# New Technology, Better Economy?

## The Heterogeneous Impact of Colonial Railroads in Nigeria

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# Colonial and Present-day Railroads and Roads in Africa

- **Colonial British West Africa.** Chaves et al (2014)
- **Kenya.** Jedwab et al. (2016)
- **Horn of Africa, Ethiopia.** Bertazzini (2022)
- **South Africa.** Herranz-Loncan et al. (2018)
- **Sub-Saharan Africa, Ghana.** Jedwab and Moradi (2015)
- **Sub-Saharan Africa.** Abbasi et al. (2022)
- **Nigeria.** Okoye et al. (2019)

# Colonial Investments in African Railroads

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  - → Railroads accounted for approximately one-third of colonial budgets
- Colonial powers primarily built railroads to facilitate export trade, as well as to maintain military dominance within their colonies
  - → Railroads typically connected ports with resource rich regions of the interior
- Railway construction took place in a diversity of geographic and technological contexts
  - → Little is known about how these contexts matter for the long-term impact of colonial railway in Africa

## This Paper: What we Do

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   - → Media access
   - → Wealth
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2. Analyze the **heterogeneous effect** of colonial railway by region and pre-railway access to **export markets**
   - → **How does access to pre-railway transportation technologies affect the impact of railway?**

3. Explore possible mechanisms:
   - → Costs of railway relative to alternative technologies
   - → Differential adoption rates of railway in northern vs. southern Nigeria

# Transportation Technologies in Colonial Nigeria

- Colonial railway was constructed between 1895 and 1935
- By the 1970s, Nigeria's railroads had fallen into disuse
- Pre-railway transportation technologies included:
  - → Head portage
  - → Bicycles
  - → Animals
  - → Carts
  - → Inland waterways
  - → Caravan routes
  - → Roads

# Motivation for Railroad Construction

> *So vast an area as Nigeria, comprising in all some 380,000 square miles... cannot be commercially developed except by railways — p.19 of the Colonial Report of Northern Nigeria, 1900-1901, as quoted in Onyewuenyi (1981, p.65).*

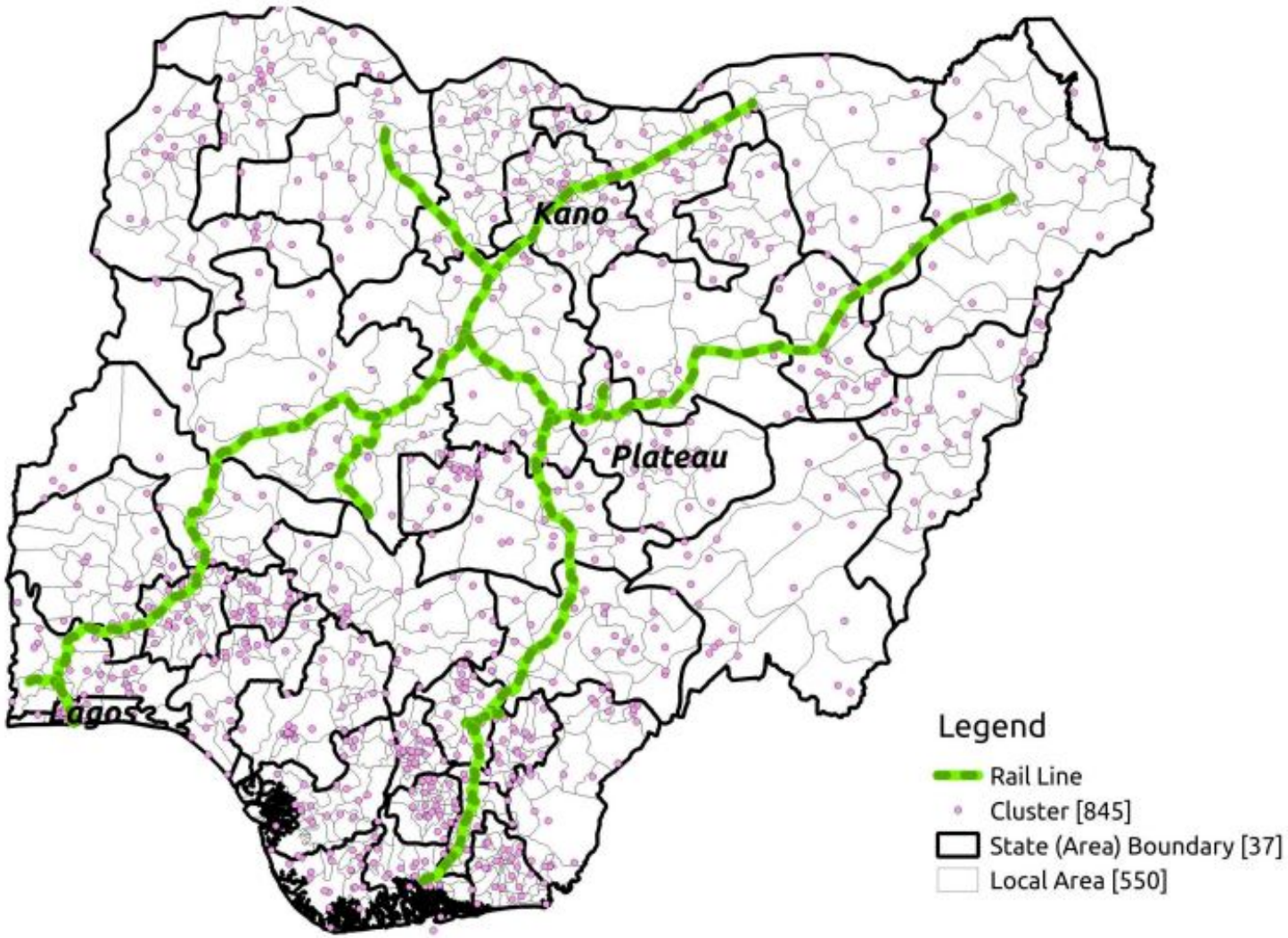
- The British saw the construction of railways as necessary to link the Nigerian interior to its coastal ports
- Railways were primarily built to facilitate the export of agricultural products



