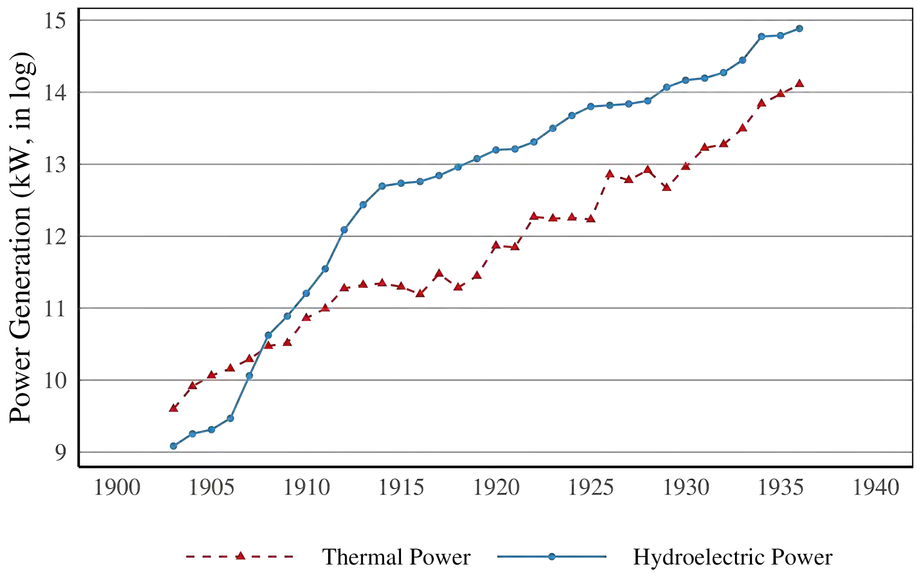
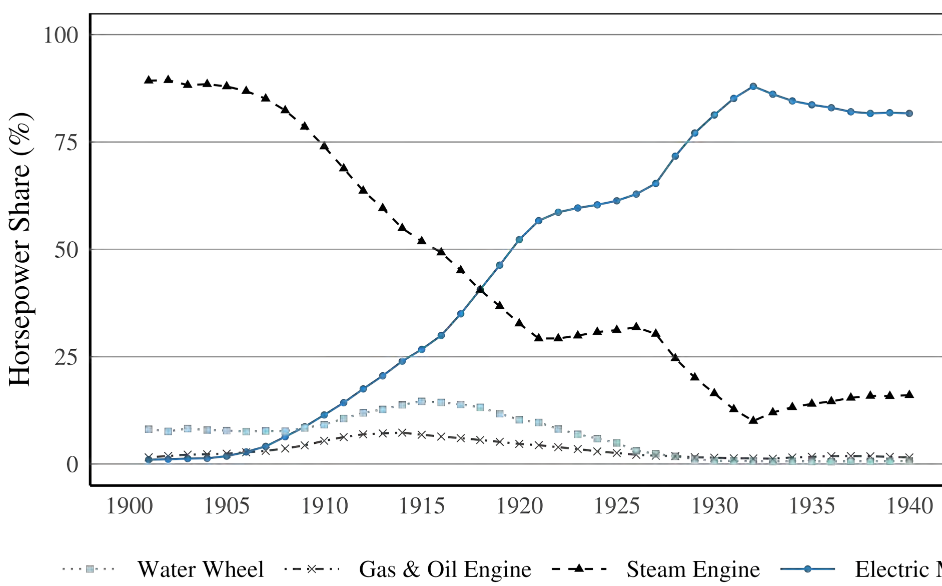
Appendix A Historical Background: Additional Details

