

SPARKING KNOWLEDGE: EARLY TECHNOLOGY ADOPTION, INNOVATION ABILITY AND LONG-RUN GROWTH

Björn Brey

Norwegian School of Economics

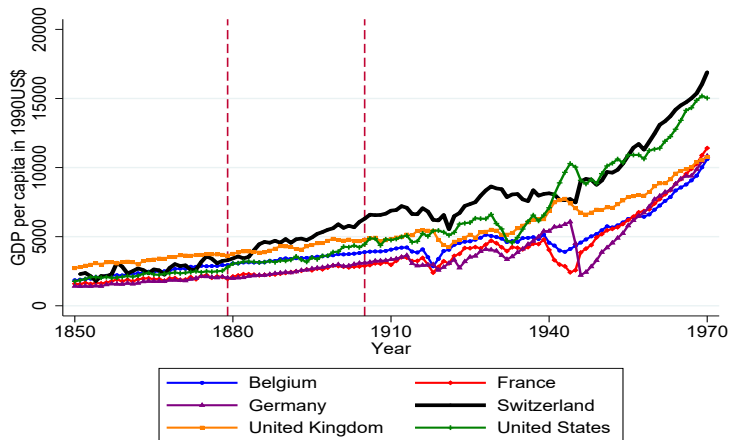
Teaching Materials

MOTIVATION

- Timing of technology adoption appears crucial for divergence in incomes across countries (Mokyr 1992; Comin & Hobijn 2010; Comin & Mestieri 2018).
- However, positive effect of major technological breakthroughs within countries has been hard to document (e.g. Solow-Paradox):
 - Rather correlated with slowdowns in economic growth (David 1989; Jovanovic & Rousseau 2005).
 - Availability of detailed data and endogeneity key issues here.

CROSS COUNTRY GDP

Emergence of electricity and diverging national incomes



Real GDP per capita in 1990US\$ across leading industrial countries from 1850-1970. Source: Madison Project Database (2018).

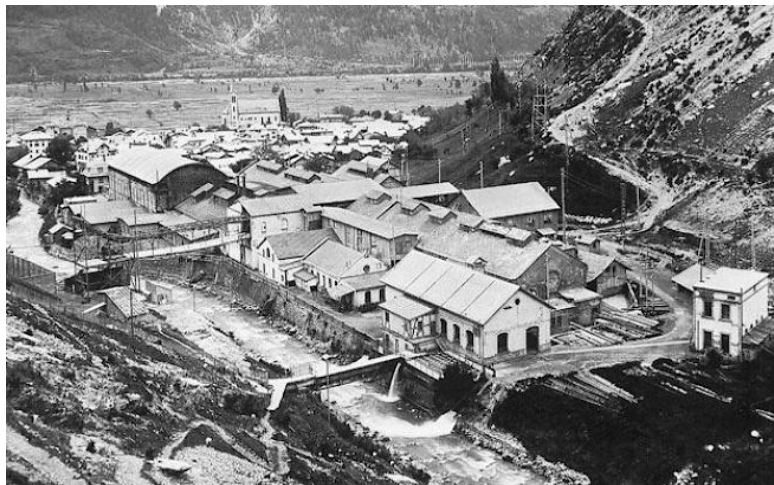
OUTLINE

- Historical context
- Research question
- Empirical approach
- Data
- Results:
 - A) Economic development
 - B) Mechanism
- Conclusions

OVERALL HISTORICAL CONTEXT

- Electricity starting to be used economically from the 1880s onwards.
- Switzerland highest per capita usage at the start of the 20th century (Paquier 2006).
- Relying on waterpower due to the prohibitive cost of imported fossil fuels (Bossard 1916).
- Electricity and chemicals key drivers of the second industrial revolution (Landes 1969; Mokyr 1998).
- Many novel chemical production processes required electricity (e.g. production of chlor-alkali, calcium carbide).

HISTORICAL EXAMPLE: LONZA



Lonza was founded in 1897 in the small municipality of Gampel (population of 421 in 1880). [▶ Historical overview](#)

HISTORICAL EXAMPLE: LONZA

Electricity generation



Calcium carbide production



Generation of electricity and production of calcium carbide.

HISTORICAL EXAMPLE: LONZA

New Visp plant in 1928



New products



Today 48th largest chemical company with 14,500 employees in 18 countries and Visp-site being the largest production and research site with 2800 employees (50% of population).