## Motivation for Railraod Construction (con'd)

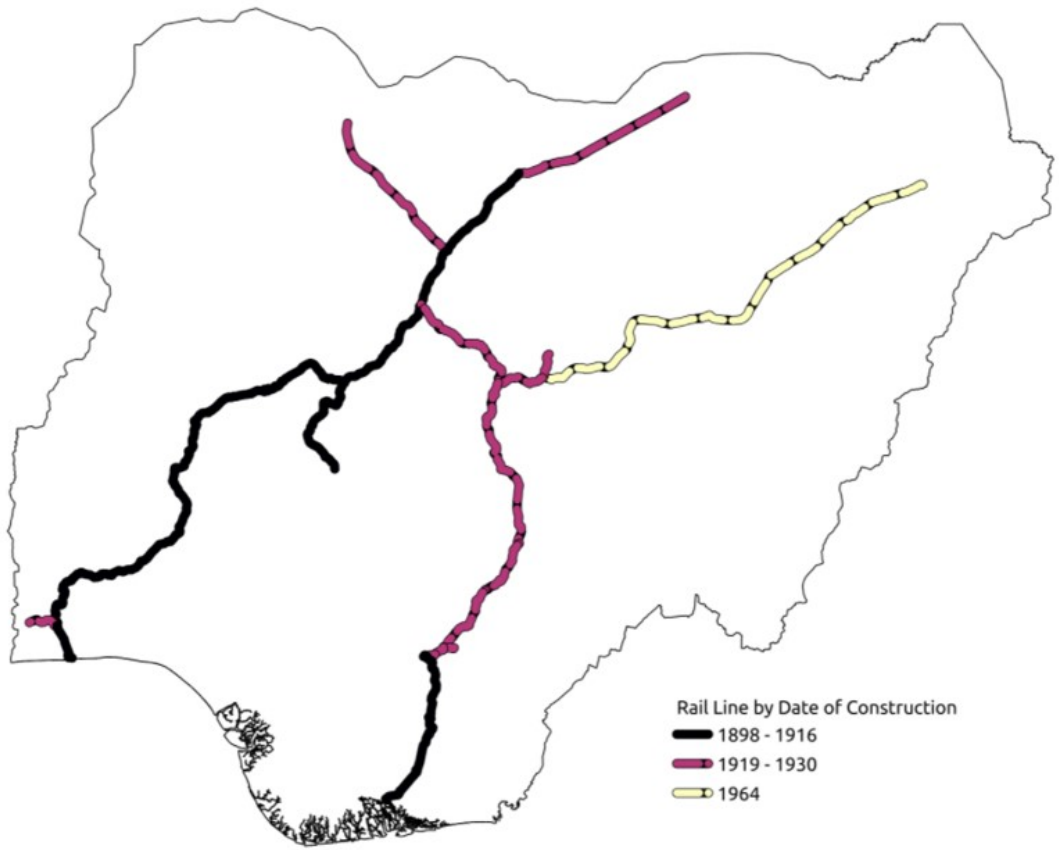
*The increase in the export of this valuable product (hides) is most gratifying, and as communication with Northern Nigeria is facilitated,* ***it is expected to divert the greater proportion of this trade, which at present is said to go across to Tripoli.*** — *p. 22 of Colonial Report, Southern Nigeria, Lagos, 1905 as quoted in (Onyewuenyi, 1981, p.66).*

# Colonial Railroad in Nigeria



# Construction of Nigeria's Colonial Railroads Occurred in Three Stages

- Phase 1: initial penetration lines
- Phase 2: linking interior to ports
- Phase 3: branch lines and extensions



# Motivation for the Construction of Railroad Lines

| Link | Date | Length(km) | Motivation |
|---|---|---|---|
| Lagos - Otta | 1898 | 32 | Administrative & Agricultural |
| Otta - Abeokuta - Ibadan | 1901 | 165 | Administrative & Agricultural |
| Ibadan - Ilorin | 1908 | 201 | Administrative & Agricultural |
| Ilorin - Jebba | 1909 | 96 | Administrative & Agricultural |
| Zaria - Jos - Bukuru | 1911 | 227 | Mineral |
| Jebba - Zungeru - Minna | 1912 | 233 | Administrative & Agricultural |
| Baro - Kano | 1912 | 573 | Administrative & Agricultural |
| Port Harcourt - Enugu | 1916 | 243 | Agricultural & Mineral |
| Enugu - Makurdi - Jos | 1927 | 596 | Agricultural & Mineral |
| Kaduna - Kafanchan | 1927 | 201 | Administrative & Mineral |
| Zaria - Gusau - Kaura Namoda | 1929 | 232 | Agricultural |
| Kano - Nguru | 1930 | 229 | Agricultural |
| Ifo - Ilaro - Idogo | 1930 | 39 | Agricultural |
| Jos - Maiduguri | 1964 | 645 | Agricultural |

## Historical Immediate Impacts of Railways

*In the Northern Provinces, the history of export cotton production, like that of groundnut has been closely linked with the history of railway expansion, and it was not until the railway reached Kano in 1912 that the export cotton production attained any importance — as quoted in Lamb (1925, p.19).*