Figure A1: Source of Power Generation



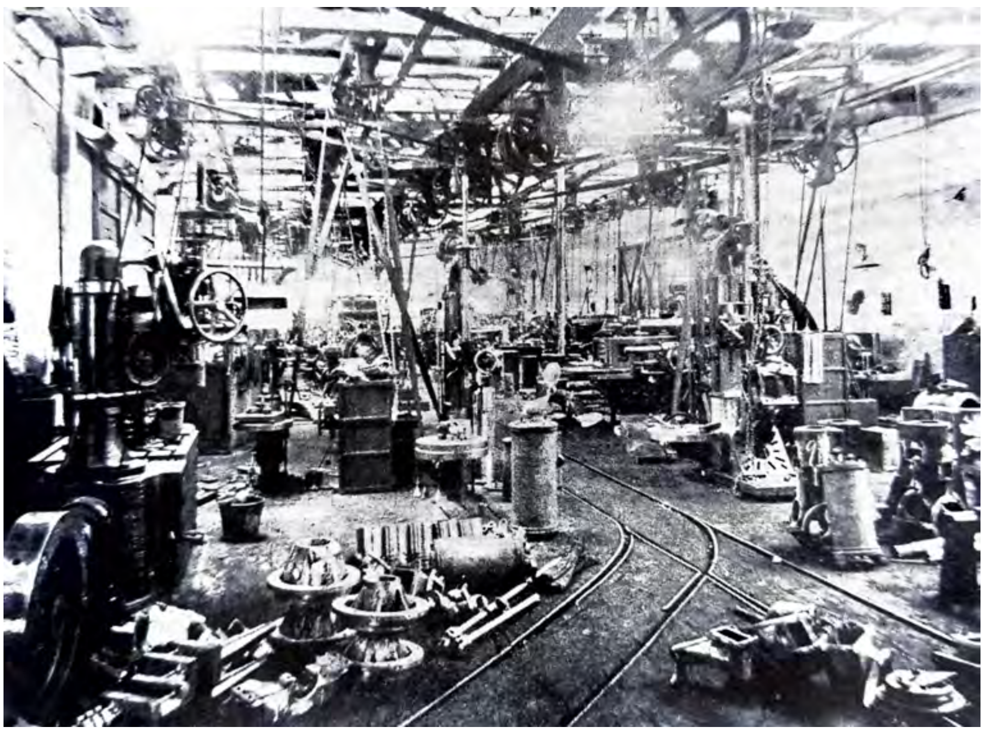
Notes: This figure shows the source of power generation in early 20th-century Japan as a five-year moving average.
Source: Ministry of Communications (1938)

Figure A2: Power Source Transition from Steam Engine to Electric Motor



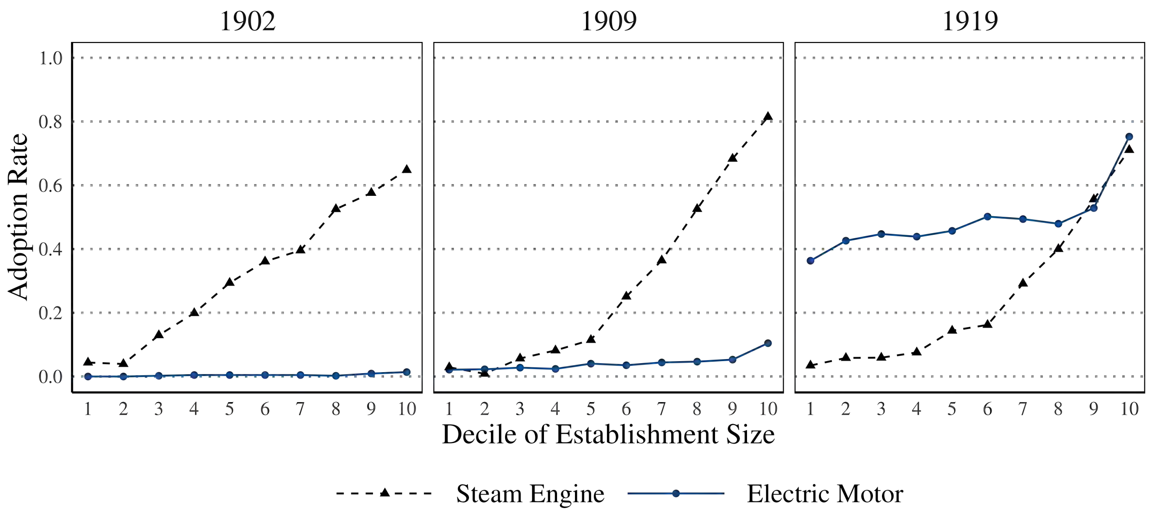
Notes: This figure displays the trends in the share of horsepower generated by each power source in Japan from 1900 to 1940 as a five-year moving average. The data comes from Minami (1979), which compiled and calculated the amount of horsepower from various statistical records published by the central government.
Source: Minami (1979)

