

Railways and Market Integration in British India

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(Preliminary—Comments Welcome)

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Abstract

Several researchers have suggested that the extensive railway system built in India after 1853 created a unified goods market. Using panel data on district wheat prices from 1860-1920, we test whether the wheat market was integrated at that time. Employing panel unit root tests, we find strong evidence for market integration. We measure the contribution of railroads to that integration by regressing absolute price differences between all district pairs by year on the presence of railways. We find that after controlling for time effects and district pair fixed effects, the contribution from railways is significant but small. This is robust across sample construction of different time periods and districts. Of the 35 percentage point drop in average absolute price differences over our sample period, railways can only explain about 3.5 percentage points or 10%. This suggests that other factors could be responsible for price convergence. We examine the effects of distance, being on the Ganges, and political variables such as effects of Princely States and being in the same state. We find that distance matters and both districts being on the Ganges or coast has at least as strong an effect as being connected by railways. We also find that price dispersion between districts in British India and independent Princely States was significantly higher and the size of the effect was comparable to being connected by railways, suggesting the existence of important border effects.

Introduction

Theory suggests that a unified goods market should generate important benefits for an economy. There is a comparative advantage effect that comes from greater regional specialization. There can be economies of scale. Larger markets may increase investment opportunities, leading to higher rates of capital formation. Finally, the ability to sell one's product in a bigger market should create greater incentives for innovation and technical progress.

Many economists believe that the introduction of railroads in the US in the 1830's was the key to unifying markets here. Railways were remarkably cheap, fast, and dependable. Lebergott estimates that in 1840 US freight charges for railroads were already 75% lower than for canals (Chandler (1977)). Passengers could suddenly travel across the US in 3 days instead of 3 weeks. Railroads were also resilient to floods, droughts, and cold winters.

At roughly the same time, India was building the fourth most extensive railway system in the world. By 1910 India had over 30,000 miles of track, just behind Germany and Russia (Hurd (1975)). Several economic historians contend that India's railway system also unified their market. However, there have been no formal statistical tests of that hypothesis. This paper does so by focusing on annual retail wheat prices in over 100 districts from 1860-1920. Market integration should imply that district wheat prices are linked to each other. We employ panel unit root tests to test that hypothesis. We find that relative wheat prices were stationary, consistent with the existence of a single market.

Then we examine the contribution of railroads to market integration. We estimate the impact of railroads on the absolute price differential between 6,441 district pairs over our 60-year period. After controlling for factors such as distance, proximity to the Ganges and the coast, the presence of large cities, the state that each district is in, and time trends we find that railroads have a statistically significant but small negative effect on price dispersion. Of the 35

percentage point drop in average absolute price differences during our sample period, railways can explain only 3.5 percentage points, or about 10%. What is driving these results is the fact that prices were converging significantly during this period, and it didn't seem to matter much whether districts had railways or not. We conclude that some other factors must have been primarily responsible for the rapid decline in price dispersion occurring at this time.

We find that among different characteristics, both districts being close to the Ganges brings price dispersion down more than being connected with railways. In addition, political and administrative variables matter. Controlling for all other characteristics, including distance, both districts belonging to the same state reduces price dispersion. The British acquired a number of important Indian states in the 1840's and 50's. This meant that within British India a common institutional framework was developing, which should have facilitated interdistrict commerce. To test that, we add a Princely State variable to our regression. Princely States remained independent during our sample period, so they were not a part of this common institutional framework. The "border effect" matters: price dispersion between Princely States and British India is about the same order of magnitude as railways. While our data on Princely States are not time varying, the results suggest that market integration in late 19th and early 20th century India therefore may have had as much to do with shrinking institutional differences between districts as with the introduction of railways. A conclusion suggests future research and discusses the implications of these results for the ongoing debate about the impact of colonialism on India.

Historical Literature

Atack and Passel (1994) report that after the introduction of steamships in America, price differences for pork and wheat flour between New Orleans and Cincinnati fell by over 70%. Similarly, after the construction of our transcontinental railroad, they claim that the notion of “one nation indivisible” became a reality. Metzger (1974) finds evidence of narrowing inter-provincial price differences in wheat and rye in Russia after railway construction began in 1851 and concludes that railways helped create a national grain market.

Whitcomb and Hurd (1983) suggest that railways had the same effects in British India:

From a country of many segmented markets, separated from each other by the high costs of transport, India became a nation with its local centres linked by rail to each other and to the world. (pg. 737)

Hurd (1975) provides some empirical support for that assertion. Using annual retail wheat and rice data from 188 districts between 1861 and 1921, he finds that price dispersion, as measured by the annual coefficient of variation, dropped as much as 60% over these years. During this time price dispersion was consistently lower for districts with railways. He concludes that railways were “instrumental in creating an India-wide market for foodgrains.” (Hurd (1975), pg. 275)

McAlpin (1974) documents a similar convergence in Indian cotton prices during this period. However, she found no statistically significant relationship over the period 1874-1900 between annual fluctuations in the relative price of cotton and annual changes in the amount of cotton acreage planted. She argues that this is because short-term price fluctuations were transitory, implying that cotton markets were still separate and governed by local supply conditions.

The Indian Famine Commission of 1901 (Famine in India (1976)) suggests that at least during famines railroads connected grain markets in different parts of the country. In their report, they refer to railways as their “salvation”. They maintain that after 1877 railways were able to provide reliable food supplies to stricken areas and end the days when millions would die from bad harvests.

Latham and Neal (1983) find that Indian internal rice prices were highly correlated with Indian rice export prices between 1868 and 1914. They test whether internal and export markets were integrated and find that they were for Indian rice markets. They find a similarly strong correlation between internal and export wheat prices, but reject complete integration between those two markets. That rejection derives from the fact that the coefficient of internal wheat prices regressed on wheat export prices (and vice versa) is statistically different from one. But they still estimate the coefficient to be 0.73.¹

Falling transportation costs could also have created a single labor market in 19th century India. Given that workers are often considered less mobile than goods, evidence of a unified labor market could suggest that goods markets were also unified. However Collins (1999) finds little evidence of what Robert Barro and Xavier Sala-i-Martin refer to as “ σ convergence” applied to wage rates: shrinking cross-section wage dispersion in British India. He also finds only weak evidence of “ β convergence”: the tendency for low wage districts to experience faster wage growth than high wage districts. The rate of convergence is slow and he generally finds no statistically significant contribution from the introduction of railways.