Figure 1: Groundnut Pyramids in Northern Nigeria

# Historical Immediate Impacts of Railways (con'd)

Figure 2: Northern crops (groundnut) shipped via railway

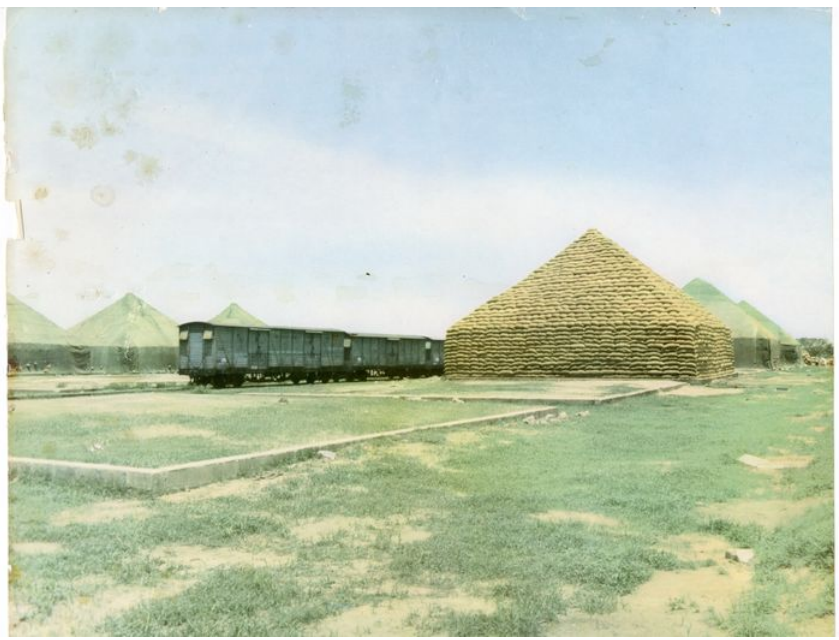


Figure 3: Southern crops (palm oil) shipped via inland waterways



# Data Sources

- Individual and household level data: **Nigeria Demographic and Health Surveys** (2008)
- Data on transportation infrastructures from **Digital Charts of the World** and **OpenStreetMaps**
- Information on planned but unconstructed (placebo) lines from **Jaekel (1997)**
- Mission stations in 1928 from **Roome (1924)** and **Ayandele (1966)**
- Historical data on cities location and urban populations (in 1890/1900, 1960, 1980 and 2010) from **Africapolis** and **Jedwab and Moradi (2015)**
- Geographic, climatic, soil conditions, crop yield potential, for each cluster and area, from the **FAO GAEZ database**

# Identification Problem and Empirical Strategies

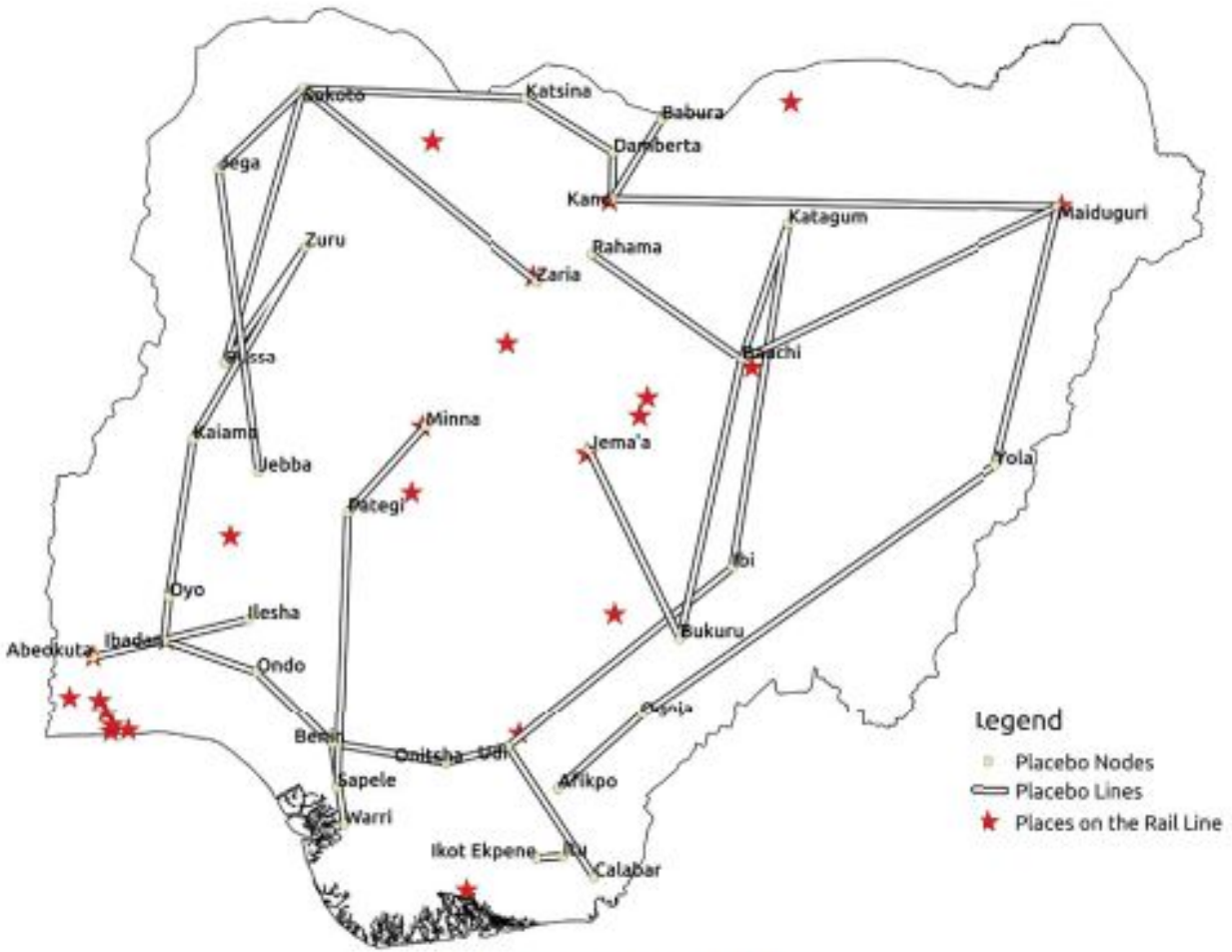
- Colonial railways were constructed to connect areas suitable for agricultural and mineral exploitation to the coast.
- Therefore, targeted and non-targeted areas likely differed in a number of economically important ways
- Three strategies to account for this issue
  - → State fixed effects
  - → Instrumental Variable
  - → Placebo lines

