Songlines

Sotiris Kampanelis[*], Aldo Elizalde[†] & **Yannis M. Ioannides**[‡]

[*] Cardiff University
[†] Queen's University Belfast
[‡] Tufts University

Growth Lab, Brown University
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Motivation

- Numerous economic studies emphasise the role of colonisation in long-run development (see, e.g. Acemoglu, Johnson, and Robinson 2001).
- A central focus of this research is to understand the drivers behind the patterns of European settlement and their long-term economic consequences (Easterly and Levine, 2016).
- To explain these patterns, scholars have mostly relied on the hypothesis of first-nature geography; natural features of the landscape playing a decisive role.
- A less explored dimension is the role of the key forces of second-nature geography, here **pre-modern** activity associated with the local knowledge possessed by the Indigenous population.

Motivation

- Several examples outside of economics of how the adoption of local knowledge shaped European colonial expansion e.g Plymouth Colony in the USA. Lewis and Clark Expedition.
- Despite that historians and anthropologists have widely recognised this important channel, the economics literature has yet not fully investigated its potential economic impacts.
- Moreover, the underlying mechanisms that explain the path-dependence of these economic effects remain unexplored.
- We fill this gap by **focusing on Australia where the adoption of Aboriginal knowledge of the landscape** was an integral part of colonial exploration and settlement.

In this paper

- We show that the adoption of Aboriginal knowledge of the landscape had a profound impact on the evolution of modern economic activity and urbanisation patterns in Australia.

- To capture this knowledge, we create a new **dataset on Aboriginal trade routes**, using unique anthropological data on 513 distinct routes, linking 1026 origins and destinations of Aboriginal trade sites.

    - Extensive trading network created by Aboriginal people based on oral traditions: **Songlines**.
    - Trading network provided Europeans with vital knowledge for exploring and settling Australia during colonisation (Kerwin 2010).

- We create a novel geo-referenced map of Aboriginal trade routes in Australia.
- We validate identification assumption via **Natural Routes**.
- **Mechanism**: Path dependence and agglomeration effects followed construction of transport infrastructure by Europeans.

Related literature

- **Colonialism and contemporary development** (see, e.g., Sokoloff and Engerman 2000; Acemoglu, Johnson, and Robinson 2001; Acemoglu, Johnson, and Robinson 2002; Acemoglu and Johnson 2005; Dell 2010; Kampanelis 2019).
- **Determinants of urbanisation** (see, e.g., Glaeser et al., 1992; Page, 1999; Bosker et al., 2013; Duranton and Puga, 2014; Bleakley and Lin, 2015; Bosker and Buringh, 2017; Barsanetti, 2021).
- **Pre-colonial factors and contemporary outcomes** (see, e.g., Gennaioli and Rainer 2007; Michalopoulos and Papaioannou 2013; Angeles and Elizalde 2017; Elizalde 2020; and Dincecco et al. 2020).

- **Long-term effects of historical trade routes** (see, e.g., Wahl, 2017; Dalgaard et al., 2018; Barjamovic et al., 2019; Michalopoulos et al., 2018; Flückiger et al., 2021; Ahmad and Chicoine, 2021).
- **Long-run effects of historical events** (see, e.g., Nunn 2008; Valencia Caicedo 2019; Lowes and Montero 2021).

Historical overview: Songlines

- At time of contact, Aboriginal people in Australia had developed an extensive trading network based on oral traditions.
- Oral traditions known as "Songlines": Information about the land and how the Aboriginal people had to travel to their various destinations (*Songlines* Chatwin 1987).
- Wositsky and Harney (1999) define these **'Songlines'** as '*epic creation songs passed to present generations by a line of singers...[and]* **provide maps for the country***...Some songlines describe a path crossing the entire Australian continent*'.
- An example of a route based on "Songlines" is the "Two Dog Dreaming", where "pituri" was traded.
- The Aboriginal trade routes were of remarkable length, some were 3,800 km long!
- Importantly, this trading network provided Europeans with vital knowledge for exploring and settling mainland Australia during colonisation (Kerwin, 2010)

Historical overview: Songlines

"*The natives were the parties who first guided the White Man through the intricacies of their forests, led them to their Rivers, their springs, and rich pastures, assisted them in keeping their stock, watched their working oxen, tracked their stray Horses, and rendered other essential assistance . . . The knowledge of their Country was thus acquired, was turned to account*" (Reynolds 1980).

"*European exploration of Australia...was made possible by Aboriginal trading paths...Surveyors quickly expanded European occupation and territories, and they coloured the map of Australia in their image*" (Kerwin 2010).

Historical overview: European explorations

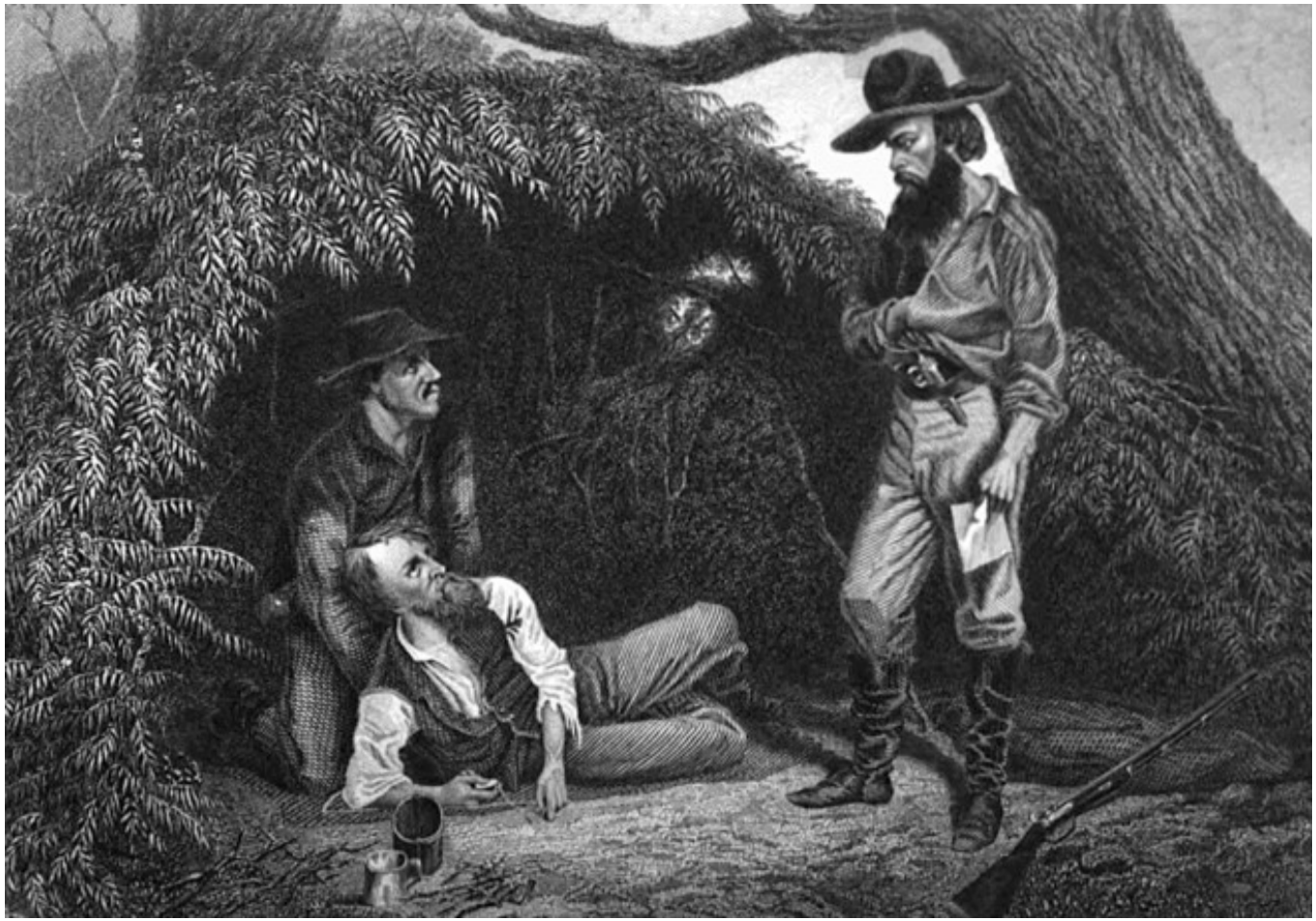
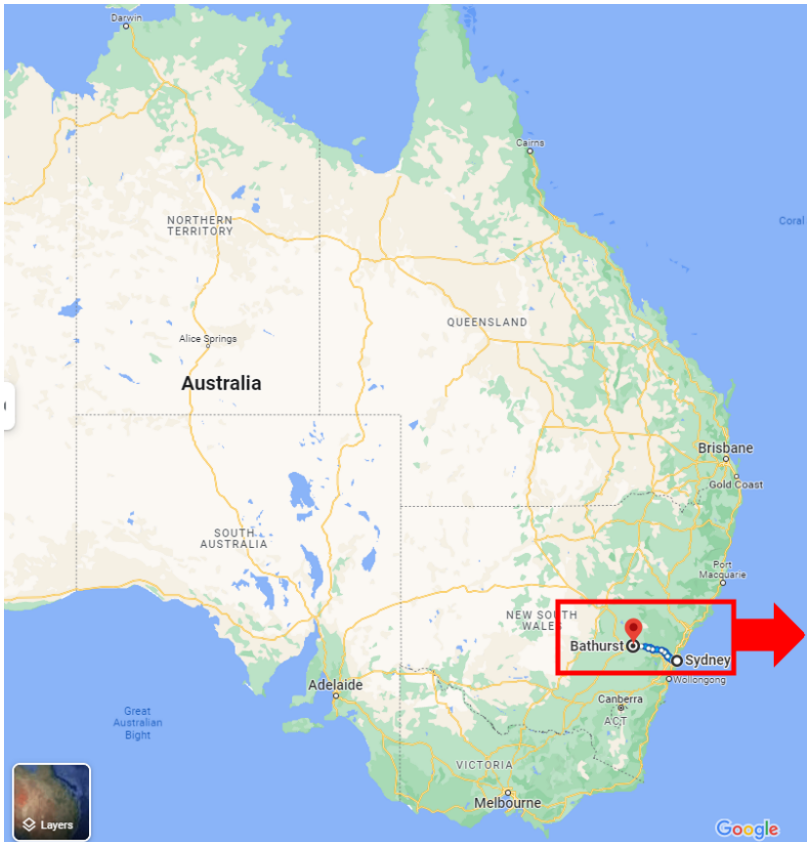