Figure A3: Inronworks Factory Powered by Steam Engine (*Group Drive System*)

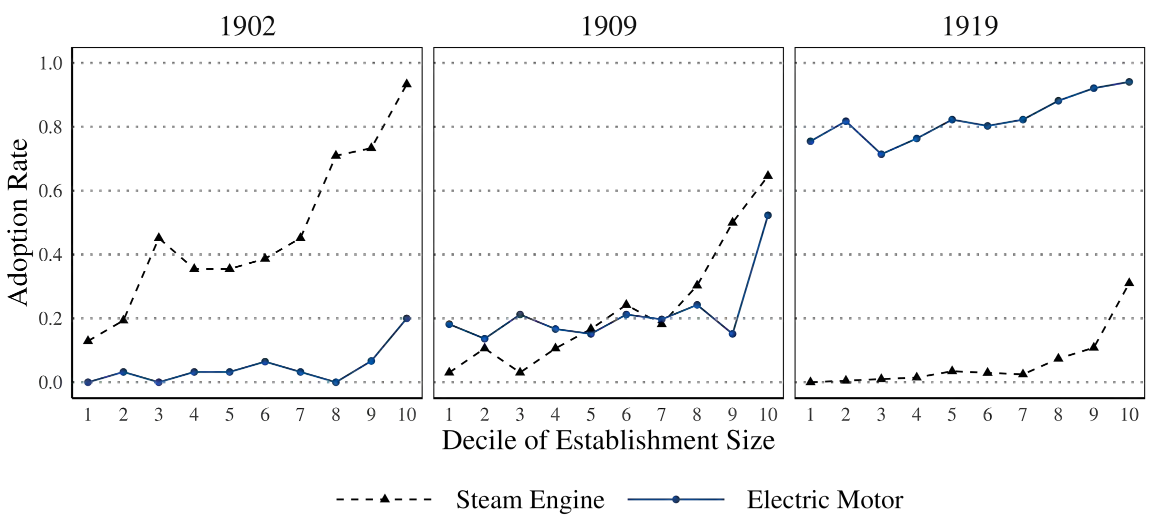


Notes: The picture shows an ironworks factory powered by steam engines in 1907, where power generated by steam engines is transmitted via shafts and belts affixed to the roof (*Group Drive System*). This production system required sizable and sturdy workshops.
Source: Ikegai Ironworks (1941)

Figure A4: Technology Adoption by Establishment Size (by Industry)



