\gamma}_2 + \hat{\gamma}_3 = -0.36$ , with a p-value of 0.076.) For a given reduction in rainfall, if a district were connected to the railroad network it faced a significantly lower probability that a food scarcity or famine would occur in that district. This is the key result of this paper.

In column (3) we ask whether rainfall shocks have effects on famine intensity even in the year after their arrival. This is plausible, as the vulnerable rural population consisted of both agricultural laborers (whose wages fell immediately due to the lack of rainfall and complementary labor demand during the agricultural season) and small-scale, subsistence farmers (for whom the relevant issue is whether a given year's harvest will be plentiful enough to provide consumption until the harvest in the *following* year). On average throughout the period, the estimates in column (3) find support for both contemporaneous and lagged effects of rainfall shortages on famine intensity. However, our estimates of the specification in column (4) suggests that both the contemporaneous and lagged effects of rainfall are significantly weaker in each district's post-rail era when compared to its pre-rail era.

A natural concern with the specification in column (4) is that the  $RAIL_{dt}$  terms in equation (1) may be correlated with unobserved aspects of India's economy or health infrastructure that, like railroad access, were steadily improving over time. It is possible that these background improvements are responsible for a weakening rainfall-to-famine relationship, and our  $RAIL_{dt}$  variable is merely a spurious proxy for this phenomenon. To control for this possibility we include in column (5) an interaction between both contemporaneous and lagged  $RAIN_{dt}$  and a trend term. The coefficient  $\gamma_3$  and its lagged rainfall equivalent are not dramatically different from their equivalents in column (4), and they continue to be



estimated precisely. This adds to the confidence with which we can assert that railroads—rather than some background trend that is correlated with the unfolding of India’s railroad network—were responsible for reducing the effect of rainfall shocks on famine in India.

Taken as a whole these results paint a coherent picture. Productivity shocks, in the form of rainfall shortages, led to famine in colonial India; but this rainfall-famine relationship was considerably attenuated after the arrival of railroads in a district. The expansion of railroads appears to have afforded some protection to Indian citizens against the vagaries of the weather.

### 3. CONCLUSION

In this paper we have conducted a preliminary analysis of the role played by openness to trade, brought about by railroads, in mitigating the effects of agricultural productivity shocks on famine in colonial-era India. Our approach was based on a qualitative index of famine severity by district and year from 1875-1919, which we constructed on the basis of classifications in Srivastava (1968). The results of our analysis suggest that rainfall shortages had large effects on famine intensity in an average district before it was penetrated by India’s expanding railroad network. But the ability of rainfall shortages to cause famine disappeared almost completely after the arrival of railroads. This lines up with findings in Donaldson (2008), where railroads were seen to significantly reduce the exposure of agricultural prices and real incomes to rainfall shocks.

Our findings have resonance for those regions, mainly in sub-Saharan Africa, whose poor integration into domestic and international markets may be a source of recurrent food scarcities and famines. Thinking through how to better integrate remote, rural regions of countries where citizens are continuously buffeted by the volatility of their environments represents a key challenge for development practitioners to take up. Our analysis of colonial-era India suggests that investments in transportation infrastructure like railroads that enable trade

can play an important part in breaking the link between weather shocks and excess mortality. Put more simply, a failure in the rains in one part of a country does not have to impose a death sentence on some fraction of the citizens inhabiting the affected region.

While these results are suggestive of a role for trade openness to help rural citizens smooth away the effects of aggregate productivity shocks, there are a number of other potential explanations for our reduced-form finding attributable to railroads. For example, it is plausible that railroads enabled cheaper movement of people, capital, and official famine relief, in addition to cheaper trade in food. In future work we aim to better understand these channels through the analysis of data on passenger flows, trade flows, trade imbalances, output, prices and records of famine relief.