# Third Strategy: Placebo Lines

- Placebo lines are segments that were extensively surveyed and proposed for railway construction but were never actually built
- Placebo lines were not constructed for 3 main reasons
  - → Idiosyncratic factors such as disagreement between experts, or the First World War
  - → Budgetary constraints
  - → Terrain conditions

# Third Strategy: Placebo Lines (con'd)

- Goal: Compare areas connected to railways to areas that were intended to be connected, but were not
- Empirical Specification



# Estimation Strategy: Placebo Lines as Control Group

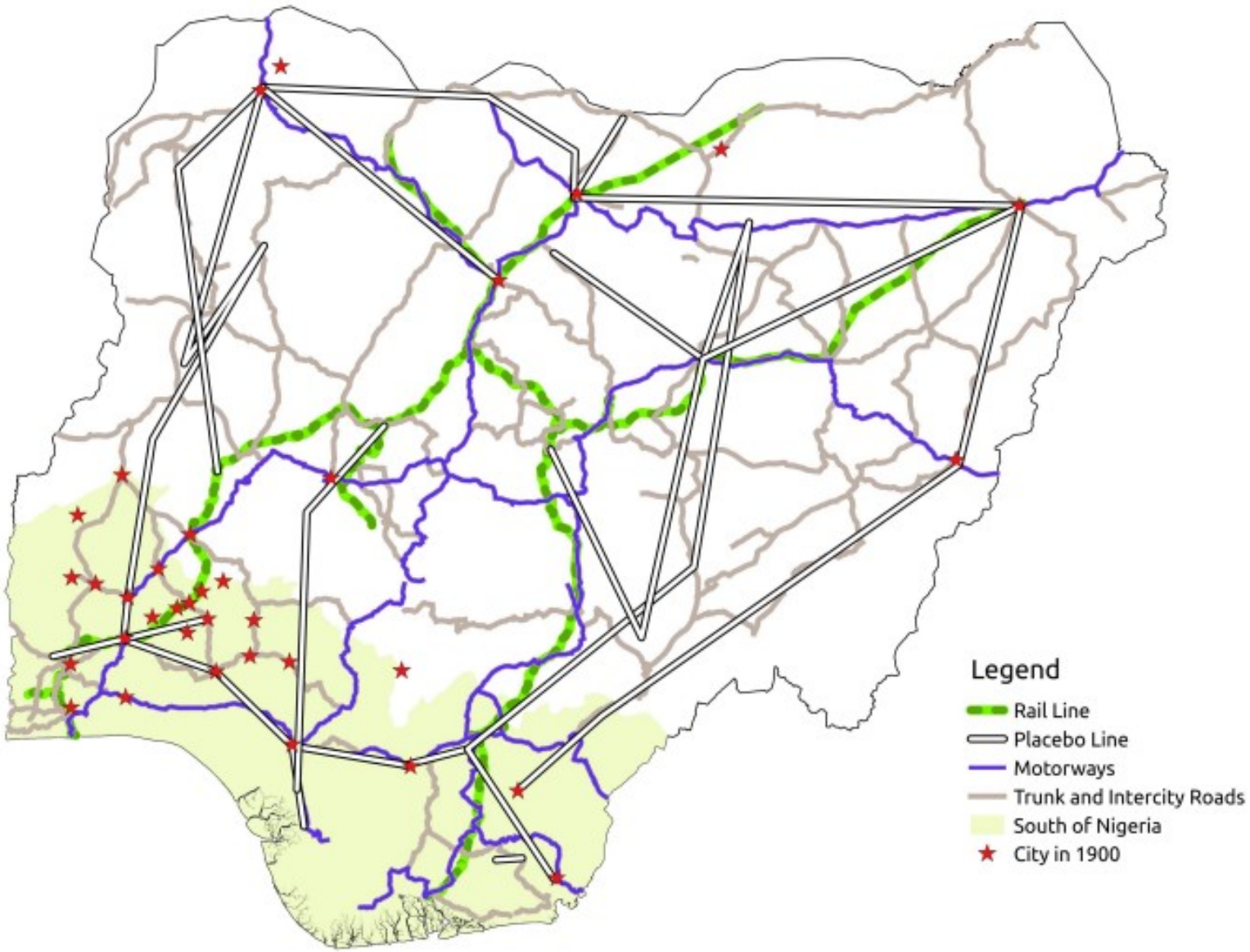
| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 *km* | 0.964*** | 0.058** | 0.490*** | 0.139* |
| | [0.348] | [0.023] | [0.147] | [0.072] |
| Observations | 16587 | 16502 | 16601 | 16601 |

State FE and IV results

# Heterogeneity in the Long-Run Impact of Colonial Railways

- How does the long-term effect of colonial railways depend on pre-railway access to viable transportation technologies and ports of export?
  - → Analyze North/South heterogeneity in the long-term impact of colonial railways in Nigeria

# North/South Heterogeneity



# North/South Heterogeneity (con'd)

- The north and south of Nigeria had very different economic and trade situations prior to the railways' construction