HISTORICAL EXAMPLE: LONZA



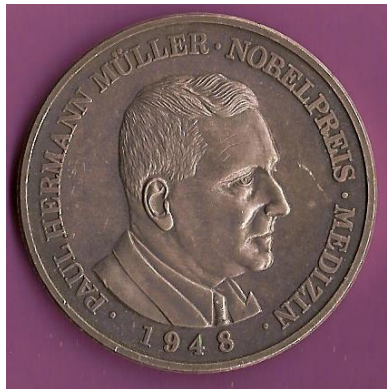
Gampel site closed in 1964. Several small industrial firms founded locally (e.g. Valbag AG in plastics, Evoset AG in precision measurement). Population remains extremely high-skilled (4.7% scientists).

HISTORICAL EXAMPLE: LONZA

Secondary school Gampel



Paul Hermann Müller



Legacy of educating local workforce (incl. Nobel laureates like Paul Hermann Müller) leading to further innovation.

RELATED LITERATURE

- Effect of **electrification during the early 20th century**: Kitchens (2014); Kitchens & Fishback (2015); Gaggl et al. (2019); Lewis & Severnini (2019); Molinder et al. (2019); Leknes & Modalsli (2020)
- The effect of **new technologies** on the accumulation of **human capital**: e.g. Galor & Moav (2006); Galor (2011); De Pleijt et al. (2018)
- **Long-run effect** of technology adoption: Juhasz (2018); Frank & Galor (2019); Lewis & Severnini (2019)

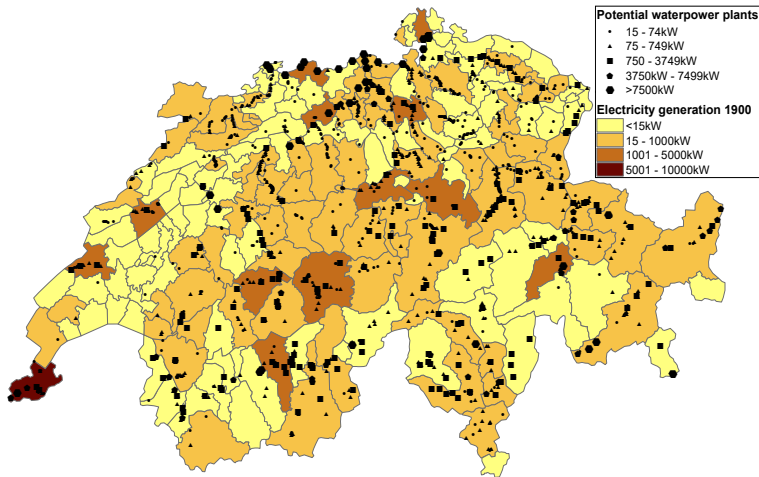
RESEARCH QUESTION

- Three key empirical questions:
 - (1) Does the early adoption of new technologies lead to economic development?
 - (2) Do differences in economic activity persist over time as new technologies become adopted widely?
 - (3) What mechanisms can explain this persistent divergence in economic activity?
- I investigate this exploiting the geographical variation in the potential to produce electricity across Switzerland.

INTERESTING SETTING

- Electricity in Switzerland provides an excellent setting:
 - At the forefront of electricity adoption with the USA till 1900s.
 - Adoption quasi-random due to reliance on waterpower.
 - After 1900, rapid expansion of the electricity grid. Access becomes universal.
- Areas as good as randomly exposed to electricity for the first 20 years.

MAP OF POTENTIAL AND GENERATED ELECTRICITY



MAIN RESULTS

- Early electricity adoption led to economic development:
 - One standard deviation higher exposure to electricity is associated with a 3% decrease (increase) in the agricultural (manufacturing) share from 1880-1900.
 - Effect on structural transformation and incomes persists up to today.
- Mechanisms:
 - The long-run effect is not explained by persistent differences in the use of electricity itself.
 - Rather early adoption sparked human capital accumulation and innovation.

EMPIRICAL APPROACH: SHORT-RUN

- Regression equation:

$$\Delta DEV_{d,1900-1880} = \beta \Delta E_{d,1900-1880} + \gamma' X_{d,1880} + \epsilon_d \quad (1)$$

- $\Delta DEV_{d,1900-1880}$ change in economic development 1880-1900.
- $\Delta E_{d,1900-1880}$ adoption electricity 1880-1900.
- $X_{d,1880}$ vector of initial controls (picking up differential trends): altitude, longitude, latitude, pop. density, agricultural share, education level, watermills, main regions.