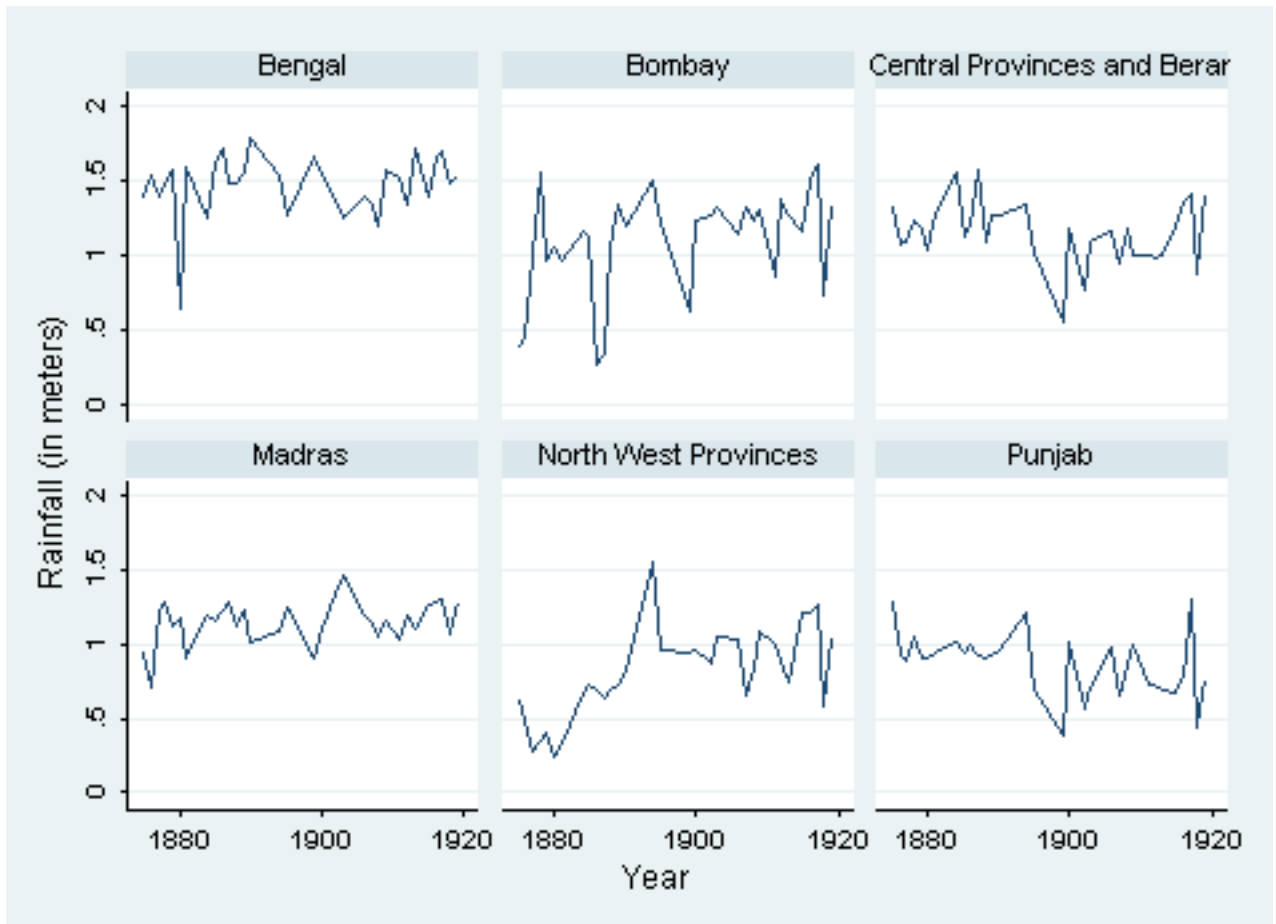
We also plan to move beyond the qualitative index of famine intensity that has been our focus here and instead use data derived from records of official vital statistics (which India began collecting in 1867). This will enable us to better understand the quantitative consequences—in terms of mortality rates—of weather induced productivity shocks in India and the number of lives saved by the entry of railroads. Because the vital statistics records are disaggregated by rural/urban residence, by month, and by cause of death, there is significant scope for understanding a great deal more about how openness mitigated weather related mortality in colonial India.