Figure: European explorers in Australia, 1863. Burke, Wills and John King travelling along south Australia in Coopers Creek. Author: Scott Melbourne

Historical overview: Early transport infrastructure



(a) Sydney to Bathurst, Australia

(b) **First road over the Blue Mountains to Bathurst**. Image drawn from John Oxley, S. Genl (1815).

Figure: Early development of the European transport infrastructure in Australia.

Historical overview: Early transport infrastructure

Figure: The Great Zig-zag, Lithgow c.1870

Adoption of Traveling Knowledge: Aboriginal Guides Examples

- **Ludwig Leichhardt**:Arriving in Newcastle on 20 September with prominent Hunter landowner, Alexander Walker Scott, Leichhardt engaged several **Aboriginal guides** to assist him during his field studies of fauna, flora and geology in the Hunter Valley.

- **Matthew Flinders**:**Bongaree**,the worthy and brave fellow who had sailed with me in the Norfolk, now volunteered again ; the other was **Nanbaree**, a good-natured lad, of whom colonel Collins has made mention in his Account of New South Wales.

- **John Howe**:His party left Windsor in October 1819, with eight Europeans and two **Aboriginal guides**. One of his guides was identified by the European name Myles and would have been well known to Howe, and probably the rest of his party.

- **Reverend George Augustus Middleton**:Another track blazed by the Reverend George Augustus Middleton, known as the Parsons Road, also became a well- used escape route from December 1821. Middleton had travelled overland to Newcastle with 173 head of cattle, guided by an unnamed **Aboriginal companion**.

Data: Aboriginal trade routes

- We utilized anthropological data to identify Aboriginal trade sites from McCarthy (1939).
- McCarthy's work relies on early written accounts from the time of contact with natives (e.g. Murdock's Ethnographic Atlas (1967)).
- Example of the description of a trade route in South Australia where pituri was traded:
  - "*Jessop...says that at "these three places, Noarlunga, Augusta and Aroona, situated at distances of 150 miles in a direct line from south to north, where they interchanged their respective earths or clays, the natives drove also a good trade in skins with those who lined further inland*"".
- We generate a set of 513 distinct "hypothetical" routes linking 1,026 sites, i.e. origins and destinations in Australia using least cost paths from HMI.
- Remainder of 1642 sites, after excluding coastal (no HMI index available) and non-Australian sites.

Data: Aboriginal trading sites

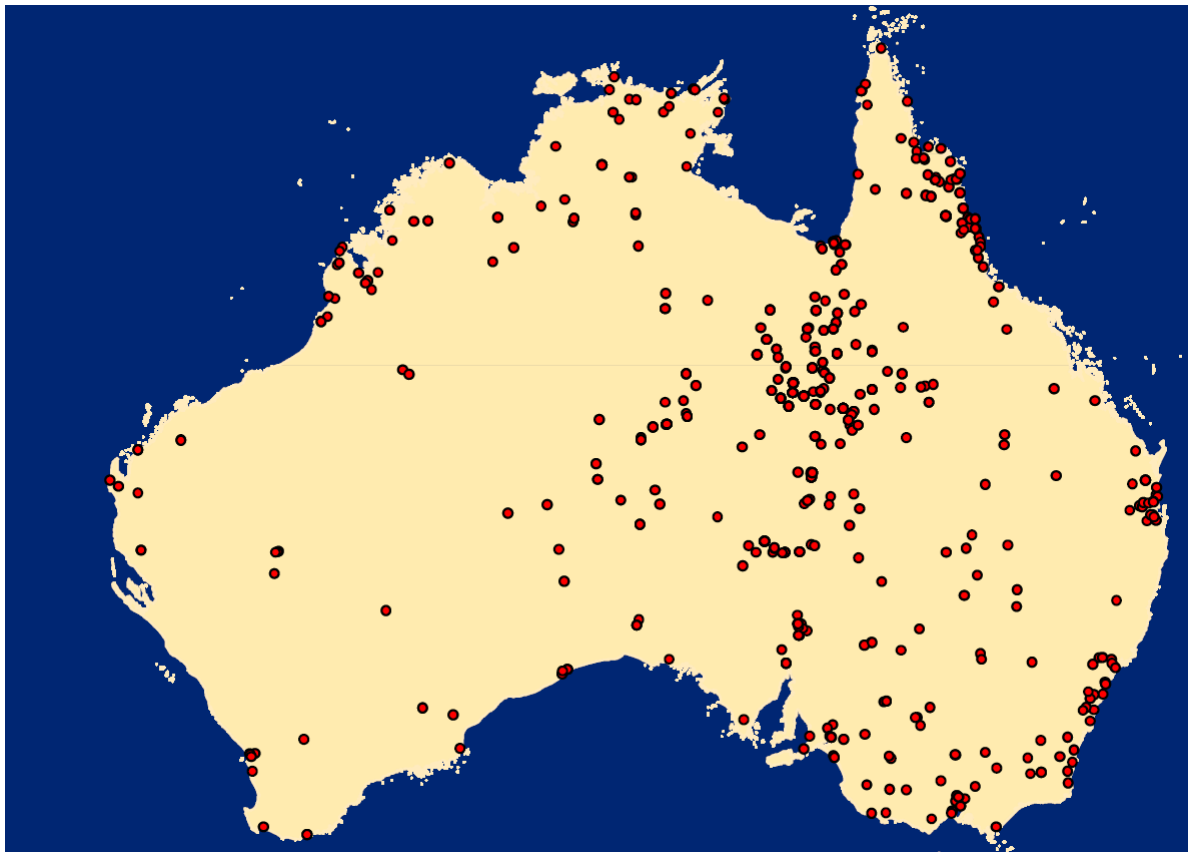


Figure: This map shows the origins and destinations that Aborigines used to exchange goods prior to colonisation, based on the work of McCarthy (1939).