- Southern Nigeria:
  - → Close to the coast and could access major ports through roads and waterways
  - → Operated trade routes with Europe for centuries prior to construction of railways

- Northern Nigeria:
  - → Had little access to coastal ports or European markets
  - → Trade was historically oriented towards Trans-Saharan trade routes

- The number of pre-railway cities was also higher in Nigeria's southern region

- These differences raise the possibility that the economic impacts of the railway differ between these regions

# North/South Heterogeneity: Placebo Line Results

Panel A: North (Estimation Strategy : Placebo Lines)

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 km | 1.716*** | 0.093*** | 0.712*** | 0.157* |
| | [0.415] | [0.024] | [0.169] | [0.087] |
| Observations | 8547 | 8487 | 8558 | 8558 |

Panel B: South (Estimation Strategy : Placebo Lines)

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 km | −0.791** | −0.044 | −0.087 | 0.008 |
| | [0.325] | [0.031] | [0.191] | [0.121] |
| Observations | 8038 | 8013 | 8041 | 8041 |

The placebo line identification strategy used is identical to the general case, with the exception that the sample is restricted to either the north or south of Nigeria.

Heterogeneity State FE Heterogeneity IV

# Long-Run Effects of Railways on Urbanization Outcomes

Panel A: Dependent Variable: Z-score of City Presence in 2010

| | (1) All | (2) North | (3) South | (4) All | (5) North | (6) South |
|---|---|---|---|---|---|---|
| Rail Within 20 *km* | 0.098* | 0.137** | -0.031 | 0.068 | 0.098** | -0.033 |
| | [0.051] | [0.054] | [0.128] | [0.044] | [0.046] | [0.107] |
| 1900 City Z-score | 0.178*** | 0.203*** | 0.167*** | | | |
| | [0.014] | [0.017] | [0.020] | | | |
| 1960 City Z-score | | | | 0.451*** | 0.472*** | 0.427*** |
| | | | | [0.009] | [0.009] | [0.016] |
| Observations | 7487 | 5978 | 1523 | 7487 | 5978 | 1523 |

Panel B: Dependent Variable: Z-score of Urban Population in 2010

| | (1) All | (2) North | (3) South | (4) All | (5) North | (6) South |
|---|---|---|---|---|---|---|
| Rail Within 20 *km* | 0.095* | 0.078* | -0.030 | -0.007 | 0.001 | -0.077 |
| | [0.054] | [0.046] | [0.084] | [0.015] | [0.010] | [0.063] |
| 1900 Pop. Z-score | 0.375*** | 1.311** | 0.241*** | | | |
| | [0.118] | [0.511] | [0.052] | | | |
| 1960 Pop. Z-score | | | | 0.830*** | 0.875*** | 0.821*** |
| | | | | [0.038] | [0.016] | [0.104] |
| Observations | 7487 | 5978 | 1523 | 7487 | 5978 | 1523 |

# Explaining North/South Heterogeneity in the Impact of Railroads

These results indicate that railroad proximity has significant positive effects on economic development in the north, but has little impact on development in the south.

- One explanation for this phenomenon is the relative cost of rail transport in north and south.

- In the south, the railway did not significantly alter shipping costs.
  - → Shipping by road and waterway remained cheaper then rail in the South.
  - → Trade and production patterns largely remained unchanged

- In the north, railways significantly reduced transportation costs and altered existing dynamics of production and trade.
  - → The railway redirected Northern trade from Trans-Saharan routes to coastal ports.
  - → Compared to palm produce (southern crop) which grew at less than 2% a year over the 1900-1949 period, groundnuts and cotton (main northern crops) grew respectively at 14% and 8% a year.

# Differential Shipping Costs

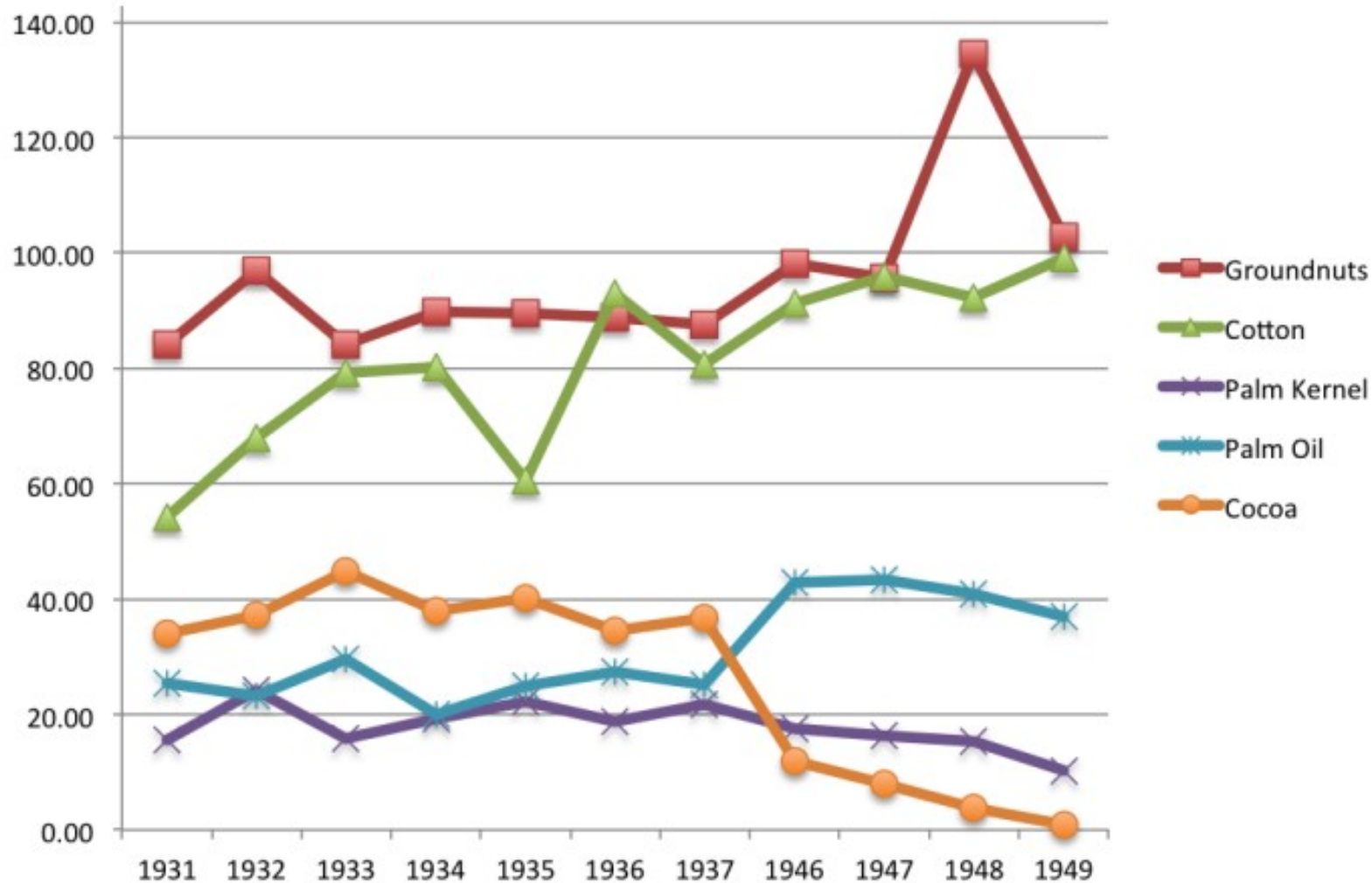
Key regional crops (1945-1949 : peak of railway use)