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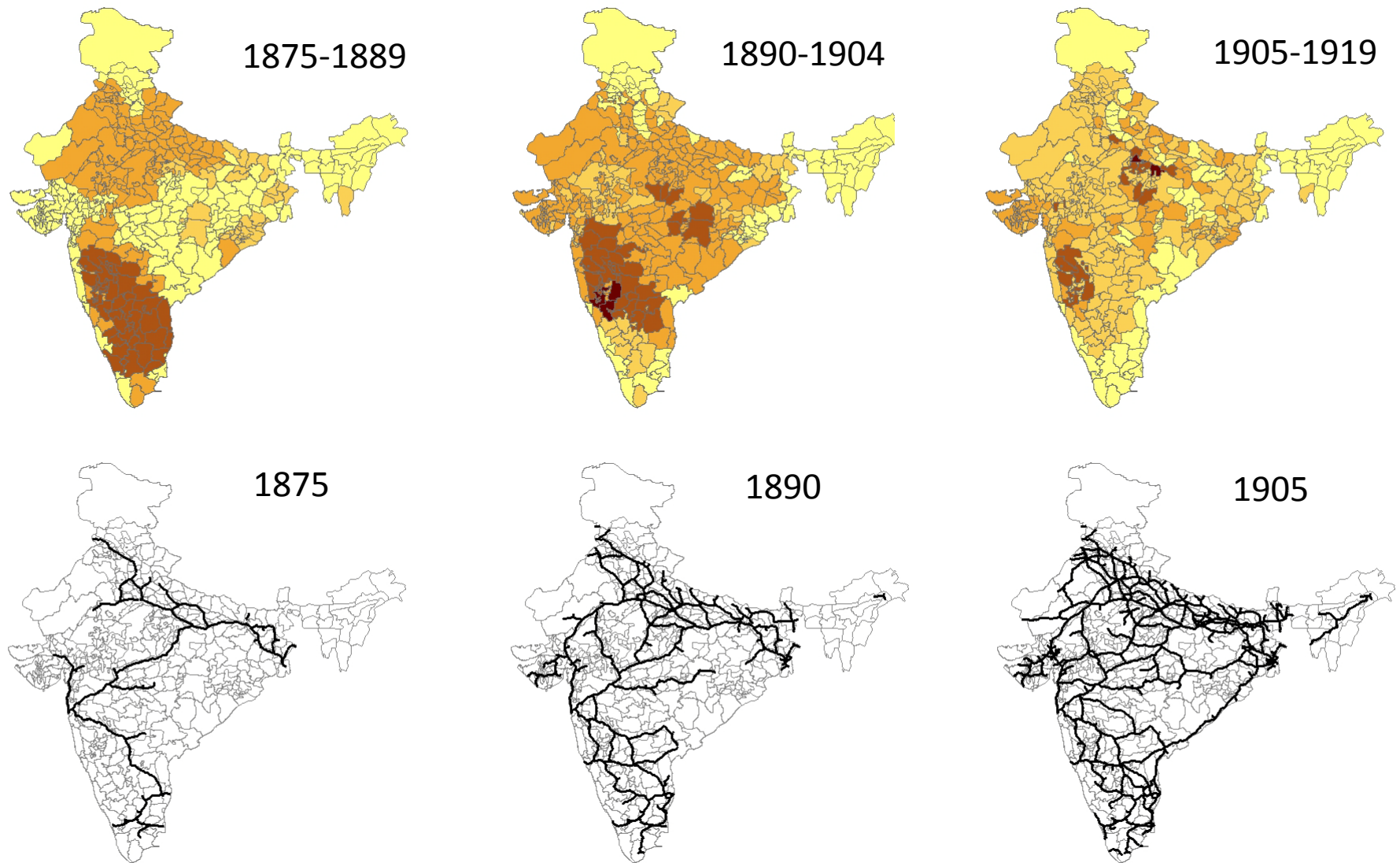
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**Figure 1: Annual Rainfall by Indian Province, 1875-1919.** This figure plots the average amount of annual rainfall by province, averaging over the British districts within each province. Source: see text.