Data: Human Mobility Index (HMI) by Özak (2018).

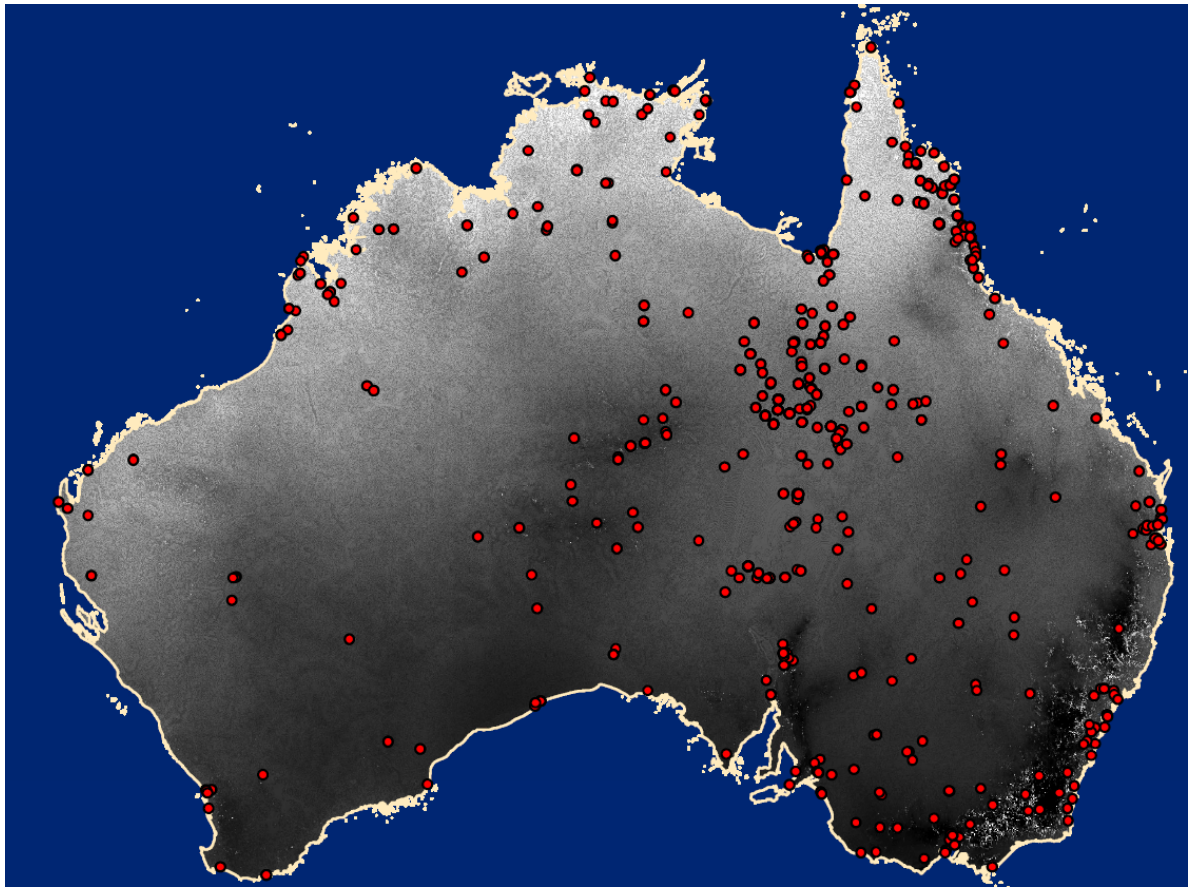


Figure: This map shows the raster for the HMI in Australia.

Data: Reconstruction of Aboriginal trade routes, Songlines, based on a least cost path algorithm using HMI

Figure: This map shows the approximate location of Aboriginal trade routes in Australia, based on the work of McCarthy (1939). White lines indicate trade routes. Trade routes were created using a least cost path algorithm. Trade routes were optimally constructed by authors using Özak (2018) with origins and destinations from McCarthy (1939).

Data: Unit of analysis, outcomes, and controls

- Unit of analysis: grid cell of 10 km x 10 km (100 km^2). For robustness, we increase the size to 50 km x 50 km.
- For each cell, we construct an indicator of economic activity using nighttime light emission data: Visible Infrared Imaging Radiometer Suite (VIIRS) sensor.
- Alternatively, used population density.
- VIIRS provides 45 times smaller pixel footprints, which increases the quality of the data in more remote areas.
- Large set of geographical and climatic controls, e.g., agricultural suitability, elevation, ruggedness, rainfall, temperature, distance to the sea, coast orientation, water percentage, etc.
- Historical controls: historical mining (gold rush in 19th century).

Empirical Strategy

Cross sectional regression:

$$Nightlight_i = \alpha_i + \beta\, TradeRoutes_i + Z_i'\rho + \epsilon_i, \tag{1}$$

where

- *Nightlight* = Binary dummy for night light in grid cell i.
- α_i = Local Government-fixed effect; β : parameter.
- $TradeRoutes_i$ = Dummy variable with value of 1, if grid cell i hosts at least one Aboriginal trade route (Songline), and 0 otherwise.
- Z' = Vector of climatic, topographic, geographic and historical variables
- ϵ_i = error term.

(Robust standard errors are clustered at local government level).

Main results

Table: Baseline results

	Dependent Variable: Binary dummy for night light			
	(1)	(2)	(3)	(4)
Trade Routes	0.035***	0.036***	0.034***	0.033***
	(0.007)	(0.007)	(0.006)	(0.006)
N	79731	79731	79731	79731
R^2	0.222	0.222	0.228	0.232

Notes: The unit of observation is a grid cell of 10km X 10km. The dependent variable is a dummy variable that takes the value of 1 if cell *i* has nightlight, and 0 otherwise. This variable uses data from Visible Infrared Imaging Radiometer Suite (VIIRS) sensor. All columns control for local government fixed effects. Columns (1)-(4) include a measure of pre-colonial Aboriginal trade routes. This measure is is a dummy variable that takes the value of 1 if cell *i* has at least one pre-colonial Aboriginal trade routes, and 0 otherwise. This variable was constructed using anthropological data from McCarthy (1939), which describes the trade routes created by Aboriginal people based on oral traditions prior to colonisation. The Human Mobility Index (HMI) from Özak (2018) was used to identify optimal routes between origins and destinations, with a least-cost algorithm. From columns (2) to (4), geographical and climatic control variables were added gradually and incrementally. The descriptions of the geographical and climatic variables can be found in the Appendix. Robust standard errors clustered at the local government district level were used and the constant term was omitted for space. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls added gradually from column (2) to (4).
- Local Government FE included in all columns

Baseline Results: Robustness checks

- "Homogeneous" sample to address strong geographical variation in Australia (drop lowest or highest 25% of observed rainfall and temperature)
- Addressing unobservable factors:
  - We use cells with Aboriginal trade routes and all adjacent (sharing edge or corner) cells that may (or may not) host a trade route.
  - We develop a contiguous pair analysis

  Model
- We address measurement error in the construction of Aboriginal trade routes:
  - We increase the size of the cells to 50 to 50 km.
  - Trade routes reconstructed using other sources. e.g., location of Aboriginal rock art and historical maps by McCarthy (1939).

    Maps/sample
  - Estimated Aboriginal trade routes were validated using Trading Sites

    Map
- Further checks:
  - Network centrality measures for the Aboriginal trading network as controls;
  - Dropping origins and destinations points;
  - Dealing further with heterogeneity: drop states individually
  - Spatial autocorrelation: large-cluster approach, as implemented by Bester et al. (2011) and Kelly (2020);
  - Oster's test on omitted variables.