Taken as a whole, then, the literature comes to no consensus on whether railways knit India into a single market at this time. The majority of researchers seem to lean towards market

¹ Also, though their procedure creates bounds for their slope estimates, they don’t seem to incorporate the standard errors for those slope estimates, which could widen those bounds to encompass the value 1.0.

integration with an important boost from railways, but there is a need for additional research on this topic.

Railway Details

The construction of the Indian railway system began at major ports and worked inland to large cities and major agricultural regions. The first commercial passenger train was introduced in Bombay in 1853. Service near Calcutta commenced the following year, with a line in Madras opening in 1856. By 1860 there were 838 miles of track and it grew rapidly after that: 4,771 miles by 1870, 9,162 miles by 1880, 16,401 miles by 1890, 24,751 miles by 1900, and 32,099 miles by 1910 (Hurd (1975)). By 1867 all of the 10 largest cities in India had railways, including Delhi deep in the interior. By 1873 the largest 20 cities had rail service. By 1871 all the major trunk lines were connected. By 1878 Lahore and Karachi were part of the network. Figure 1 displays the system as of March 1868.

Placement of railway track was not always based on economic considerations. So-called “famine lines” were built to protect regions from disastrous crop failures by facilitating the importation of food. Military considerations were also a factor in the northwest, as lines were constructed to buttress frontier defenses. The result was a more widespread grid than would have developed solely for commercial purposes. Evidence of this is that many of the lines were unprofitable. In 1900, lines earning a rate of return less than 5% and requiring government subsidies made up 70% of track mileage (Whitcombe and Hurd (1983)).

Theory

In a friction-less world of complete information, arbitrage should ensure that all homogeneous commodities sell for the same price. In the real world, however, the Law of One Price (LOP) may not hold for several reasons. They include: 1) incomplete information and search costs; 2) transportation costs; 3) trade barriers; 4) menu costs; and 5) local monopolies engaging in differential pricing in separate markets. It is difficult to quantify most of these, but there is evidence that transportation costs in India prior to railroads were high. Wheat is fairly heavy, so unless one was near a river or the coast, transportation was expensive. Estimates supplied by the Famine Commission of 1880 suggest that freight charges for goods shipped by cart ranged from 15-50% of the price of wheat per 100 miles carried depending upon the condition of the roads (Hurd (1975)).

The effect of proportional transport costs on the LOP has been extensively studied (e.g. Taylor (2001) and O'Connell and Wei (2002)). In its simplest "iceberg" form, assume a fraction f of the good melts in transit. Let P_A be the price of wheat in market A and P_B be the price in market B . Then it is profitable to ship wheat from market A to market B if $(1-f) P_B > P_A \rightarrow 1-f > P_A/P_B$. Likewise shipments in the reverse direction would only occur if $(1-f) P_A > P_B \rightarrow P_A/P_B > 1/(1-f)$. Thus there is a band within which relative wheat prices can fluctuate given by $(1-f) < P_A/P_B < 1/(1-f)$. Outside that band arbitrage should push relative prices back into it. The band ensures that deviations from the LOP are stationary. However, if the band is wide, there could still be substantial random walk movements in relative prices. This could make it difficult to reject nonstationarity in standard unit root tests.

By significantly reducing transportation costs, railroads should dramatically narrow this no-arbitrage band making it much easier to reject a unit root. Hurd (1975) provides estimates

that railroads reduced the cost of transporting wheat in bulk by 80-95% compared with cart rates.² They also dramatically reduced the time it took to ship goods across land. It is estimated that while a cart could only travel 13 miles a day, railroads could cover 400 miles. They could also transport much larger quantities of grain. One loaded train was able to carry as much as 220,000 carts using three-quarters of a million men and bullocks (Hurd (1975)). All of these features of railway transport should have pushed district wheat prices much closer together.

Previous LOP Tests

The most researched version of the LOP is the theory of purchasing power parity (PPP). Early tests found only weak evidence for it (Adler and Lehman (1983) and Mishkin (1984)). However, with the advent of panel unit root tests, that evidence strengthened considerably. Frankel and Rose (1995), Oh (1996), MacDonald (1996), Coakley and Fuertes (1997), and Choi (2001) all find evidence for PPP, though the estimated half-life of exchange rate disturbances varies from 1-4 years. Parsley and Wei (1996) examine 51 different final good and service prices from 48 US cities over the period 1975:1 to 1992:4. Using the Levin-Lin test, they reject the unit root hypothesis for the majority of goods and services, though they are less successful at rejecting it using fixed effects. They estimate half-lives for parity deviations of 5 to 15 quarters.

Engel and Rogers (1996, 2001) and Engel, Rogers, and Wang (2003) look at relative price volatility for city pairs in the US and Canada. In general they find that price variation is systematically related to distance and the presence of a national border. Cecchetti, Mark, and Sonora (2002) and Nenna (2001) both reject the presence of a unit root in studies of consumer prices in US and Italian cities respectively. Both estimate long half-lives for convergence: 9-24

² Hurd (1975) also reports that rates for water transport in 1880 were not that different from those charged by railroads. But rivers were not generally available and even when they were, they were not always navigable.

years. Yousef (1999), on the other hand, finds rapid mean reversion in goods prices in Egypt during the inter-war period, with half-life estimates of as little as two months. Finally Asplund and Friberg (2001) look at Scandinavian duty-free stores that post prices for items in two currencies. With no transportation costs or trade barriers, the conditions for the strict LOP would seem to be optimal, but the authors reject it. However, they conclude that deviations from LOP are usually short-lived and small, averaging 5-10%.

In general, panel data unit root tests of relative goods prices find evidence of stationarity and mean reversion. The speed of that reversion, however, varies considerably.

Data

Annual retail wheat price data by district were obtained from the 1896 and 1922 issues of *Prices and Wages in India* published by the Department of Statistics of the Government of India and are expressed in rupees per ser (2.057 lbs). They were based on fortnightly purchases at district headquarters. The data run from 1861 to 1920. There were 114 districts with price data in 1861, but that grew to 162 districts by 1920. All of the major cities in India were located in districts in our sample except Madras. Three of the districts had so few observations that they were dropped from the sample, leaving 159 districts initially.