| | Northern Crops | | Southern Crops | |
|---|---|---|---|---|
| **Estimates** | **Groundnuts** | **Cotton** | **Palm Oil** | **Cocoa** |
| **Rail Price (pence per ton km)** | 1.95 | 1.37 | 3.95 | 2.08 |
| **River Price (pence per ton km)** | .9 (+ 3.1 rail) | 2.5 (+ 3.1 rail) | 1.8 | 1.8 |
| **Road Price (pence per ton km)** | 5.6 | 5.6 | 2.5 | 1.3 |
| **Distance Rail (km)** | 1127 | 1159 | 61 | 193 |
| **Distance River (km)** | 575 river (+573 rail) | 575 river (+573 rail) | 61 | 193 |
| **Quantity in tons (1945-1949)** | 268409 | 5508 | 447920 | 96614 |
| **Cost Reduction From Rail** | | | | |
| gold **As % of River Cost** | -4.2 | -50.6 | 119.4 | 15.6 |
| lavender **As % of Road Cost** | -65.2 | -75.5 | 58.0 | 60.0 |

## Low Shipping Costs of Northern Crops

*In the Northern Provinces, the history of export cotton production, like that of groundnut has been closely linked with the history of railway expansion, and it was not until the railway reached Kano in 1912 that the export cotton production attained any importance — as quoted in Lamb (1925, p.19).*

# Railway Adoption for Northern and Southern Main Exports



## Robustness Checks

- Impacts do not vary by timing and stated reason for construction
- Placebo lines do not show similar impacts
- Similar impacts when placebo lines used as control
- No difference in impact beyond $20km$
- Balance test valid for North/South, and also Rail/Placebo
- Impacts do not vary with different control groups (within $40, 60, 80km$)
- Robust to other measures of connectedness (continuous, rail in local area)
- Robust to using an artificial grid instead of official divisions
- Robust to excluding:
  - $\rightarrow$ migrants
  - $\rightarrow$ areas with missions, observations with rail/stations in local area
- Robust to using Conley Standard errors to correct for spatial autocorrelation
- Do not change when we control for major roads and rivers, or distance to early cities

# Conclusions and Implications

- On average, proximity to colonial rail lines has a significant positive impact on local development in Nigeria
- However, further analysis reveals that this effect is concentrated in the north and largely absent in the south.
  - → The south had cheaper pre-exisitng alternatives to rail transport
  - → Railways altered the pre-railway trade equilibrium only in the north
- These findings are consistent with Fogel's hypothesis
  - → Larger impact of rail in areas where new trade developed as a result
  - → Areas with no viable alternatives
  - → Lessons for transportation planning

# Thank you!

# First Strategy: State Fixed Effects

- Within targeted areas (states), compare areas close to rail lines with areas further away
- **Claim: Within a targeted area, after controlling for construction motives (agricultural, mineral) and geo-climatic factors, precise location of the rail line was plausibly exogenous to contemporary or future development**
- Balance Test
- Empirical Specification