Urban evolution of Australia

- We investigate the dynamic effects of Aboriginal trade routes on the emergence of new urban settlements in Australia.
- This analysis allows investigation of change in importance of these routes in the face of other historical shocks.
- We utilise data from Kampanelis (2019) on year of foundation for 249 major cities in Australia, 1788 — 2000. Map
- Four groups were created according to their year of establishment: cities established:
  1788 — 1850, 1850 — 1900, 1900 — 1950, and 1950 — 2000.
- Four stages of urbanization, defined by dummy variables, assign the value 1, if cell "i" is associated with one of these groups, of cities, 0 otherwise; use as dependent variables.

Dynamic effects: Results

Table: Establishment of Cities

	All Cities	Cities est. before 1850	Cities est. in 1850-1900	Cities est. in 1900-1950	Cities est. in 1950-2000
	(1)	(2)	(3)	(4)	(5)
Trade Routes	0.004***	0.001*	0.002***	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
N	79731	79731	79731	79731	79731
R^2	0.054	0.089	0.029	0.018	0.010

Notes: The unit of observation is a grid cell of 10km X 10km. OLS estimates are shown with robust standard errors clustered at the local government district level. In column (1), the dependent variable is a dummy variable that takes the value of 1 if cell *i* has a major city that was established by Europeans between 1788 and 2000 in Australia. In column (2), the dependent variable is a dummy variable that takes the value of 1 if cell *i* has a major city that was established by Europeans between 1788 and 1850. In column (3), the dependent variable is a dummy variable that takes the value of 1 if cell *i* has a major city that was established by Europeans between 1850 and 1900. In column (4), the dependent variable is a dummy variable that takes the value of 1 if cell *i* has a major city that was established by Europeans between 1900 and 1950. In column (5), the dependent variable is a dummy variable that takes the value of 1 if cell *i* has a major city that was established by Europeans between 1950 and 2000. Dummy variables from all columns were constructed using data from Kampanelis (2019) on the year of establishment of 249 major cities in Australia. All columns control for local government fixed effects, as well as for a set of geographical, climatic and historical variables, which include: the coordinates of each grid cell, agricultural suitability, elevation, ruggedness (standard deviation of elevation), rainfall and standard deviation of rainfall, temperature and standard deviation of temperature, distance to the sea, distance to Sydney, distance the state capital, distance to historical mines, and water percentage. The descriptions of the geographical, climatic, and historical variables can be found in the Appendix. The constant term was omitted for space. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

Mechanism: Path dependence and agglomeration effects

- Early European transport infrastructure:
  - As the first settlements emerged along these routes, modern transport infrastructure was developed to connect them to the main colonies.
  - Hence, early transport infrastructure $\Rightarrow$ better connectivity $\Rightarrow$ concentration of economic activities in the long run (Flückiger et al.).
- Historical maps of Australian network of **railways and highways** in the 19th and early 20th centuries, respectively.

Mechanism: Results

Table: Mechanisms

	Early Railways	Early Highways
	(1)	(2)
Trade Routes	0.013**	0.027***
	(0.006)	(0.007)
N	79731	79731
R^2	0.200	0.135

Notes: The unit of observation is a grid cell of 10km X 10km. OLS estimates are shown with robust standard errors clustered at the local government district level. In columns (1), the dependent variable is a dummy variable that takes the value of 1 if cell *i* has at least one railway built between 1880 and 1920, and 0 otherwise. In column (2), the dependent variable is dummy variable that takes the value of 1 if cell *i* has at least one highway built in Australia until the early 1950s, and 0 otherwise. The measure uses only major interstate and state highways. Both measures were constructed by digitising and georeferencing a series of historical maps, with sources provided in the description of variable section in the Appendix. All columns control for local government fixed effects, as well as for a set of geographical, climatic and historical variables, which include: the coordinates of each grid cell, agricultural suitability, elevation, ruggedness (standard deviation of elevation), rainfall and standard deviation of rainfall, temperature and standard deviation of temperature, distance to the sea, distance to Sydney, distance the state capital, distance to historical mines, and water percentage. The descriptions of the geographical, climatic, and historical variables can be found in the Appendix. The constant term was omitted for space. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

Validating identification assumption: Natural Routes

- Adoption of Aboriginal knowledge of the landscape influenced Europeans exploration and settlement of Australia: $\rightarrow$ shaping spatial distribution of modern urbanisation patterns
- Do our findings reflect:
  a genuine adoption of Aboriginal knowledge? *Or*
  are due to the inherent characteristics of Australian topography?
- Following Barjamovic et al. (2019) (Optimal Travel Routes), we exploit exogenous variation in European exploration and settlement by defining "Natural Routes."
- Natural Routes were defined as geographically intrinsically "friendly" travel routes from each coastal cell to every other coastal cell.
- The number of intersections of these travel paths with each pixel indicates its degree of effective connectedness, i.e. best Natural Routes, between all pairs of coastal cells.
- Suggestions we have **yet** to adopt:
  - identify "difficult" passes, define routes via them: **most exogenous**.
  - deal with water (no data in HMI).

Natural Routes

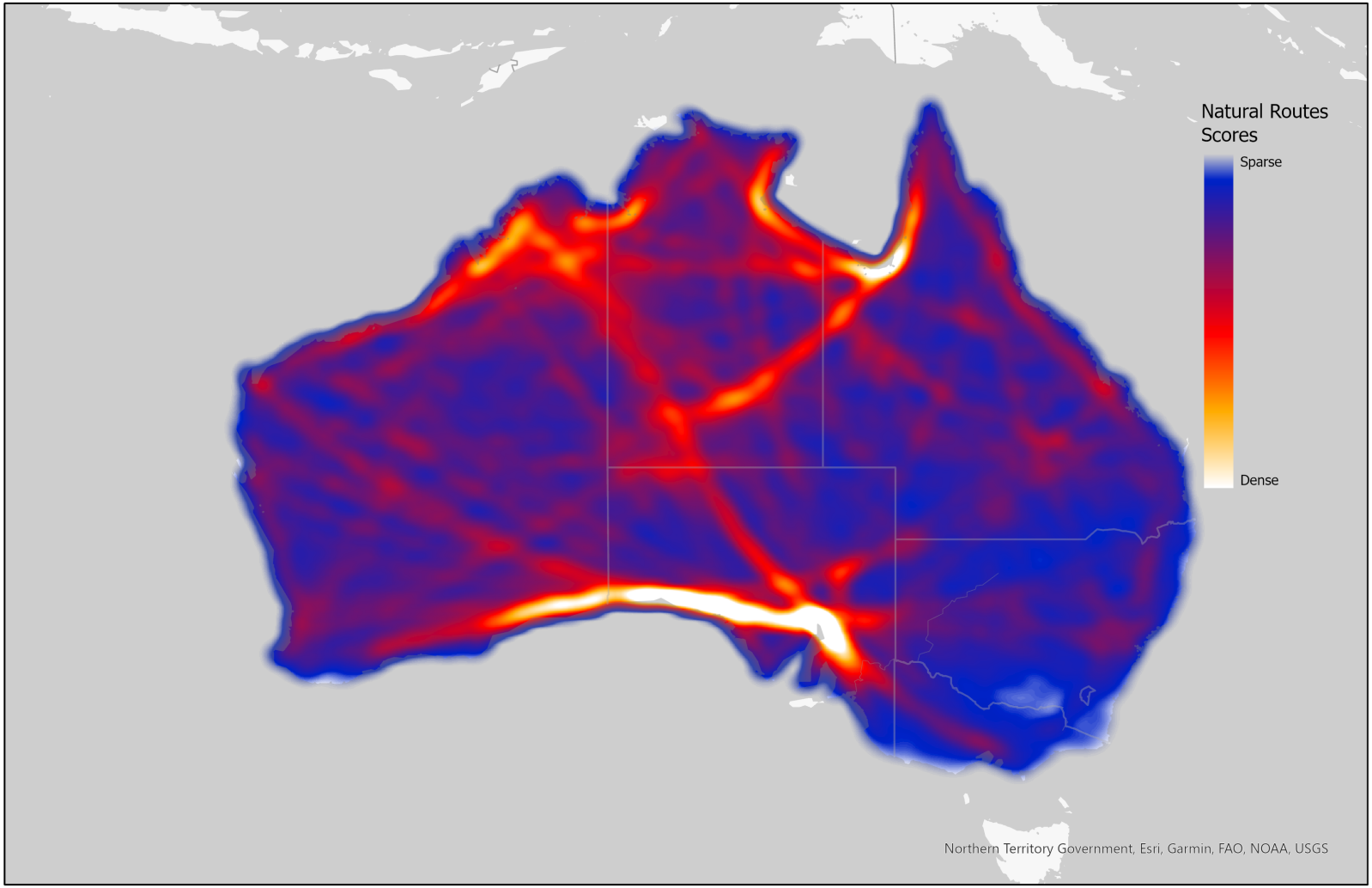


Figure: Natural Routes Scores

European exploration routes

Figure: European exploration routes, 1601-1901. Source: Robinson (1927).