(a) Textile Industry

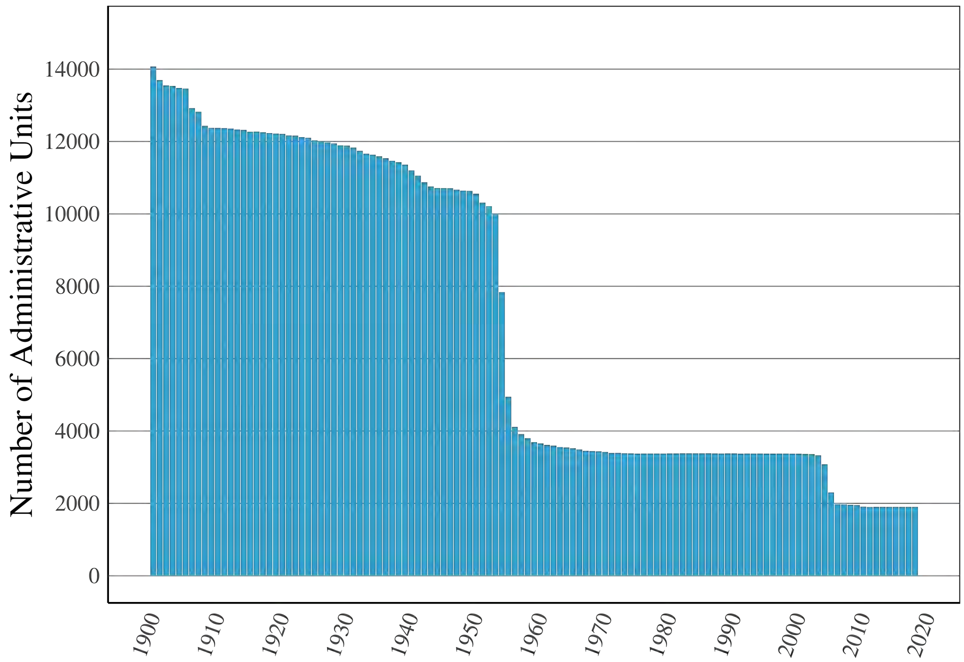


(b) Machinery Industry

Notes: These figures display the adoption rate of steam engines and electric motors by establishment size in 1902 (left), 1909 (center), and 1919 (right), where we define the number of workers as a measure of establishment size. Each point represents the average adoption rate among establishments in each decile bin. Note that the minimum number of workers is ten.
Source: Ministry of Agriculture and Commerce (1904, 1911, 1921)

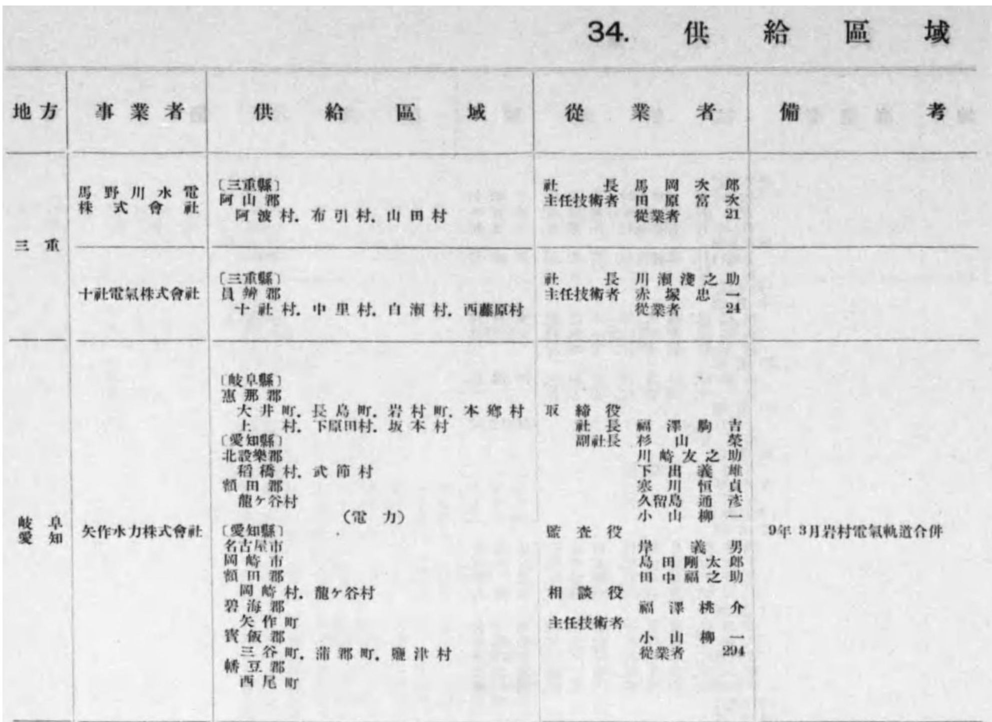
Appendix B Data: Additional Details

Figure A5: Administrative Changes in Japan



Notes: This figure shows the trend in the number of administrative units in Japan from 1900 to 2020. In all analyses throughout this paper, I use the harmonized municipality unit, which represents the most aggregated unit from 1900 to 1940. For a validity check, I also harmonized the municipality transitions from 1940 to 2020, although this was not used in the main analysis.
Source: Higashide (2024)