Go back to Strategy

# First Strategy: State Fixed Effects - Balance Test

| | **Within 20 km of Rail** | | | | **Outside 20 km of Rail** | | | | **Difference** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | North | South | Mean | SD | North | South | Overall | Within |
| Rainfall(m) | 1.47 | .59 | .91 | 1.79 | 1.5 | .71 | .94 | 2.02 | -.03 | -.01 |
| Temperature | 26.36 | .62 | 26.03 | 26.54 | 26.38 | .84 | 26.4 | 26.35 | -.02 | .01 |
| Nutrient Retention | 1.53 | .69 | 1.61 | 1.48 | 1.38 | .64 | 1.45 | 1.31 | .15 | -.03 |
| Workability | 1.99 | .86 | 1.49 | 2.28 | 1.75 | .77 | 1.44 | 2.04 | .24** | .01 |
| Elevation (km) | .22 | .21 | .45 | .08 | .25 | .19 | .38 | .13 | -.03 | -.01 |
| Oil Palm Suit | 2.86 | 2.05 | .35 | 4.29 | 2.44 | 2.08 | .5 | 4.2 | .42* | .11* |
| Cocoa Suit | .67 | .47 | .09 | 1 | .59 | .49 | .14 | 1 | .08 | 0 |
| Cotton Suit | .35 | .48 | .97 | 0 | .43 | .49 | .85 | .04 | -.08 | -.04* |
| Groundnut Suit | 1.82 | .39 | 2 | 1.72 | 1.8 | .4 | 2 | 1.62 | .02 | -.01* |
| Mission Station | .25 | .43 | .11 | .32 | .21 | .4 | .1 | .3 | .04 | .12** |
| Waterway Within 20 km | .37 | .48 | .27 | .43 | .33 | .47 | .26 | .39 | .05 | .02 |
| City Presence 1900 | .07 | .26 | .08 | .07 | .07 | .26 | .02 | .12 | 0 | .01 |
| City Pop 1900 (K) | 4.26 | 19.23 | 2.07 | 5.51 | 1.8 | 7.74 | .27 | 3.18 | 2.46 | 2.16 |
| Number of Observations | 10386 | 10386 | 4617 | 5769 | 28980 | 28980 | 15312 | 13668 | 39366 | 39366 |
| Number of Clusters | 208 | 208 | 94 | 114 | 637 | 637 | 343 | 294 | 845 | 845 |
| Number of Local Areas | 134 | 134 | 66 | 69 | 436 | 436 | 243 | 193 | 550 | 550 |

Back to State Fixed Effects

# Baseline Specification: State Fixed Effects

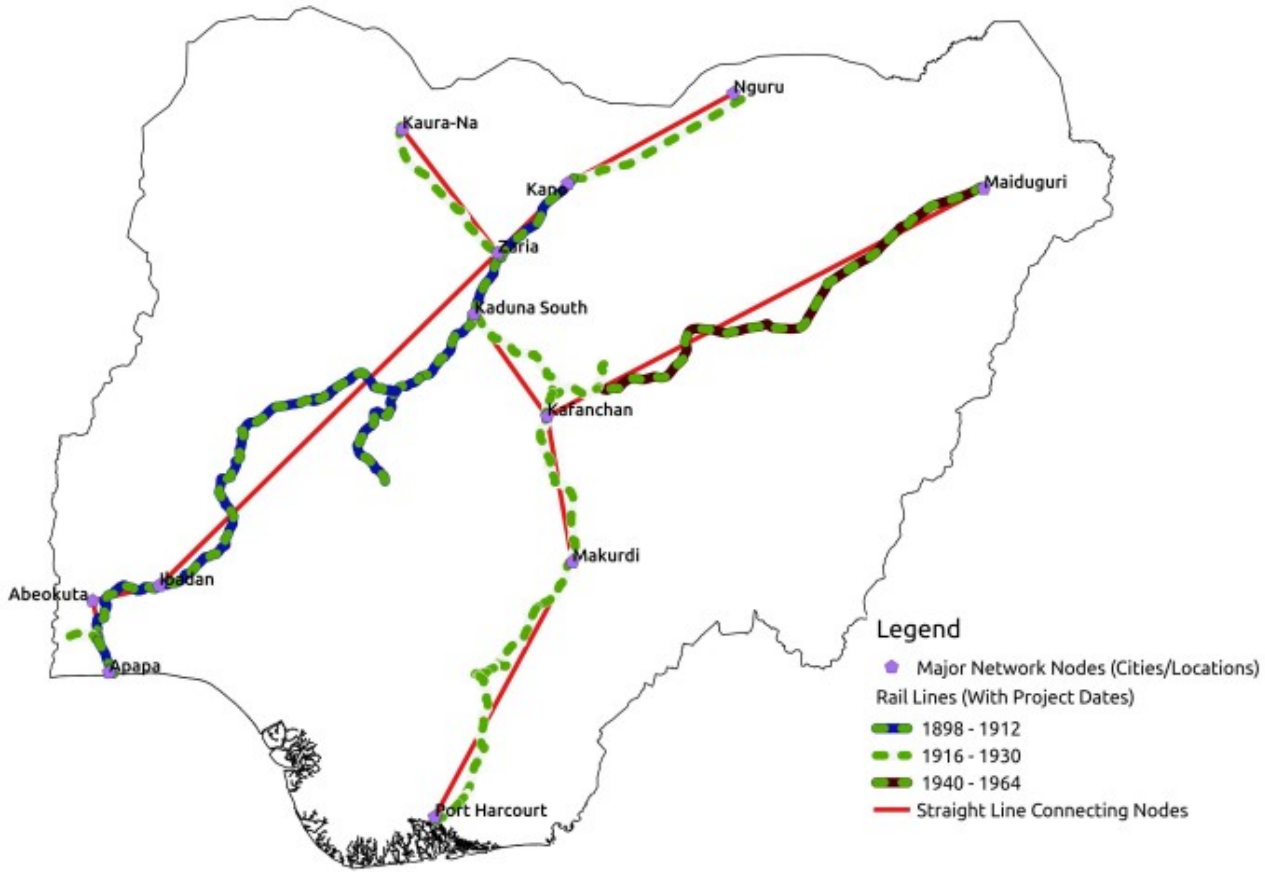
$$Y_{i,h,a,e,s} = \Phi + \beta R_{i \leqslant 20} + X_a \Lambda + X_i \Pi + \alpha_s + \gamma_e + \epsilon_{i,h,a,e,s}$$

- $R_{i \leqslant 20}$ is a binary variable equal to one if an individual lives within 20 km of a railway
- $\alpha_s$ and $\gamma_e$ stands for state and ethnicity fixed effects, respectively
- $X_i$ is a vector of individuals characteristics
- $X_a$ is a vector of households characteristics
- $\epsilon_{i,h,a,e,s}$ is the error term.