European exploration routes: Digitised

Figure: European exploration routes, 1601-1901. Source: Robinson (1927).

Natural Routes analysis: Results

Table: Natural Routes *versus* Aboriginal Trade Routes

	Exploration routes	Cities	Early Railways	Early Highways	Night LIghts
	(1)	(2)	(3)	(4)	(5)
Natural Routes	0.007*	0.000	0.001	0.011***	0.005***
	(0.004)	(0.000)	(0.002)	(0.004)	(0.001)
Aboriginal Trade Routes	0.019***	0.001***	0.004**	0.008***	0.010***
	(0.003)	(0.000)	(0.002)	(0.002)	(0.002)
N	79731	79731	79731	79731	79731
R^2	0.068	0.054	0.200	0.136	0.232

Notes: The unit of observation is a grid cell of 10km X 10km. OLS estimates are shown with robust standard errors clustered at the local government district level. All columns show standardised coefficients. Natural Routes is the logarithm of the number of optimal travel routes that intersects within each pixel. Aboriginal Trade Routes is a dummy variable that takes the value of 1 if cell *i* has at least one Aboriginal trade route, and 0 otherwise. In column (1), the dependent variable is an indicator that takes the value of 1 if grid cell *i* has at least one European exploration route, or of 0, otherwise. In column (2), the dependent variable is a indicator that takes value of 1 if grid cell *i* is associated to the establishment of a city in Australia between 1788 and 2000, and 0 otherwise. In column (3), the dependent variable is an indicator that takes value 1 if at least one railway was built in grid cell *i* between 1880 and 1920, and zero otherwise. In column (4), the dependent variable is an indicator that takes value 1 if at least one highway was built in grid cell *i* until the early 1950s, and zero otherwise. In column (5), the dependent variable is an indicator that takes the value of 1 if grid cell *i* has nightlight, and 0 otherwise. All columns control for local government fixed effects, as well as for a set of geographical, climatic and historical variables, which include: the coordinates of each grid cell, agricultural suitability, elevation, ruggedness (standard deviation of elevation), rainfall and standard deviation of rainfall, temperature and standard deviation of temperature, distance to the sea, distance to Sydney, distance the state capital, distance to historical mines, and water percentage. The descriptions of the geographical, climatic, and historical variables can be found in the Appendix. The constant term was omitted for space. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

Conclusion

- We document that the adoption of **local knowledge** by Europeans in their colonial expansion had long-term economic effects on contemporary societies.
- We use a unique **historical experiment** in colonial Australia, when Europeans drew on **Aboriginal knowledge of the landscape for exploration and settlement**.
  - Extensive **network of trade routes** created by Aboriginal people **based on oral traditions, known as Songlines**.
  - Anthropological evidence suggests that Aboriginal trade routes provided Europeans with important knowledge for exploration and settlement.
- We create a **new dataset on Aboriginal trade routes** and explore their impact on contemporary economic activity.
- We show that Aboriginal trade routes in Australia had a significant impact on the spatial patterns of modern economic activity and urbanisation.

Songlines

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Contiguous analysis: Model

Cross sectional regression:

$$Nightlight_{i(j)} = \alpha_{i(j)} + \beta\, TradeRoutes_{i(j)} + Z'_{i(j)}\rho + \epsilon_{i(j)} \qquad (2)$$

where

- *Nightlight* = Binary dummy for night light in grid cell i that has a trade route, and is also adjacent (sharing edge or corner) to cell j, which does not have a trade route.
- $\alpha_{i(j)}$ = **Pairs-fixed effect**.
- β = Aboriginal trade routes.
- Z' = Vector of climatic, topographic, geographic and historical variables.
- ϵ = error term.

(Robust standard errors are clustered at local government level)

Population density and primary roads

Table: Alternative measures of modern economic activity

	Population Density	Primary Roads
	(1)	(2)
Trade Routes	0.534***	0.108***
	(0.160)	(0.023)
N	79731	79731
R^2	0.581	0.344

Notes: The descriptions of the variables can be found in table in the Appendix. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

Homogeneous sample

Table: Homogeneous sample

	Dependent Variable: Binary dummy for night light	
	(1) $\geq$25% Precipitation	(2) $\leq$25% Temperature
Trade Routes	0.044***	0.028***
	(0.006)	(0.006)
N	59457	59678
R^2	0.238	0.252

Notes: The descriptions of the variables can be found in table in the Appendix. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

Alternative Sources of Measurement Error

Table: Alternative sources

	Dependent Variable: Binary dummy for night light					
	(1) HMI & RA	(2) DIG & RA	(3) DIG	(4) HMI=HMI & RA	(5) HMI=DIG & RA	(6) HMI=DIG
Trade Routes	0.012***	0.012***	0.011***	0.052***	0.051***	0.053***
	(0.002)	(0.003)	(0.003)	(0.009)	(0.008)	(0.008)
N	79731	79731	79731	59266	62922	62323
R^2	0.231	0.231	0.231	0.222	0.217	0.216

Notes: The descriptions of the variables can be found in table in the Appendix.
(1): cell contains either HMI Route or Rock Art; (2): cell contains either Rock Art or digitized McCarthy Route; (3): cell contains digitized McCarthy route; (4): cell contains both HMI and Rock Art; (5): cell either HMI Route and Digitized McCarthy or Rock Art; (6): cell contains both HMI Route and Digitized McCarthy Route. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

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Trading Sites: Results excluding sites near the Coast

Table: Trading Sites

	Dependent Variable: Binary dummy for night light					
	(1) all cells	(2) excl. 50km	(3) excl. 100km	(4) excl. 200km	(5) excl. 300km	(6) excl. 500km
Trading Sites	0.200***	0.168***	0.168***	0.169***	0.159***	0.070***
	(0.023)	(0.026)	(0.028)	(0.029)	(0.033)	(0.020)
Local Gov FE	✓	✓	✓	✓	✓	✓
Geo & Hist Controls	✓	✓	✓	✓	✓	✓
N	79731	72474	65382	52803	41838	23744
R^2	0.233	0.167	0.151	0.113	0.063	0.032

Notes: The descriptions of the variables can be found in table in the Appendix. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls included in all columns.
- Local Government FE included in all columns

back

Contiguous pair analysis: Model

Cross sectional regression:

$$Nightlight_{i(j)} = \alpha_{i(j)} + \beta\, TradeRoutes_{i(j)} + Z'_{i(j)}\rho + \epsilon_{i(j)} \tag{3}$$

where

- *Nightlight* = Binary dummy for night light in grid cell i that has a trade route, and is also adjacent to cell j, which does not have a trade route.
- $\alpha_{i(j)}$ = **Pairs-fixed effect**.
- β = Aboriginal trade routes.
- Z' = Vector of climatic, topographic, geographic and historical variables.
- ϵ = error term.