The quality of the price data appears to be high. In 1886 the Department of Finance and Commerce of the Government of India cross-checked the retail price data with the books of merchants and grain dealers and with other Administration reports and found that the data were trustworthy. Hurd (1975) expresses confidence in the data and argues that accurate retail price data should have been easy for bureaucrats to collect from local bazaars. McAlpin affirms that

the data are internally consistent and concludes that they were “probably among the more reliable statistics available for historical work on India.” (1983, pg. 900)

Railway opening dates by city were found in the 1947 issue of the *History of Indian Railways* published by the Ministry of Railways of the Government of India. The district opening date for railways used in our analysis was the first year a railway entered each district. We got district boundary information from historical maps and the 1911 *Encyclopedia Britannica*. By 1861, there were 16 districts in our sample with railways. By 1920, 156 of our 159 districts had railways. The growth over time in the number of districts with railways is displayed in Figure 2.

Data on how close districts were to the coast and the Ganges were obtained from historical and current maps of India. Distances between districts were based on the longitude and latitude of an important city (almost always the district headquarters) in each district. Most came from www.mapsofindia.com/lat_long. The Haversine formula was employed to estimate the distance between them. City population data came from the Indian Census of 1872 found in the *Statistical Abstract Relating to British India from 1867/8 to 1876/7*. Finally, the list of districts that operated as quasi-independent Princely (Native) States during this period came from the same *Statistical Abstract* supplemented by the 1911 *Encyclopedia Britannica*.³

Figure 2 displays a measure of the dispersion in wheat prices over our sample period. The measure is the annual standard deviation of the log of wheat prices across districts. Despite some fluctuations, the trend is clearly downward. The standard deviation fell approximately 50% between the early 1860's and the early 1900's. Wheat prices therefore moved significantly closer together during this period of railway expansion, in contrast to Collins' (1999) data on

wage rates. This convergence is consistent with Hurd's (1975) data and it suggests, as did Hurd, that the introduction of railways was an important factor in this price convergence.

Time Series Tests

One means of assessing whether there was a unified market for wheat is examining whether relative price deviations persist or not. Market integration should imply a stable long-run relationship in relative wheat prices. A divergence from that long-run relationship should eventually be reversed. So we should expect to see mean reversion in relative wheat prices. Market segmentation, on the other hand, would allow for permanent relative price changes.

That suggests testing whether there is a unit root in relative wheat prices. The unit root equation that we use in our tests is:

$$(1) \quad \Delta q_{i,t} = \alpha_i + \theta_t + \beta_i q_{i,t-1} + \varepsilon_{i,t}$$

where $q_{i,t}$ is the log-price of district i at time t , α_i is a district-specific constant that controls for omitted district factors affecting wheat prices, θ_t is a common time effect across districts, and $\varepsilon_{i,t}$ is the error term whose variance and pattern of higher-order serial correlation can differ across districts. An estimate for β_i of 0 would be evidence of a unit root. Mean reversion would imply a negative β_i so that positive shocks in the relative price of wheat are followed by an offsetting decline in that relative price. The estimated half-life of shocks to wheat prices is $-\ln(2)/\ln(p_i)$

³ Districts from the province of Berar were not counted as Princely States because starting in 1860 they were held in trust by the British Administration. Districts from the province of Mysore were counted as Princely States because, although in the 1870's they were temporarily under British Administration, in 1881 they were restored to the Raja.

where $p_i = 1 + \beta_i$. The larger the estimate of β_i , the shorter the predicted half-life for a price disturbance.

One could employ separate time-series unit-root tests for each relative price in our sample. However, studies indicate that such tests have low power for distinguishing between unit roots and near unit-root processes. Panel unit-root tests, however, have proven to have much more power against close alternatives. We used two of them: the Levin-Lin and Im-Pesaran-Shin tests. Both allow for individual-specific intercepts effects as well as common time effects. However, the alternatives to the null are different. The Levin-Lin alternative hypothesis assumes a common β across districts (Levin, Lin, and Chu (2002)). The Im-Pesaran-Shin alternative hypothesis allows the β 's to vary. Im-Pesaran-Shin (2003) show that the small sample performance of their test may be better than the Levin-Lin test.

To account for possible common time effects, the data were cross-sectionally demeaned.⁴ The results of the Levin-Lin tests are shown in Table 2. Because of missing data, we tried two different samples. The first spans the entire 60 years period from 1861-1920 but has only 114 districts in it. This is the sample we use later in the paper. The other contains 149 districts, but only runs from 1873-1931. The results were not sensitive to our choice of samples. They were also not sensitive to the number of lags included in the regression, so we worked with zero lags.

T-star has a standard normal distribution. The p-values for these tests indicate a strong rejection of the unit root null. The approximate half-lives are very short: in the neighborhood of one-year or less. That indicates rapid convergence after a relative price shock. This suggests that India's wheat market was integrated and that district markets were linked to each other.

⁴ See Levin, Lin, and Chu (2002)

We also test for the time series properties of deviations from the mean inflation rate each year. Again, we are able to reject easily the null of a unit root. The coefficients on the lagged inflation rate deviation are actually less than -1, implying more than 100% convergence within a year. However, the estimates are close to 0. These results are insensitive to our choice of subsamples. Finally, in Table 3 we perform the Im-Pesaran-Shin test and in all cases are again able to reject the null of a random walk.

Overall then, time series tests strongly support the hypothesis that Indian wheat markets were integrated during our sample period. Deviations from average price levels and average inflation rates were quickly corrected. In the next section we try to identify the contribution of railways to that integration.

Railways and Declining Absolute Price Differences

One approach to evaluating the effects of railways on market integration is to measure their impact on absolute price differentials between districts: $|p_{i,t} - p_{j,t}|$ where $p_{i,t}$ is the log of the wheat price in district i at year t . The variable approximately measures the percentage gap between prices in the two districts. By shrinking the band within which relative prices can fluctuate, lower transportation costs should reduce absolute price differentials across districts.