THREAT TO IDENTIFICATION

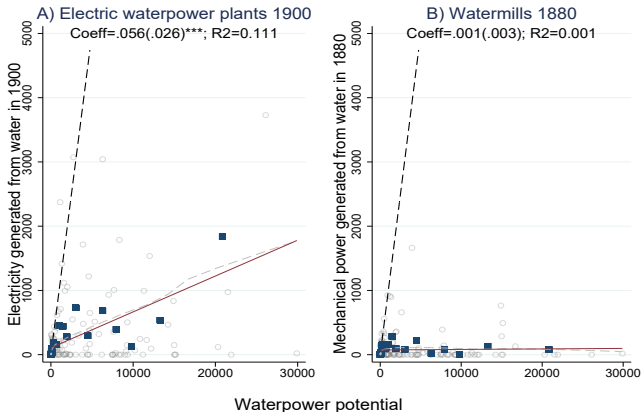
- Electrification not random and depends on other factors:
 - Higher electricity demand in industrialising areas (upward-bias).
 - Industrializing areas unable to exploit water-power for electricity due to earlier allocated water-concessions (lasting 50-100 years) and rivers used for transport (downward-bias).
- Instrument the change in electricity produced per person from 1880-1900 with log water-power potential per person.

▶ Adoption Basel

▶ Bias OLS

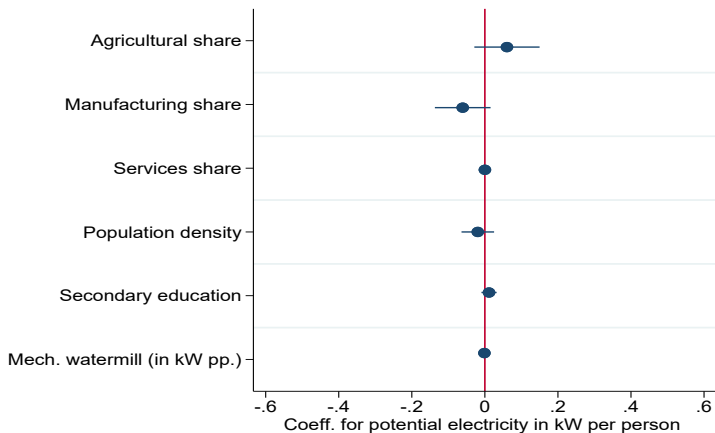
EXCLUSION RESTRICTION

- Aims of engineers:
 - Maximise energy that could be generated.
 - Disregard existing development.
 - Disregard economic viability.
- Features irrelevant before ▶ Random ▶ Random2 ▶ Pre-trend:



BALANCE CHECKS

Electricity potential and economic development by 1880



Relationship between electricity potential in kW per person and measures of economic development in 1880 across districts. Including controls for major geographic differences: altitude, latitude & longitude. X-axis scale corresponds to size of baseline coefficient. 90% confidence interval, N=178.

EMPIRICAL APPROACH: LONG-RUN

- Regression equation:

$$\Delta DEV_{d,t-1880} = \beta_t \Delta E_{d,1900-1880} + \gamma_t \Delta E_{d,t-1900} + \gamma_t' X_{d,1880} + \epsilon_d \quad (2)$$

- $\Delta DEV_{d,t-1880}$ change in economic development to period t.
- $\Delta E_{d,1900-1880}$ early adoption electricity 1880-1900.
- $\Delta E_{d,t-1900}$ controls for generation of electricity after 1900. [▶ Detail](#)
- $X_{d,1880}$ vector of initial controls.

DATA

- Data on exploited and potential water-power across Switzerland from the "Statistics of water-power of Switzerland in 1914".
 - Information on building/extension date and kW produced of water-power plants.
 - Information on type of energy usage.
 - Map of exploited and potential waterpower.
- Sectoral employment in 178 Swiss districts from the census for 1860-2011.
- Other data sources: Education level 1880-1910 (Swiss military exams); Electricity usage of firms in 1929 and 1955 (Census) and others.

SHORT-RUN RESULT

Effect of electricity on structural change 1880-1900

A. Agriculture (OLS)	(1)	(2)	(3)	(4)	(5)
Δ Electricity pp 1880-1900	-0.291*** (0.041) [0.050]	-0.315*** (0.050) [0.046]	-0.321*** (0.057) [0.052]	-0.314*** (0.057) [0.051]	-0.291*** (0.042) [0.037]
Altitude (km)		0.037** (0.014)	0.045** (0.020)	0.044** (0.020)	0.061** (0.028)
Longitude		-0.004 (0.004)	-0.006 (0.005)	-0.005 (0.005)	-0.049*** (0.014)
Latitude		0.047*** (0.014)	0.043*** (0.013)	0.045*** (0.013)	0.040 (0.032)
Share agricultural employment 1880			-0.031 (0.028)	-0.037 ⁺ (0.027)	-0.020 (0.033)
Population density 1880			0.003 (0.007)	0.001 (0.007)	0.006 (0.006)
Average educ. grade 1880			-0.014 (0.021)	-0.012 (0.021)	-0.013 (0.021)
Watermills 1880				-0.667 ⁺ (0.413)	-0.739* (0.399)
Region _i FE	No	No	No	No	Yes
adj. R^2	0.048	0.089	0.090	0.097	0.131
N	178	178	178	178	178