Figure A6: Original Sample Page of the Handbook of Electric Utility Industry



34. 供　給　區　域

地方	事業者	供給區域	從業者	備考
三重	馬野川水電株式會社	〔三重縣〕 阿山郡 阿波村，布引村，山田村	社長 馬岡次郎 主任技術者 田原富次 從業者 21	
	十社電氣株式會社	〔三重縣〕 員辨郡 十社村，中里村，自瀬村，西藤原村	社長 川瀬淺之助 主任技術者 赤塚忠一 從業者 24	
岐阜 愛知	矢作水力株式會社	〔岐阜縣〕 惠那郡 大井町，長島町，岩村町，本鄉村 上村，下原田村，坂本村 〔愛知縣〕 北設樂郡 稻橋村，武節村 額田郡 龍ヶ谷村 （電　力） 〔愛知縣〕 名古屋市 岡崎市 額田郡 岡崎村，龍ヶ谷村 碧海郡 矢作町 寶飯郡 三谷町，蒲郡町，塩津村 幡豆郡 西尾町	取締役 社長 福澤駒吉 副社長 杉山榮 川崎友之助 下出義雄 寒川恒貞 久留島通彦 小山柳一 監査役 岸義男 島田剛太郎 田中福之助 相談役 福澤桃介 主任技術者 小山柳一 從業者 294	9年3月岩村電氣軌道合併

Notes: This picture shows a sample page from Ministry of Communications (1930), providing information on the electricity supply areas for each utility company. I digitized this table across several editions to construct a panel dataset of electricity access status for the years 1909, 1914, 1919, 1924, and 1929.
Source: Ministry of Communications (1930)