Since the introduction of railways varies both across districts pairs and over time, we can isolate the effect of the railways variable by using a dummy variable for each district pair. Thus our standard econometric specification uses district pair fixed effects to capture all time invariant effects specific to a district pair:

$$(2) \quad APD_{j,k,t} = \alpha + \beta_1 \text{BothRail}_{j,k,t} + \sum \beta_{ik} D_{j,k} + \mu_{j,k,t}$$

where APD is the absolute (log) price differential at time t between districts j and k , α is the constant, $BothRail$ is a dummy equal to one when both districts have railways that year and $D_{j,k}$ is a dummy variable equal to 1 for each district pair j, k .

We have data on 160 districts that spans 60 years (1861-1920), but some districts are missing values for some years. We worked with two different subsamples. Essentially the tradeoff was between getting a longer time series versus a better coverage of districts. Our first sample is restricted to the 114 districts that had all 60 years of data. That meant that each year there were 6,441 different district pairs for price comparisons, or a total of 386,460 observations over the entire sample period. In the second sample, we included the 147 districts that had complete data from 1873 to 1913. We then used all the available observations for these districts from 1861-1920. This created an unbalanced panel, but all districts had full data for 1873-1913. This yielded a total of 617,384 observations.

The summary stats are presented in Table 1. The mean absolute price differential in both samples is 0.26 or roughly 26%. It varies from 0 to more than 2.4, so there were some large price gaps between districts. The two samples are quite similar in the distance, Ganges, population, large city and the coastal variable. Roughly 7% were both big cities, 2% were both on the Ganges, 0.9% were both on the coast, 55% were connected by railways, and the mean log distance between districts was 6.19 or 490 miles. The two samples, however, differed in the political variables. Eighteen percent of our district pairs were in the same state and 5% were between a Princely State and British India in sample 1. Sample 2 had many more Princely States - more than 13% of the pairs were between Princely States and British India.

Regression Results

Table 4 displays the results of our first set of regressions. The coefficients on the district pair dummies are not reported. The results for both samples are quite similar. The first column is our base case with no time controls. In that case in both the samples, we see a large and significant negative effect of railways on absolute price dispersion. With mean absolute price differences falling from 0.5 in the 1860's to 0.15 just before 1910, the introduction of railways is estimated to be responsible for about 45% ($.16/.35$) of that decline. This supports the hypothesis that railways dramatically reduced transportation costs and greatly facilitated market integration in British India.

However, the estimated effect of railways could be artificially inflated by a spurious correlation between falling price dispersion and a rising number of railways. Figure 1 and 2 clearly show that dispersion was falling over time and the spread of railways was increasing over time as well. Clearly something was reducing price differences across districts over time, but it may not have been the growth in railways. Figure 3 displays the problem with the hypothesis that railways were primarily responsible for price convergence in British India. The graph comes from regressing mean absolute price dispersion on dummies measuring the number of years before and after railways linked districts. Price dispersion clearly falls in the year railways connect two districts, but it also falls in years districts were not being linked by rail. Price dispersion was trending downward at this time and the introduction of railways doesn't seem to affect that trend much.

To test that, we added yearly dummies to our regression. The results are in column 2 of Table 4. There is a big change in our railways coefficient: the estimate falls by more than 80%, though it still remains highly significant. Column 3 runs the same regressions but with a

quadratic time trend instead of yearly dummies. The estimates are virtually identical, though the R-squared declines a bit. Both regressions, therefore, suggest that the introduction of railways still has a statistically important impact on price dispersion, but the magnitude of the impact is relatively small now. Railways are estimated to reduce wheat price differences no more than 8% (.028/.35) of the total fall in the price dispersion over the sample period.

That railways do not account for a major part of the fall in price dispersion leaves room for other explanations. Unfortunately we do not have other data that vary both across districts and over time. We do have information however on many district characteristics that are time invariant, so one can assess their relative importance in explaining the absolute price dispersion. This means though that we cannot use district pair fixed effects now. Our new specification is

$$(3) \quad APD_{j,k,t} = \alpha + \beta_1 BothRail_{j,k,t} + \beta_2 LDistance_{j,k} + \beta_3 BothLargeCity_{j,k} + \beta_4 BothGanges_{j,k} \\ + \beta_5 BothonCoast_{j,k} + \beta_6 SameState_{j,k} + \beta_7 PrincelyState_{j,k} + \mu_{j,k,t}$$

LDistance is the log of the distance between the main cities in each district (there is a consensus in the gravity equation literature that some concave function of distance should be used), *BothLargeCity* is a dummy equal to one if both districts have a city in them with more than 50,000 people according to the 1872 census, *BothGanges* is a dummy equal to one when both districts are within 10 miles of the Ganges River, *BothonCoast* is equal to one if both districts are within 10 miles of the coast, and *SameState* equals one when both districts fall in the same state. *PrincelyState* is a dummy equal to 1 if only one of the districts in the pair is a Princely State.

As shown in much of the literature, price dispersion should increase with distance. The size of the city captures among other things the variety of communication and transportation

linkages that would tend to reduce price dispersion. However, when controlling for the other covariates, larger cities might also have larger non traded components in pricing that could increase price dispersion. Being near the Ganges or the coast implies a richer set of communication and transportation means and should lower dispersion. Since we are controlling for distance, the same state variable captures the effects of administered pricing within a state as well as other institutional and cultural factors specific to that state.

During the 1840s and 50s a number of important Indian states were absorbed into the British Empire including the Punjab (1849), Sambalpur (1849), Bhagat (1850), Udaipur (1852), Jhansi (1853), Tanjore (1853), Nagpur (1854), and Oudh (1856). These acquisitions brought most of India under the same administrative rule with a similar set of legal, economic, and even linguistic institutions over time. That could easily have paved the way for increased commerce between districts. To test this we included a Princely State dummy variable in our regressions. Princely States remained independent after 1857, so they did not participate in this process of political integration.

The effect of railways on price dispersion follows the same pattern as in the fixed effects regression. It is large when we don't control for time effects and then falls to a small but statistically significant effect after controlling for time. Table 5 presents the results for both samples after controlling for time effects. Connecting both districts by rail reduces price dispersion by about 4 percentage points. Both districts being on the Ganges has a slightly larger effect. In the larger sample 2, being on the Ganges reduces dispersion by 1.5 percentage points more than being connected with railways. Distance boosts price dispersion: a distance of 500 miles (close to the average in the sample) boosts price dispersion by 53 percentage points. Both districts having large cities is not that important. It has an effect roughly ten times smaller than

being on Ganges and changes signs across samples. Finally being from the same state reduces dispersion by almost 4 percentage points.