(Robust standard errors are clustered at local government level)

Results

Contiguous pair analysis: Results

Table: Neighbouring analysis

	Dependent Variable: Binary variable for night light
	(1)
Trade Routes	0.014***
	(0.002)
N	115024
R^2	0.465

Notes: The descriptions of the variables can be found in table in the Appendix. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

- Geographical and historical controls added gradually from column (2) to (4).
- Local Government FE included in all columns

Back

Adoption "Frictions:" Sites of Colonial Massacres

- We explore constraints that might have interfered with Europeans adopting Aboriginal knowledge using data on massacres during colonisation.
- The aim of this analysis is to show that in areas of conflict, Europeans were unable to adopt such knowledge. It is thus more likely that they did not explore nor settle in these areas; as a result economic activity should be null today.
- We use data on massacres during colonisation from the project "*Colonial Frontier Massacres in Australia*", led by historian and Professor Emeritus Lyndall Ryan (University of Newcastle).
- The project documents a total of 426 massacres between 1788-1930, of which almost all were against Aboriginal people (412).
- The project defines a massacre: the deliberate killing of six or more relatively undefended people in one operation.
- Project describes massacres mainly as either (1) reprisal or (2) opportunity. We use only reprisal massacres. (*An 'opportunity' massacre is not in response to a specific incident*).
- A 'reprisal' massacre is carried out in response to a specific incident, such as:
  - the suspected killing of a Colonist or an Aboriginal person
  - the suspected kidnapping by a Colonist or Colonists of an Aboriginal person or persons
  - the suspected killing or taking of Colonial livestock by Aboriginal people
  - the suspected burning of Colonial property by Aboriginal people.
  - among others

Adoption "Frictions": Massacres, 1788-1930

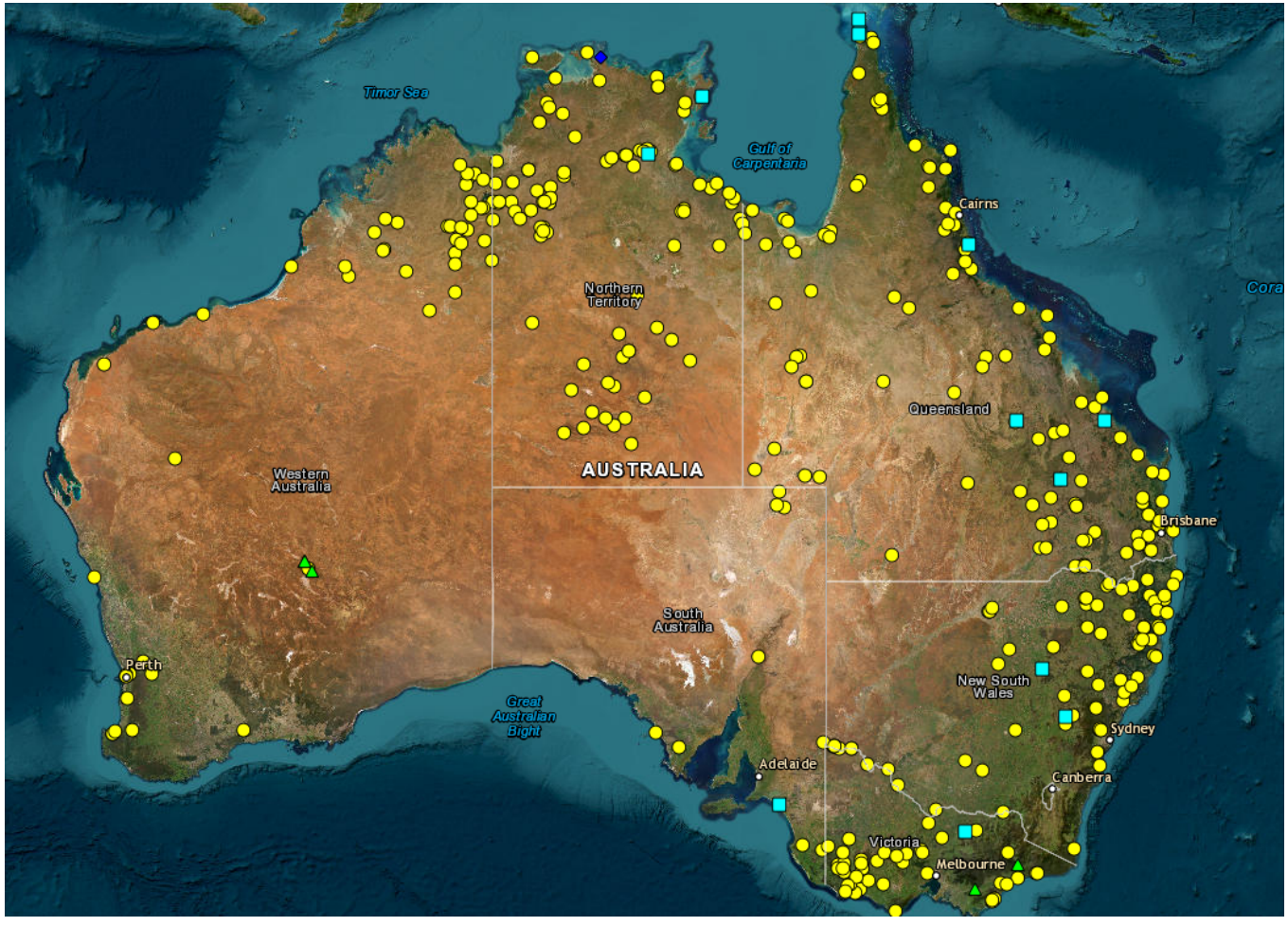


Figure: Colonial Massacres, Australia, 1788 to 1930. Source: Colonial Frontier Massacres in Australia 1788-1930 Project.
https://c21ch.newcastle.edu.au/colonialmassacres/

Adoption "Frictions"

- We develop two analyses:
  - **I**, we identify pixels that lie within 5km, 10km, 15km, and 20km of a massacre site; run regression using only this restricted sample of pixels.
  - We find no relationship between Songlines and luminosity close to areas of massacres – where Europeans faced arguably hostile environment, not conducive to adoption of Aboriginal knowledge.
  - This may show that close to hostile areas ,where Europeans might have experienced "friction" in adopting Aboriginal knowledge, our main relationship does not hold.
  - **II**, we exclude the pixels with Songlines close to massacres (assuming those sites hostile to Europeans' adoption of Aboriginal Knowledge).
  - Even in this case, our main results hold.
- "Smoking-gun" evidence of transmission of Aboriginal knowledge?

Adoption "Frictions:" Results I

Table: Adoption "Frictions": Sites of Massacres

	Dependent Variable: Dummy variable for night light			
	(1) pixels within 5km	(2) pixels within 10km	(3) pixels within 15km	(4) pixels within 20km
Trade Routes	0.258	0.051	0.066*	0.055**
	(0.172)	(0.064)	(0.037)	(0.028)
N	141	528	1173	1995
R^2	0.078	0.231	0.280	0.303

Notes: The unit of observation is a grid cell of 10km X 10km. The dependent variable is a dummy variable that takes the value of 1 if cell *i* has nightlight,and 0 otherwise. This variable uses data from the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor. The analysis only includes pixels that are 5 km (column (1)), 10km (column (2), 15km (column (3), and 20km (column (4)) closer to a massacre. All columns control for local government fixed effects, as well as for a set of geographical, climatic and historical variables, which include: the coordinates of each grid cell, agricultural suitability, elevation, ruggedness (standard deviation of elevation), rainfall and standard deviation of rainfall, temperature and standard deviation of temperature, distance to the sea, distance to Sydney, distance the state capital, distance to historical mines, coastal presence, and water percentage. The descriptions of the geographical, climatic, and historical variables can be found in the Appendix. The constant term was omitted for space. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

Adoption "Frictions:" Results II

Table: Adoption "Frictions:" Sites of Massacres Excluded

	Dependent Variable: Dummy variable for night light			
	(1) excl. pixels within 5km of a massacre & with Songlines	(2) excl. pixels within 10km of a massacre & with Songlines	(3) excl. pixels within 15km of a massacre & with Songlines	(4) excl. pixels within 20km of a massacre & with Songlines
Trade Routes	0.029***	0.028***	0.026***	0.025***
	(0.005)	(0.005)	(0.005)	(0.005)
N	79703	79621	79506	79365
R^2	0.232	0.231	0.230	0.228