Appendix C Descriptive Statistics

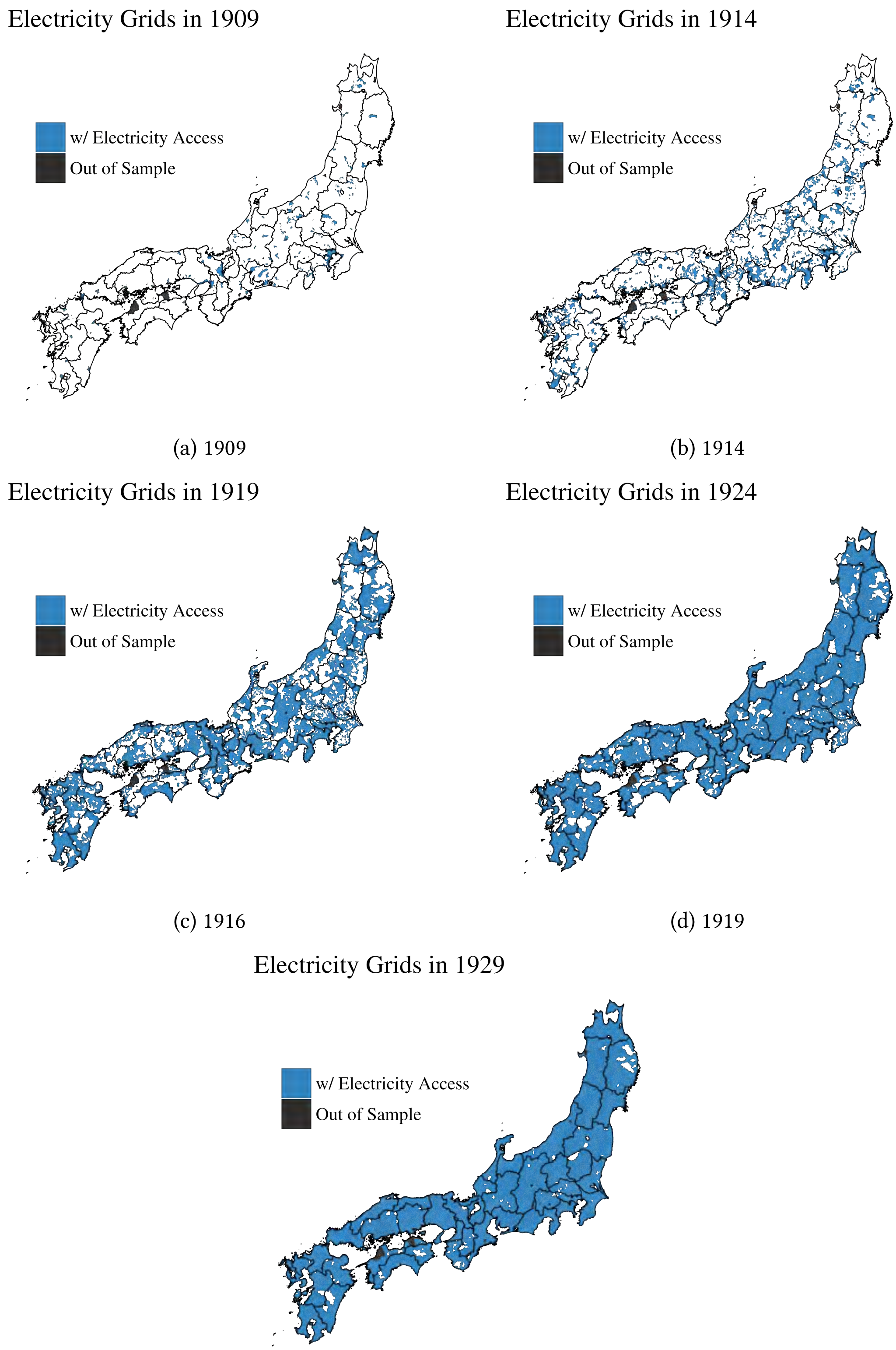
Appendix C.1 *Summary Statistics*

Table A1: Descriptive Statistics

Variable	Observation	Mean	SD	Min	Max
Geography					
Area Size (km^2)	10429	27.199	40	0.105	699
Distance to Coast (km)	10429	25.111	24.8	0.01	113
Distance to the Metropolis (km)	10429	192.256	156.7	0	655
Hydropower Potential	10429	0.003	1	-0.471	11
Ruggedness (degree)	10429	10.082	7.9	0.007	35
Streamflow	10429	0.004	1	-0.844	8
Pre-Access Economic Development					
Population in 1908	10429	4631.128	15718.5	42	625193
Railway Access in 1909 (km)	10429	13.337	15.2	0.014	106
Electricity Access					
Electricity Access in 1909	10429	0.041	0.2	0	1
Electricity Access in 1914	10429	0.26	0.4	0	1
Electricity Access in 1919	10429	0.714	0.5	0	1
Electricity Access in 1924	10429	0.935	0.2	0	1
Electricity Access in 1929	10429	0.987	0.1	0	1
Manufacturing Activities in 1909					
Number of Establishments	10429	1.327	9.5	0	432
- w/ Water Wheel	10429	0.125	0.8	0	35
- w/ Steam Engine	10429	0.321	2.1	0	91
- w/ Electric Motor	10429	0.085	1.4	0	65
Number of Workers	10429	60.623	557.5	0	30121
Today's Economic Activity					
Number of Firms	10429	113.257	618.8	0	31084
Employment ($\times 10^3$)	10429	0.982	7.9	0	301
Sales ($\times 10^6$ yen)	10429	1.533	28.6	0	2151

Notes: This table shows the summary statistics of the municipality characteristics. The Metropolis refers to Tokyo, Yokohama, Nagoya, Kyoto, Osaka, and Kobe, stipulated as the six largest cities by the law in 1922. "Streamflow" indicates the estimated mean annual streamflow weighted by the area size and "Ruggedness" is the average slope of the municipality. Note that "Hydropower Potential" and "Streamflow" are standardized so that the mean is zero and the standard deviation is one. Railway Access means the minimum distance to the nearest railway station.

Figure A7: Expansion of Electricity Grids in Japan



(a) 1909

(b) 1914

(c) 1916

(d) 1919

(e) 1924

Appendix D Additional Results

Appendix D.1 *IV: Hydropower potential*

Table A2: Hydropower Potential and Manufacturing Activities

	Number of Establishments					
	Total			w/ Water Wheel		
	(1)	(2)	(3)	(4)	(5)	(6)
Hydropower Potential × 1902	-0.024	-0.020	-0.004	-0.017	-0.016	-0.010
	(0.022)	(0.023)	(0.023)	(0.020)	(0.020)	(0.021)
Hydropower Potential × 1916	0.015	0.023	0.018	-0.001	-0.002	-0.003
	(0.016)	(0.016)	(0.017)	(0.010)	(0.010)	(0.011)
Hydropower Potential × 1919	0.091**	0.090**	0.080**	0.000	0.001	0.000
	(0.036)	(0.037)	(0.038)	(0.021)	(0.021)	(0.021)
Municipality FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Geography × Year FE	✓	✓	✓	✓	✓	✓
Pop. density 1908 × Year FE	✓	✓	✓	✓	✓	✓
Streamflow × Year FE		✓	✓		✓	✓
Ruggedness × Year FE			✓			✓
Observations	40,020	40,020	40,020	40,020	40,020	40,020
Adjusted R^2	0.68	0.68	0.68	0.58	0.58	0.58
Mean of dep.var	0.72	0.72	0.72	0.09	0.09	0.09