**Figure 2: Famines and Railroads in India, 1875-1919.** The upper panel illustrates our index, based on Srivastava (1968), of famine intensity. The average famine intensity over each 15-year period is plotted for each British district and native state. Famine intensity was coded as 0 (no mention of famine/scarcity), 1 (mild food scarcity), 2 (mild famine) or 3 (severe famine). Darker colors reflect higher values of this 0-3 index. The lower panel illustrates the extent of India's railroad network in each of the three years indicated. Sources: see text.

**Table 1: Descriptive Statistics**

Variable:	1875-1889	1890-1904	1905-1919
Rainfall in district [meters]	1.02 (0.64)	1.27 (1.20)	1.38 (1.90)
Coefficient of variation of rainfall in district	0.34 (0.20)	0.29 (0.13)	0.24 (0.09)
Railroad in district [0,1]	0.58	0.82	0.93
Index of famine intensity (% of observations)			
0 (no mention)	0.85	0.78	0.83
1 (mild food scarcity)	0.02	0.00	0.01
2 (mild famine)	0.04	0.01	0.07
3 (severe famine)	0.09	0.21	0.09
Observations	1,275	1,253	1,281

*Notes:* Means of variables, with standard deviations in parentheses. 'Rainfall in district' is the amount of rainfall that fell in the district and year in question (measured in meters). 'Coefficient of variation of rainfall' is the standard deviation of district rainfall divided by the mean amount of district rainfall. 'Railroad in district' is a dummy variable whose value is one if any part of the district in question is penetrated by a railroad line. 'Index of famine severity' is our index of famine intensity in each district and year, derived from Srivastava (1968). This qualitative index takes the values from 0-3, as indicated. Data sources and construction are described in the text.

**Table 2: Famines, Rainfall and Railroads**

Dependent variable: Famine Severity Index	(1)	(2)	(3)	(4)	(5)
Railroad in district [0,1]	0.194 (0.374)	-1.625*** (0.572)	0.309 (0.390)	-2.178*** (0.690)	-2.136*** (0.754)
Rainfall in district, year t [meters]	-0.855*** (0.208)	-2.218*** (0.532)	-0.860*** (0.204)	-2.316*** (0.518)	-17.35 (20.40)
(Railroad in district) x (Rainfall in district, year t)		1.858*** (0.541)		1.848*** (0.521)	1.729*** (0.565)
Rainfall in district, year t-1 [meters]			-0.699*** (0.215)	-1.171*** (0.395)	9.316 (21.51)
(Railroad in district) x (Rainfall in district, year t-1)				0.692* (0.404)	0.758* (0.458)
(Rainfall in district) x (trend) interactions	NO	NO	NO	NO	YES
Observations	3809	3809	3551	3551	3551
Pseudo R-squared	0.248	0.260	0.255	0.271	0.271

*Notes:* Ordered logit regression estimates of equation (1) using our index of famine intensity constructed on the basis of descriptions in Srivastava (1968). All regressions include district and year fixed effects, with 125 British districts in modern-day India and years between 1875 and 1919. 'Railroad in district' is a dummy variable whose value is one if any part of the district in question is penetrated by a railroad line. 'Rainfall in district' is the amount of rainfall that fell in the district and year in question (measured in meters). Data sources and construction are described in the text. Standard errors corrected for clustering at the district level are reported in parentheses. \*\*\* indicates statistically significantly different from zero at the 1%, \*\* at the 5%, and \* at the 10% levels, respectively.