*Notes:*The unit of observation is a grid cell of 10km X 10km. The dependent variable is a dummy variable that takes the value of 1 if cell *i* has nightlight,and 0 otherwise. This variable uses data from the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor. The analysis excludes pixels that are 5 km (column (1)), 10km (column (2), 15km (column (3), and 20km (column (4)) closer to a massacre and have a Songline. All columns control for local government fixed effects, as well as for a set of geographical, climatic and historical variables, which include: the coordinates of each grid cell, agricultural suitability, elevation, ruggedness (standard deviation of elevation), rainfall and standard deviation of rainfall, temperature and standard deviation of temperature, distance to the sea, distance to Sydney, distance the state capital, distance to historical mines, coastal presence, and water percentage. The descriptions of the geographical, climatic, and historical variables can be found in the Appendix. The constant term was omitted for space. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

Sites of European Exploration and Distance to Songlines

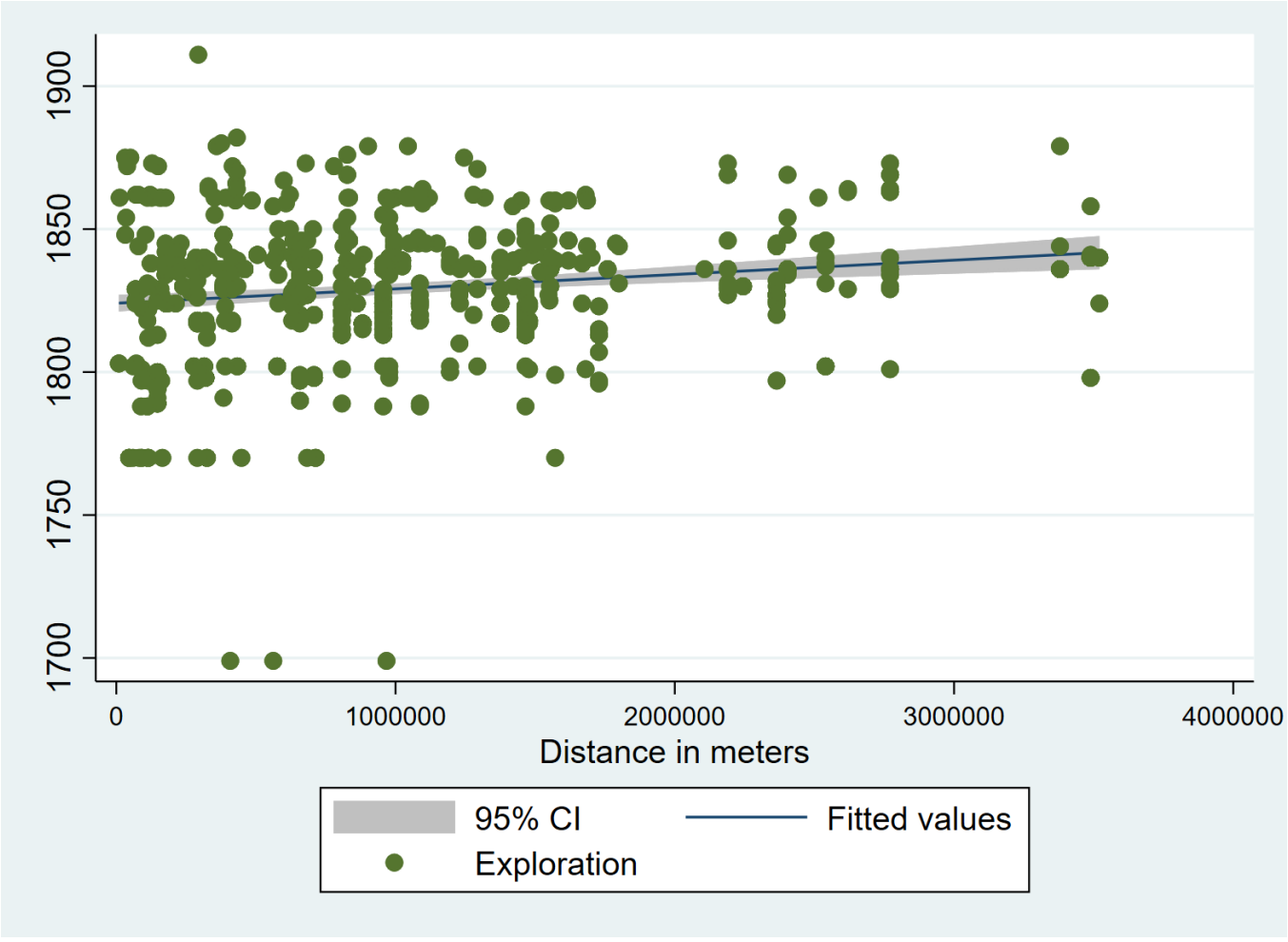


Figure: Years of Exploration of Australian Sites and Distance to Songlines.
Source: Robinson (1927) map and Songlines

Table: Analysis of balance: Environment and early European exploration

	Dependent Variable: Binary dummy for early European explorations						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Agriculture Suitability	−0.012***						
	(0.004)						
Elevation		−0.000**					
		(0.000)					
Ruggedness			−0.000*				
			(0.000)				
Precipitation				0.000			
				(0.000)			
Temperature					0.000**		
					(0.000)		
Distance to the Sea						−0.000	
						(0.000)	
Water Percentage							−0.082***
							(0.027)
Local Gov FE	✓	✓	✓	✓	✓	✓	✓
N	79731	79731	79731	79731	79731	79731	79731
R^2	0.000	0.003	0.000	0.000	0.002	0.000	0.000

Notes: The descriptions of the variables can be found in table in the Appendix. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

Table: Analysis of balance: Environment and Aboriginal trade routes

	Dependent Variable: Binary dummy for pre-colonial Aboriginal trade routes						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Agriculture Suitability	0.020						
	(0.015)						
Elevation		−0.000***					
		(0.000)					
Ruggedness			−0.001***				
			(0.000)				
Precipitation				−0.000			
				(0.000)			
Temperature					0.000		
					(0.000)		
Distance to the Sea						0.001	
						(0.001)	
Water Percentage							0.260***
							(0.099)
Local Gov FE	✓	✓	✓	✓	✓	✓	✓
N	79731	79731	79731	79731	79731	79731	79731
R^2	0.002	0.035	0.003	0.000	0.000	0.003	0.005

Notes: The descriptions of the variables can be found in table in the Appendix. The estimates include a constant term, which is omitted to save space. Robust standard errors are in parentheses. *, ** and *** mean that the coefficient is statistically significant at 10%, 5% and 1% respectively.