▶ Additional controls

▶ Bias OLS

SHORT-RUN RESULT

Effect of electricity on structural change 1880-1900

A. Agriculture (OLS)	(1)	(2)	(3)	(4)	(5)
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Geographic controls		✓	✓	✓	✓
Economic controls			✓	✓	✓
Mechanical watermills				✓	✓
Region FE					✓
adj. R^2	0.048	0.089	0.090	0.097	0.131
N	178	178	178	178	178
B. Agriculture (IV)					
Δ Electricity pp 1880-1900	-0.500** (0.238) [0.256]	-0.756*** (0.260) [0.250]	-0.731*** (0.251) [0.245]	-0.734*** (0.249) [0.245]	-0.625*** (0.212) [0.214]
First stage estimate	0.048*** (0.008)	0.051*** (0.011)	0.054*** (0.012)	0.054*** (0.012)	0.057*** (0.014)
F-stat (1st stage)	36.56	20.51	19.96	19.98	16.66
Reduced form estimate	-0.024* (0.012)	-0.038*** (0.010)	-0.039*** (0.010)	-0.039*** (0.010)	-0.036** (0.013)
C. Manufacturing (IV)					
Δ Electricity pp 1880-1900	0.417* (0.241)	0.536** (0.271)	0.570** (0.282)	0.573** (0.279)	0.532** (0.262)
D. Services (IV)					
Δ Electricity pp 1880-1900	0.083 (0.206)	0.220 ⁺ (0.135)	0.161 (0.151)	0.162 (0.152)	0.093 (0.162)

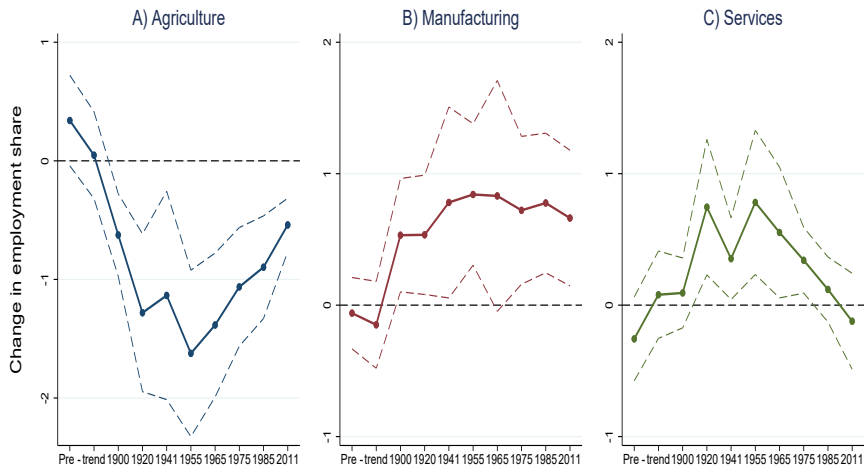
SHORT-RUN RESULT

Effect of electricity on structural change 1880-1900

A. Agriculture (OLS)	(1)	(2)	(3)	(4)	(5)
Δ Electricity pp 1880-1900	-0.291*** (0.041) [0.050]	-0.315*** (0.050) [0.046]	-0.321*** (0.057) [0.052]	-0.314*** (0.057) [0.051]	-0.291*** (0.042) [0.037]
Geographic controls		✓	✓	✓	✓
Economic controls			✓	✓	✓
Mechanical watermills				✓	✓
Region FE					✓
adj. R^2	0.048	0.089	0.090	0.097	0.131
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D. Services (IV)					
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LONG-RUN RESULT I