Back to State fixed effects

# Second Strategy: Instrumental Variable

- Use distance to straight line segments between nodes as an instrument.
- Exclude nodes
- Line segments are the minimum straight-line paths connecting pre-railway trading, mining, and agricultural centers to the Nigerian coast.




Go back to Strategy

## Baseline Specification: Instrumental Variable Approach

Regression equation for first stage least squares:

$$R_{i\leqslant 20,h,a} = \Phi + \beta R_i + X_h \Lambda + \epsilon_{i,h,a},$$

$R_{i\leqslant 20,h,a}$ is a binary variable equal to one if a an individual lives within 20km of a rail line.

- $R_i$ is the natural log of the distance to the network of strait lines connecting nodes.
- $X_h$ is a vector of local area characteristics.
  - Specifically: rainfall, temperature, elevation, proximity to historical mission stations, palm oil suitability, cocoa suitability, cotton suitability, groundnut suitability, the workablity of the soil, and the soil's level of nutrient retention.
- $\epsilon_{i,h,a}$ is the error term.

Back to IV

# State FE and IV Results

Panel A: Estimation Strategy: State Fixed Effects

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 *km* | 1.367*** | 0.080*** | 0.657*** | 0.186*** |
| | [0.259] | [0.016] | [0.103] | [0.050] |
| Baseline Controls | Yes | Yes | Yes | Yes |
| State FE | Yes | Yes | Yes | Yes |
| Ethnicity FE | Yes | Yes | Yes | Yes |
| Observations | 39156 | 38986 | 39191 | 39191 |
| Adjusted R-sq. | 0.47 | 0.20 | 0.49 | 0.29 |
| Control Means | 6.004 | 0.266 | 2.866 | 0.275 |

Panel B: Estimation Strategy: Instrumental Variables

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 *km* | 1.504*** | 0.086*** | 0.663*** | 0.119 |
| | [0.394] | [0.026] | [0.162] | [0.078] |
| Observations | 37447 | 37284 | 37481 | 37481 |
| Centered R-sq. | 0.47 | 0.20 | 0.48 | 0.29 |
| Control Means | 6.004 | 0.266 | 2.866 | 0.275 |
| Kleibergen-Paap UnderId | 85.22 | 85.32 | 85.28 | 85.28 |
| Kleibergen-Paap Wald F | 199.23 | 197.64 | 199.51 | 199.51 |

Back to Placebo results

## Baseline Specification: Instrumental Variable Approach

Regression equation for second stage least squares:

$$Y_{i,h,a,e,s} = \Phi + \beta \hat{R}_{i \leqslant 20,h,a} + X_a \Lambda + X_i \Pi + \alpha_s + \gamma_e + \epsilon_{i,h,a,e,s}$$

- $\hat{R}_{i \leqslant 20,h,a}$ is the predicted value of $R_{i \leqslant 20,h,a}$ from the first stage regression.
- $\alpha_s$ and $\gamma_e$ stands for state and ethnicity fixed effects, respectively
- $X_i$ is a vector of individuals characteristics
- $X_a$ is a vector of households characteristics
- $\epsilon_{i,h,a,e,s}$ is the error term.

Back to IV

# Baseline Specification: Placebo Lines

$$Y_{i,h,a,e,s} = \Phi + \beta R_i + X_a \Lambda + X_i \Pi + \alpha_s + \gamma_e + \epsilon_{i,h,a,e,s}$$

- $R_i$ is a binary variable equal to one if an individual lives within 20 km of a railway and equal to zero if an individual lives within 20km of a placebo line
- $\alpha_s$ and $\gamma_e$ stands for state and ethnicity fixed effects, respectively
- $X_i$ is a vector of individuals characteristics
- $X_a$ is a vector of households characteristics
- $\epsilon_{i,h,a,e,s}$ is the error term.

Back to Placebo lines

# North/South Heterogeneity: State FE Results

Panel A: North (Estimation Strategy : State Fixed Effects)

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 km | 1.967*** | 0.108*** | 0.867*** | 0.245*** |
| | [0.356] | [0.020] | [0.130] | [0.060] |
| Observations | 19765 | 19654 | 19795 | 19795 |

Panel B: South (Estimation Strategy : State Fixed Effects)

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 km | 0.527 | 0.055 | 0.370* | 0.113 |
| | [0.455] | [0.041] | [0.223] | [0.122] |
| Observations | 18624 | 18565 | 18628 | 18628 |

The state fixed effects identification strategy is identical to the general case, with the exception that the sample is restricted to either the north or south of Nigeria.

Back to Heterogeneity Placebo Lines

# North/South Heterogeneity: IV Results

Panel A: North (Estimation Strategy : IV)

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 km | 2.321*** | 0.113*** | 0.943*** | 0.168* |
| | [0.569] | [0.035] | [0.214] | [0.095] |
| Observations | 18823 | 18719 | 18853 | 18853 |

Panel B: South (Estimation Strategy : IV)

| | (1) Schooling | (2) Read Paper | (3) Wealth Index | (4) Urban |
|---|---|---|---|---|
| Rail Within 20 km | 0.527 | 0.055 | 0.370* | 0.113 |
| | [0.455] | [0.041] | [0.223] | [0.122] |
| Observations | 18624 | 18565 | 18628 | 18628 |

The IV identification strategy used is identical to the general case, with the exception that the sample is restricted to either the north or south of Nigeria.

Back to Heterogeneity Placebo Lines