Data: Aboriginal trading sites

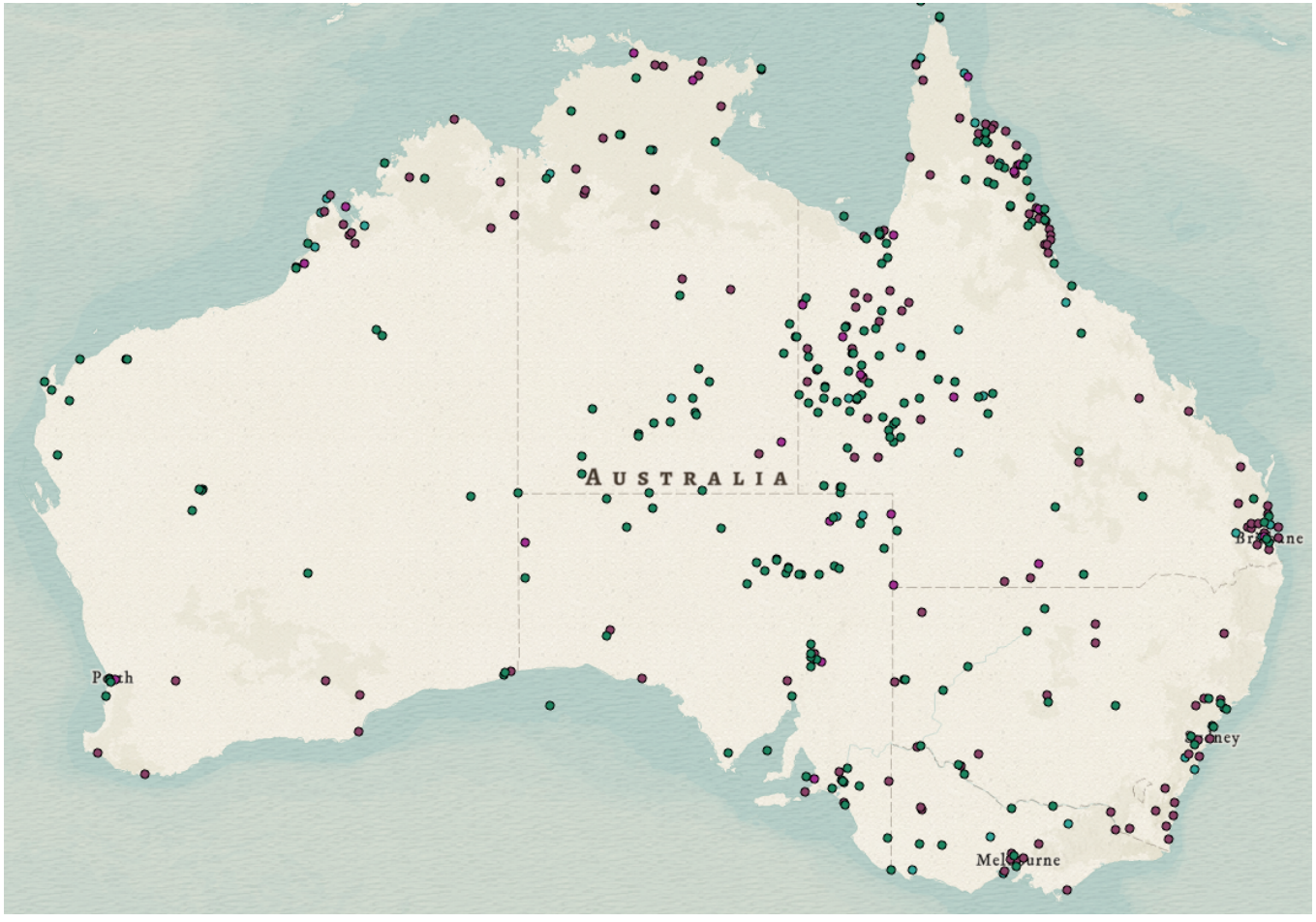
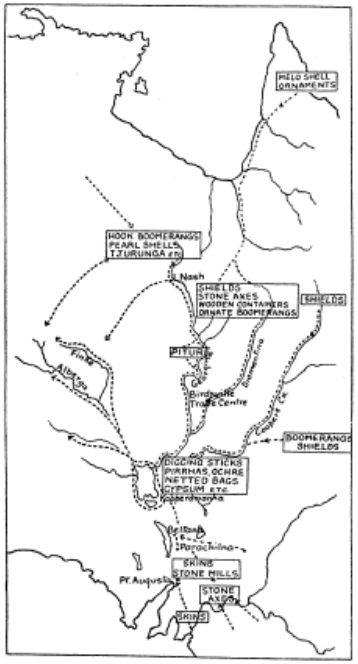


Figure: This map shows the origins and destinations that Aborigines used to exchange goods prior colonisation, based on the work of MćCarthy (1939).

Aboriginal trade routes in Australia: McCarthy's maps

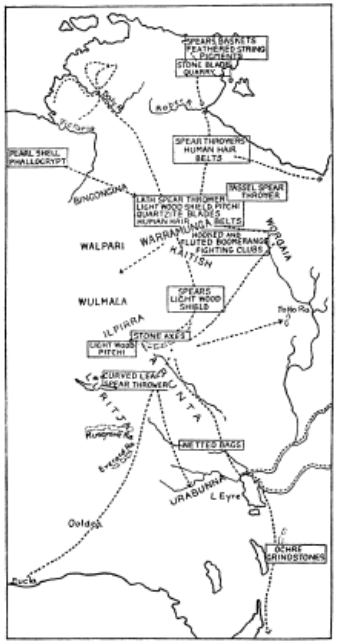
Figure: Aboriginal trade routes in Australia: McCarthy's maps

McCarthy's maps



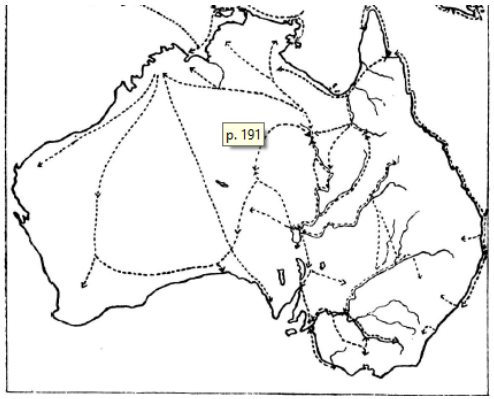
Map 7.—Trade between western Queensland and the Lake Eyre tribes along the Mura Mura route.

(a)



Map 8.—Trade in central and north Australia. The roots of the Central Trunk Route and the links with neighbouring regions are shown.

(b)



Map 16.—The intra- and extra-Australian trunk trade routes. It is important to realize that these routes function sectionally, and that traits and ideas diffuse along their entire extent.

(c)

Figure

McCarthy's maps illustrating location for some Aboriginal trade routes in Australia.

Map

Cities and Towns in Australia, 1788-2000

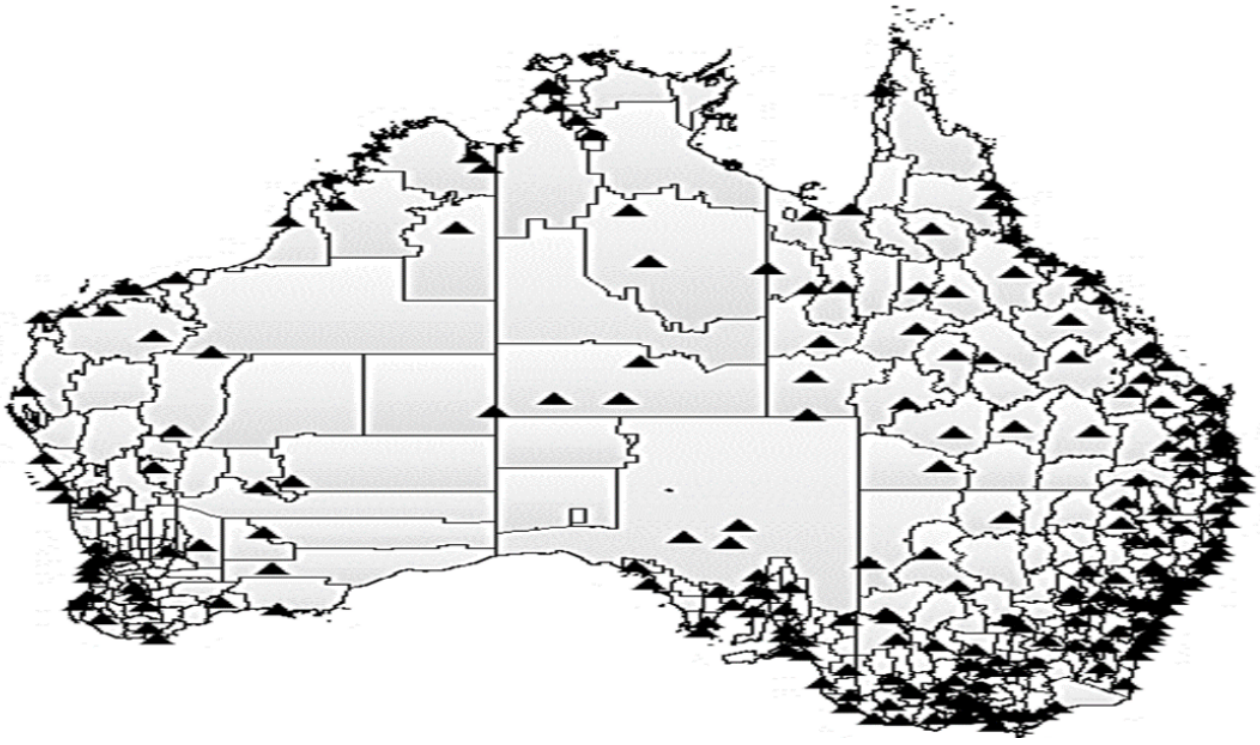


Figure: Black triangles illustrate the location of Australian cities (n=249).
Source: Kampanelis (2019)

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