Price dispersion between districts in British India and Princely States is significantly higher: In sample 1, where only 5% of the pairs are between a Princely State and British India, the difference is extremely large--17 percentage points or roughly 67% more dispersion than in the rest of the sample. Crossing national boundaries is estimated to affect price dispersion roughly 5 times as much as the presence of railways. This is reminiscent of the huge border effects that Engel and Rogers (1996) found in their research. It is possible, then, that growing institutional homogeneity in India at this time may have had a more significant effect on market integration than the introduction of railways. However, in the larger sample where 13% of the pairs are between Princely States and British India, price dispersion goes up by only 3.3 percentage points, a slightly smaller effect than that of being connected by railways.

Endogeneity of Railways

The possible endogeneity of our railways timing variable is an important consideration. Clearly when and where railroads were built was not random. Our results from the first set of regressions control for district pair fixed effects. Thus any omitted variables that are time invariant and affect the railway timing between a district pair are taken into account by that setting. In the second set of regressions, we do control for a number of observable characteristics that could potentially affect the onset of railways. As mentioned earlier, many of the first districts to get railways were large cities. In our sample, 9 of the first 16 districts to have railways were big in the sense that their population exceeded 50,000. There were also provincial differences. Punjab got railways quickly because it was a major wheat-producing area. Other

districts got railways because they were of military importance or susceptible to famine.⁵ By including dummies for large populations, nearness to the coast, nearness to the Ganges, and being in the same state our regressions should control for some of the endogeneity of railway timing. With respect to the remaining endogeneity, it is not obvious which way it would bias our estimates. The process used by the British in choosing where and when to build railways was cryptic. For instance, for some reason many of the most abundant cotton lands were entirely bypassed by railroads until close to the end of the century. Also, a number of major marketing centers were avoided (Whitcombe and Hurd (1983)). The fact that our results are fairly similar with and without fixed effects suggests that this endogeneity problem is not severe.

To estimate possible anticipation effects from the building of railways, we added dummies for several years before their introduction to our fixed effect regression. Table 5 reports the result. The year just before railways were added is significantly negative, though the estimate is small: about half a percentage point. But in the years before that the effects are positive as often as negative. Thus it doesn't seem to be the case that railways have much of an effect on price dispersion before they are built.

Conclusion and Extensions

Evidence suggests that late 19th century India was indeed an integrated market, but that the contribution from railways was relatively small. Having railways reduces price dispersion between districts about as much as being on the Ganges or the coast. Price dispersion was falling rapidly from 1860-1920, but railways only seem capable of explaining about 10% of the drop. The modest contribution derives from the fact that prices were converging almost as rapidly between districts without railways.

⁵ Though it seems that the "famine lines" were mostly built after 1880 (McAlpin 1979)

So perhaps some other factors were responsible for most of the price convergence at that time. Evidence on the significant level of price dispersion between districts in British India and Princely States suggests that political barriers might have mattered. It is therefore noteworthy that just before the beginning of our sample period a number of important states were added to British India. Over time this would have led to increased institutional homogenization in our sample.

These results bear on the ongoing debate on the impact of colonialism on India. Proponents of the view that the British economic influence was positive (Morris (1963)) often cite the extensive railway system as a landmark achievement. Landes (1998) suggests that railways helped to alleviate famines. Opponents of this view (Chandra 1968, Davis 2001) argue that railways were built to benefit the British, not India, and that they exacerbated famines. Our results fall in the middle. On the one hand, the direct impact of railways on market integration appears to be small, so perhaps their contribution to the Indian economy was exaggerated. On the other hand, the possibility that institutional homogenization may have played a key role in that integration implies that the total economic benefits of colonialism may have been more positive. Of course, the magnitude of those benefits depends on how much market integration helped the country, something we don't attempt to measure in this paper.

One could extend this analysis in a number of ways. Most importantly would be to obtain a measure of institutional differences to rigorously test our hypothesis of institutional integration. We are also curious about the impact of the telegraph system that the British built at the same time on market integration. Lew and Cater (2004) provide evidence that the diffusion of the telegraph was an important factor in the growth of world trade in the late nineteenth century. Figure 5 shows the rise of telegraph signal office in India in the nineteenth century.

Since the rise of telegraph at the all India level is positively correlated with rise of railway linkages, we need to get the spread of telegraph across districts and over time. Keller and Shiue (2004) look at the predictive power of market integration in the 17th century in China on current economic outcomes. Banerjee and Iyer (2003) also look at the impact of historical institutions and events such as land revenue systems on current outcomes in India. Our paper could be expanded to estimate the persistent effects of market integration in 19th century India on economic outcomes there today. Finally we have panel data on rice prices during our sample period, which could be used to test the robustness of our results. Further research is clearly called for to confirm the linkages between institutions and technology in promoting economic activity.