Notes: This table presents the effects of hydropower potential on manufacturing activities and water wheel adoption. Observations are municipalities where the electricity supply began after 1909. Robust standard errors clustered at the municipality level are reported in parentheses. The dependent variable "w/ Water Wheel" and "w/ Steam Engine" represent the number of establishments using water wheels and the number of establishments using steam engines, respectively. The independent variable, "Hydropower Potential", is a standardized measure of municipality-level potential for hydropower generation, with standard deviation of one, thus the estimates reflect differences in economic activities with one standard deviation higher hydropower potential. The vector of control variables, "Geography", includes the municipality area size (in log), the distance to the coast (in log), and the distance to the metropolis (in log). *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Table A3: First Stage: Relationship between Hydropower Potential and Electricity Access

	Electricity Access in 1914			Early Electricity Access		
	(1)	(2)	(3)	(4)	(5)	(6)
Hydropower Potential	0.041***	0.042***	0.041***	0.216***	0.219***	0.250***
	(0.007)	(0.007)	(0.007)	(0.074)	(0.076)	(0.076)
Prefecture FE	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓	✓	✓	✓
Pop. density 1908	✓	✓	✓	✓	✓	✓
Streamflow		✓	✓		✓	✓
Ruggedness			✓			✓
Observations	10,005	10,005	10,005	10,005	10,005	10,005
Adjusted R^2	0.23	0.23	0.23	0.31	0.31	0.31
F-test (1st stage)	72.7	70.1	65.9	18.0	17.9	22.7
Mean of dep.var	0.23	0.23	0.23	15.7	15.7	15.7

Notes: First stage estimates are reported. Observations are municipalities where the electricity supply began after 1909. Robust standard errors clustered by municipalities within 30km radius, following Conley (1999), are reported in parentheses. The instrumental variable, "Hydropower Potential", is a standardized measure of municipality-level potential for hydropower generation, with standard deviation of one, thus the estimates reflect differences in electricity access with one standard deviation higher hydropower potential. The vector of control variables, "Geography", includes the municipality area size (in log), the distance to the coast (in log), and the distance to the metropolis (in log). *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Appendix D.2 *Short-run effect: Robustness*

Table A4: Robustness: Effect of Electricity Access on Industrialization

	Δ Number of Establishments (1909-1919)				Demographics	
	Total	w/ Electric Motor	Total	w/ Electric Motor	Δ Mnf. Workers (1909-1919)	Δ Pop. (1908-1918)
	(1)	(2)	(3)	(4)	(5)	(6)
Electricity Access in 1914	0.298***	0.551***	2.02*	1.29***	122.5***	156.0
	(0.088)	(0.062)	(1.04)	(0.409)	(44.7)	(376.8)
Δ Railway Access	-0.038	-0.034	0.036	-0.002	2.19	-28.4
	(0.044)	(0.026)	(0.070)	(0.032)	(3.13)	(28.1)
Model	OLS	OLS	IV	IV	IV	IV
Prefecture FE	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓	✓	✓	✓
Pop. density 1908	✓	✓	✓	✓	✓	✓
Streamflow	✓	✓	✓	✓	✓	✓
Ruggedness	✓	✓	✓	✓	✓	✓
Observations	10,005	10,005	10,005	10,005	10,005	9,991
First stage F-stat			64.6	64.6	64.6	65.5
Mean of dep.var	0.30	0.36	0.30	0.36	24.7	228.1