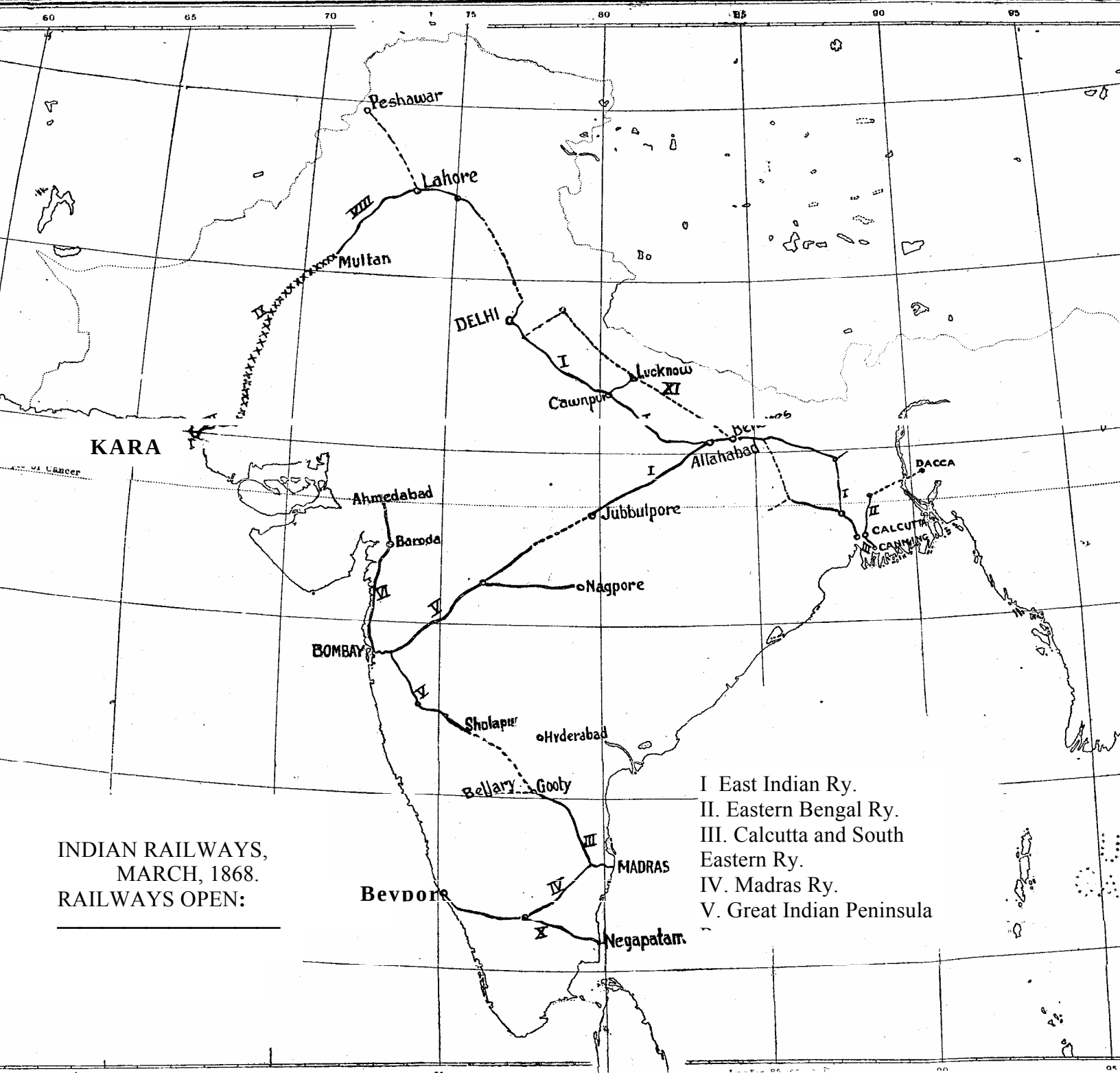


Figure 1. Map of Indian Railways in 1868
Source: Sanyal (1930)

Figure 2: Standard Deviation of the Log Wheat Price and the Number of Districts with Railways (out of 159 districts)

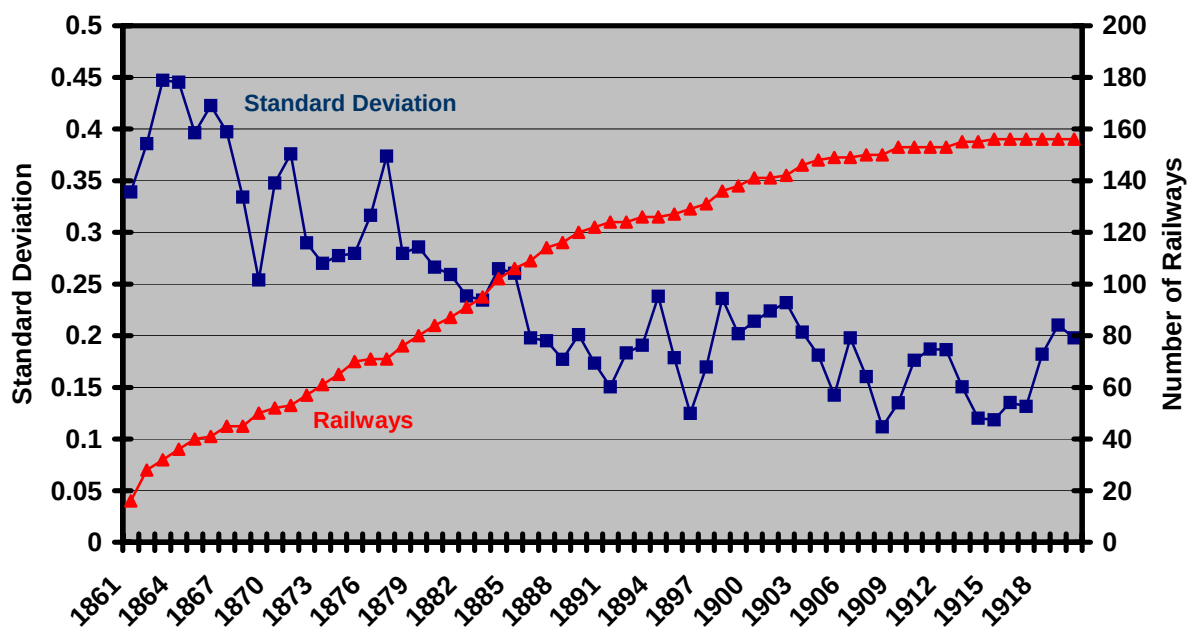


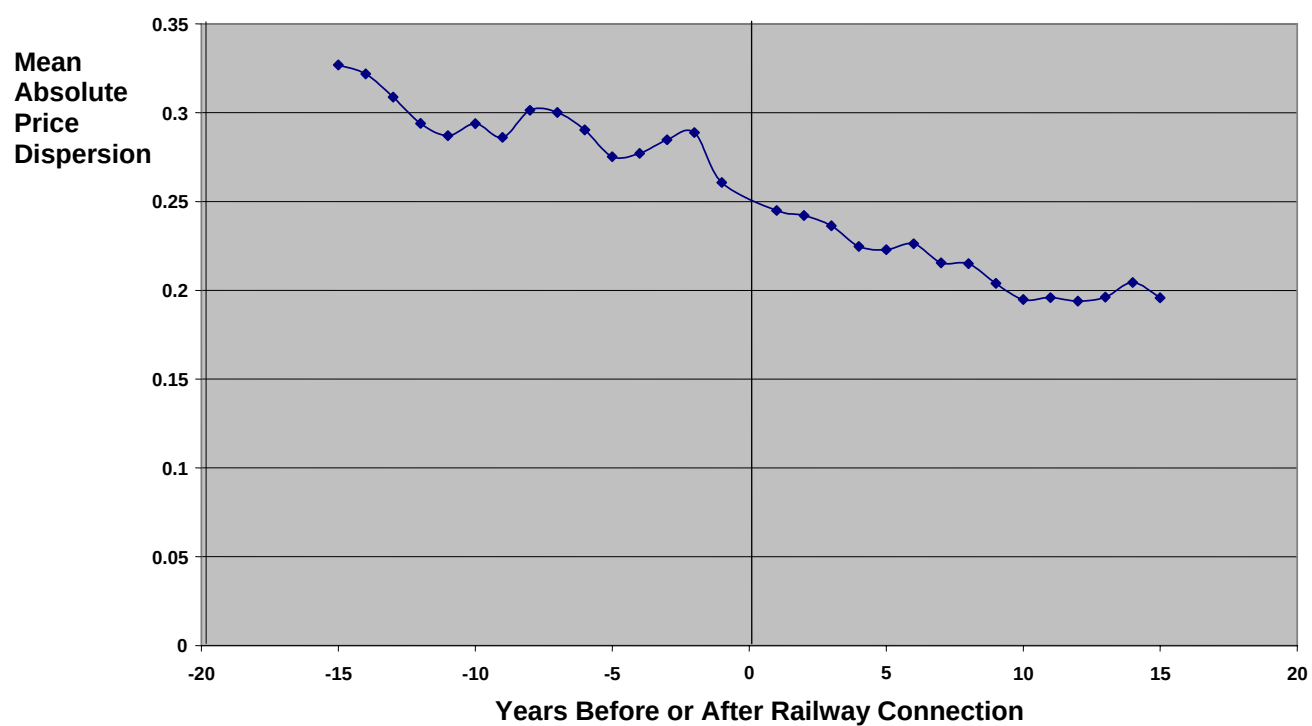
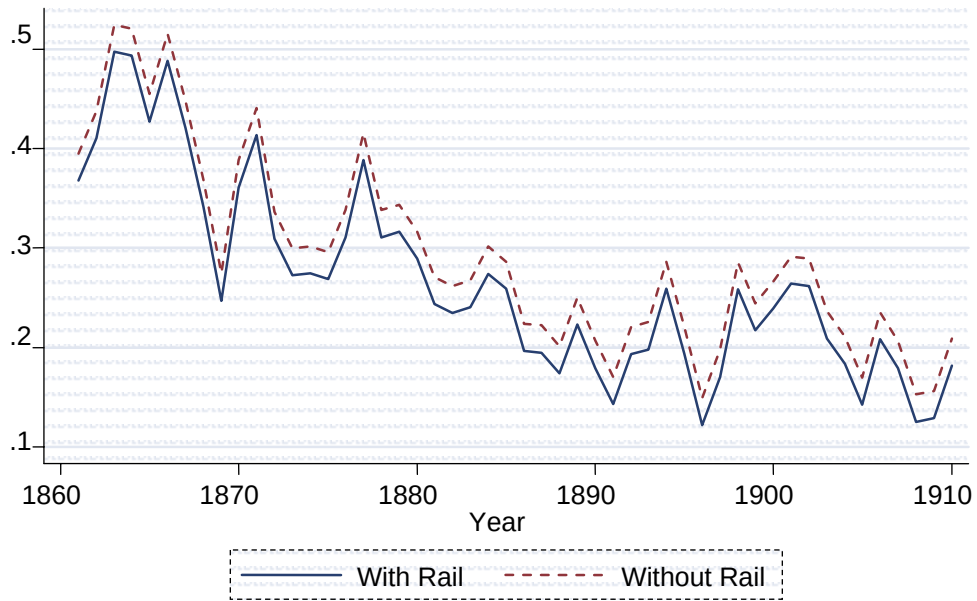
Figure 3: Price Dispersion Before and After Railways