Notes: This table presents the effects of electricity access in 1914 on manufacturing activities, electric motor adoption, and demographics, estimated using OLS and IV methods. For IV regressions, the second-stage estimates are reported. Observations are municipalities where the electricity supply began after 1909. Estimates are from instrumental variables specifications in which the endogenous variable is "Electricity Access in 1914" and the instrument is the "Hydropower Potential". Robust standard errors clustered by municipalities within 30km radius, following Conley (1999), are reported in parentheses. The vector of control variables, "Geography", includes the municipality area size (in log), the distance to the coast (in log), and the distance to the metropolis (in log). The variable "Δ Railway Access" represents the change in the distance to the nearest railway station between 1909 and 1919. *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Table A5: Robustness: Drop Municipalities with Large Hydropower Stations

	Δ Number of Establishments (1909-1919)				Demographics	
	Total	w/ Electric Motor	Total	w/ Electric Motor	Δ Mnf. Workers (1909-1919)	Δ Pop. (1908-1918)
	(1)	(2)	(3)	(4)	(5)	(6)
Electricity Access in 1914	0.328***	0.560***	1.34*	1.32***	90.0**	121.1
	(0.090)	(0.064)	(0.771)	(0.395)	(40.8)	(357.6)
Model	OLS	OLS	IV	IV	IV	IV
Prefecture FE	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓	✓	✓	✓
Pop. density 1908	✓	✓	✓	✓	✓	✓
Streamflow	✓	✓	✓	✓	✓	✓
Ruggedness	✓	✓	✓	✓	✓	✓
Observations	9,864	9,864	9,864	9,864	9,864	9,850
First stage F-stat			67.4	67.4	67.4	68.3
Mean of dep.var	0.30	0.37	0.30	0.37	24.5	224.3

Notes: This table presents the effects of electricity access in 1914 on manufacturing activities, electric motor adoption, and demographics, estimated using OLS and IV methods. For IV regressions, the second-stage estimates are reported. Observations are municipalities where the electricity supply began after 1909. Estimates are from instrumental variables specifications in which the endogenous variable is "Electricity Access in 1914" and the instrument is the "Hydropower Potential". Robust standard errors clustered by municipalities within 30km radius, following Conley (1999), are reported in parentheses. The vector of control variables, "Geography", includes the municipality area size (in log), the distance to the coast (in log), and the distance to the metropolis (in log). *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Table A6: Falsification: Effect of Electricity Access on Entrant Activities (1902-1909)

	Number of Establishments						Demographics	
	Total		w/ Steam Engine		w/ Electric Motor		Mnf. Workers	
	(1) Δ All	(2) Entrant	(3) Δ All	(4) Entrant	(5) Δ All	(6) Entrant	(7) Δ All	(8) Entrant
Electricity Access in 1914	0.176	0.762*	0.383**	0.181	0.012	0.011	24.4	32.8**
	(0.693)	(0.406)	(0.170)	(0.127)	(0.016)	(0.009)	(28.0)	(14.5)
Model	IV	IV	IV	IV	IV	IV	IV	IV
Prefecture FE	✓	✓	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓	✓	✓	✓	✓	✓
Pop. density 1908	✓	✓	✓	✓	✓	✓	✓	✓
Streamflow	✓	✓	✓	✓	✓	✓	✓	✓
Ruggedness	✓	✓	✓	✓	✓	✓	✓	✓
Observations	10,005	10,005	10,005	10,005	10,005	10,005	10,005	10,005
First stage F-stat	65.9	65.9	65.9	65.9	65.9	65.9	65.9	65.9
Mean of dep.var	0.33	0.33	0.07	0.10	0.004	0.002	10.5	11.7

Notes: This table presents the effects of electricity access in 1914 on manufacturing activities, technology adoption, and demographics, estimated using IV methods. For IV regressions, the second-stage estimates are reported. Observations are municipalities where the electricity supply began after 1909. Estimates are from instrumental variables specifications in which the endogenous variable is "Electricity Access in 1914" and the instrument is the "Hydropower Potential". Robust standard errors clustered by municipalities within 30km radius, following Conley (1999), are reported in parentheses. The vector of control variables, "Geography", includes the municipality area size (in log), the distance to the coast (in log), and the distance to the metropolis (in log). *, **, and *** indicate significance at the 10%, 5%, and 1% levels.