Figure 4: Predicted Value of Mean Absolute Price Differential

Regression Results from Table 4 Column 2, Sample 1

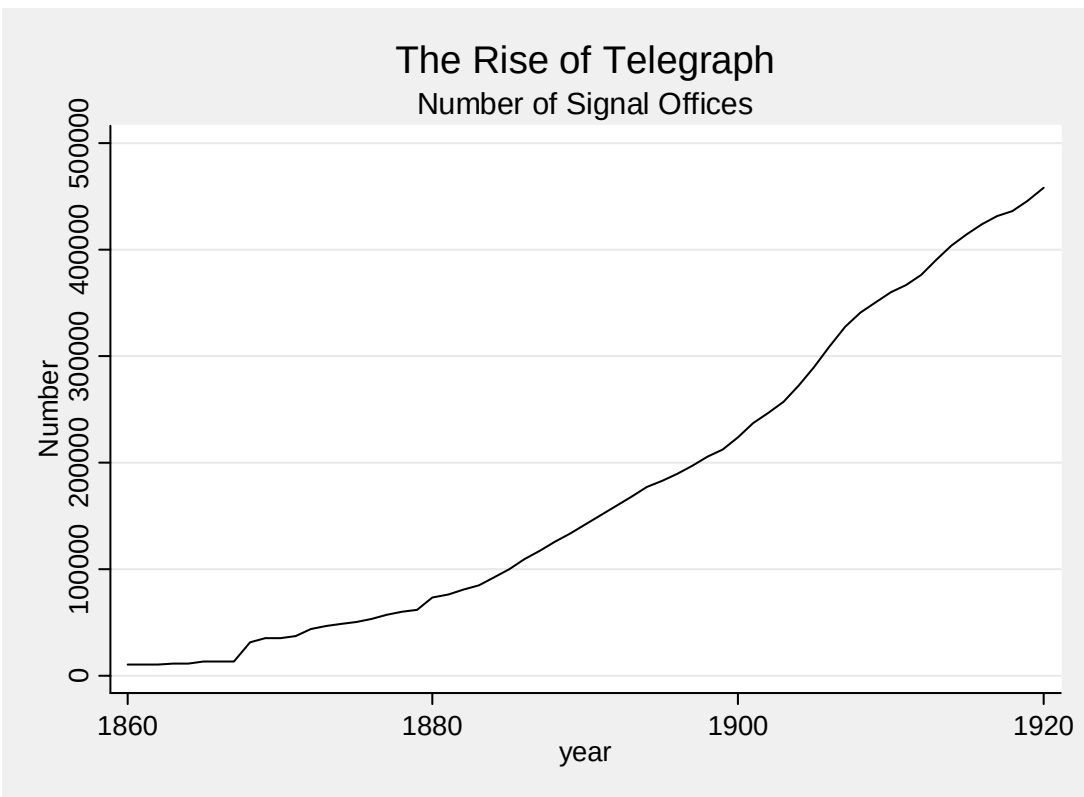
Figure 5

Table 1
Summary Statistics of Variables

Sample 1: 114 Districts

Years 1861-1920

No Missing Prices

Variable	Obs.	Mean	St. Dev.	Minimum	Maximum
Absolute Price Differential	386,460	0.262	0.248	0	2.427
Log Distance	386,460	6.147	0.751	2.024	8.178
One Princely State	386,460	0.052	0.221	0	1
Both Big Cities	386,460	0.072	0.259	0	1
Both on Ganges	386,460	0.021	0.144	0	1
Both on Coast	386,460	0.009	0.090	0	1
Same State	386,460	0.180	0.385	0	1
Both have Railways	386,460	0.555	0.497	0	1

Sample 2: 147 districts

No missing prices 1873-1913

Prices for all available consecutive years 1861-1920

Variable	Obs.	Mean	Std. Dev.	Min	Max
Absolute Price Differential	617,439	0.260	0.242	0	2.580
Log Distance	617,439	6.194	0.728	1.949	8.178
One Princely State	617,439	0.143	0.350	0	1
Both Big Cities	617,439	0.061	0.240	0	1
Both on Ganges	617,439	0.025	0.157	0	1
Both on Coast	617,439	0.007	0.085	0	1
Same State	617,439	0.136	0.343	0	1
Both have Railways	617,439	0.535	0.499	0	1

Table 2
Levin-Lin Panel Unit Root Tests

Sample	t-star	p -value	$\hat{p}$	Approximate half-life (years)
<u>Price Level Test</u>				
1861-1920 (114 districts)	-37.544	0.000	0.506	1.019
<u>Inflation Rate Test</u>				
1862-1920 (114 districts)	-98.358	0.000	-0.133	*
<u>Price Level Test</u>				
1874-1913 (149 districts)	-28.417	0.000	0.544	1.140
<u>Inflation Rate Test</u>				
1875-1913 (149 districts)	-77.352	0.000	-0.103	*

Notes: The price level is the deviation of the log price from the mean log price each year. The inflation rate is the deviation of the difference in log prices (current minus lagged) from the mean difference in log prices each year. * cannot be estimated given the negative estimate of $\hat{p}$.

Table 3
Im-Pesaran-Shin Panel Unit Root Tests

Sample	standardized t-bar	p -value
<u>Price Level Tests</u>		
1861-1920 (114 districts)	-41.374	0.000
<u>Inflation Rate Tests</u>		
1862-1920 (114 districts)	-95.766	0.000
<u>Price Level Tests</u>		
1874-1913 (149 districts)	-29.913	0.000
<u>Inflation Rate Tests</u>		
1875-1913 (149 districts)	-75.835	0.000

Notes: The price level is the deviation of the log price from the mean log price each year. The inflation rate is the deviation of the difference in log prices (current minus lagged) from the mean difference in log prices each year.

Table 4
Absolute Price Dispersion

Sample 1 114 districts		w/o time effects	with year dummy	with quadratic trend
	BothRail	-0.1680 (225.71)***	-0.0273 (28.95)***	-0.0273 (27.74)***
	Observations	386460	386460	386460
	R-squared	0.44	0.53	0.50
Sample 2 147 districts				
	BothRail	-0.1560 (263.48)***	-0.0283 (37.94)***	-0.0281 (36.30)***
	Observations	617439	617439	617439
	R-squared	0.43	0.51	0.48

All regressions control for district pair fixed effects

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 5
Absolute Price Dispersion

	Sample 1	Sample 1	Sample 2	Sample 2
	Year	Quadratic	Year	Quadratic
	Dummies	Trend	Dummies	Trend
BothRail	-0.0388 (0.0009)***	-0.0386 (0.0009)***	-0.0446 (0.0007)***	-0.0443 (0.0007)***
LnDistance	0.0852 (0.0006)***	0.0852 (0.0006)***	0.0829 (0.0004)***	0.0830 (0.0004)***
BothLargeCity	-0.0058 (0.0013)***	-0.0059 (0.0013)***	0.0045 (0.0011)***	0.0043 (0.0011)***
BothonGanges	-0.0399 (0.0016)***	-0.0399 (0.0015)***	-0.0595 (0.0012)***	-0.0592 (0.0012)***
BothonCoast	-0.0291 (0.0029)***	-0.0291 (0.0030)***	-0.0453 (0.0025)***	-0.0452 (0.0025)***
Same State	-0.0337 (0.0009)***	-0.0337 (0.0009)***	-0.0216 (0.0008)***	-0.0217 (0.0008)***
OnePrincelyState	0.1750 (0.0019)***	0.1750 (0.0020)***	0.0338 (0.0008)***	0.0330 (0.0008)***
Observations	386460	386460	617439	617439
R-squared	.30	.27	0.25	0.22

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6
Absolute Price Dispersion
Sample 1

	(1)	(2)	(3)	(4)
BothRail	-0.027307 (28.95)***	-0.0280 (28.75)***	-0.0261 (26.00)***	-0.0284 (25.77)***
BeforeYear1		-0.0066 (2.95)***	-0.0053 (2.34)**	-0.0069 (3.05)***
BeforeYear2			0.0185 (7.93)***	0.0168 (7.14)***
BeforeYear3				0.0027 (1.11)
BeforeYear4				-0.0133 (5.42)***
BeforeYear5				-0.0137 (5.69)***
Observations	386,460	386,460	386,460	386,460
R-squared	0.53	0.53	0.53	0.53

All regressions run with district pair fixed effects and year dummies

Robust t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

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