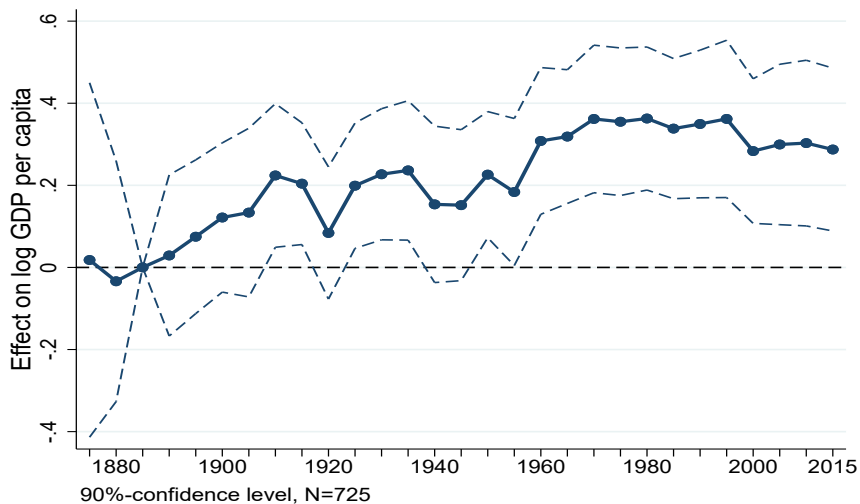
Effect of early adoption electricity on structural change



90%-confidence level, N=10*178

LONG-RUN RESULT II

Effect of early adoption electricity on cantonal GDP



POTENTIAL MECHANISMS

- Persistent differences in technology adoption. ▶ Usage ▶ Generation
- Agglomeration forces.
- Local government revenue and spending. ▶ Fiscal capacity.
- Human capital accumulation and innovation.
- Role of infrastructure. ▶ Network ▶ Demand

MECHANISM: POPULATION AGGLOMERATION

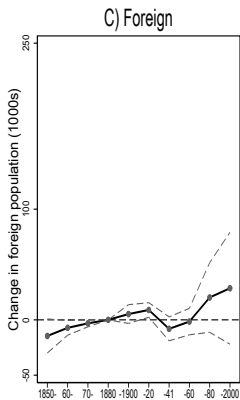
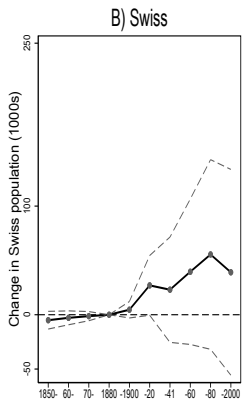
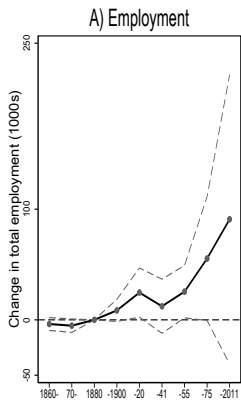
Effect of electricity on employment and population growth

	Employment growth 1880-1900			
	All (1)	Agriculture (2)	Manufacturing (3)	Services (4)
Δ Electricity pp 1880-1900	1.242*** (0.456)	-0.553*** (0.180)	2.527** (1.255)	1.203 ⁺ (0.839)
	Population growth & migration 1880-1900			
	Municipality (5)	Canton (6)	Swiss (7)	Foreign (8)
Δ Electricity pp 1880-1900	0.199 (0.282)	0.425 (0.516)	-1.381 (2.604)	3.264 (2.986)
Controls	Yes	Yes	Yes	Yes
N	178	178	178	178

- Increase in local labour force participation.
- But no effect on local population growth or in-migration (inconsistent with e.g. Bleakley & Lin 2012).

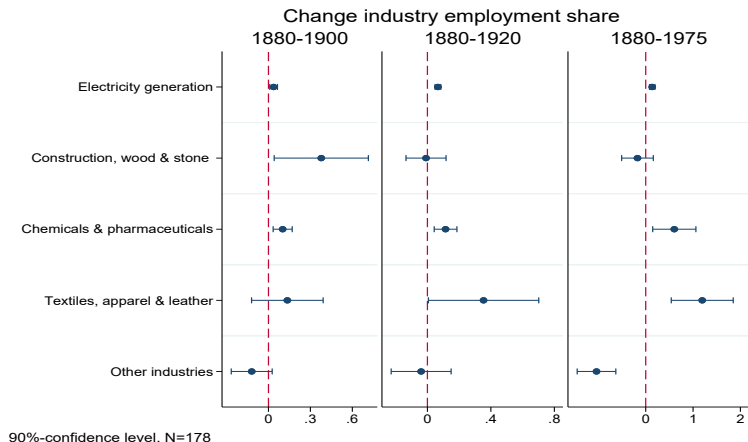
▶ Additional evidence

MECHANISM: POPULATION AGGLOMERATION



90%-confidence level

MECHANISM: WHICH INDUSTRIES GAINED?



- Chemical industry development consistent with agglomeration forces based on initial location (coeff. explains 1900: 47%, 1975: 72%). E.g. Krugman (1991).
- Textile industry survival inconsistent as peaked in 1880.

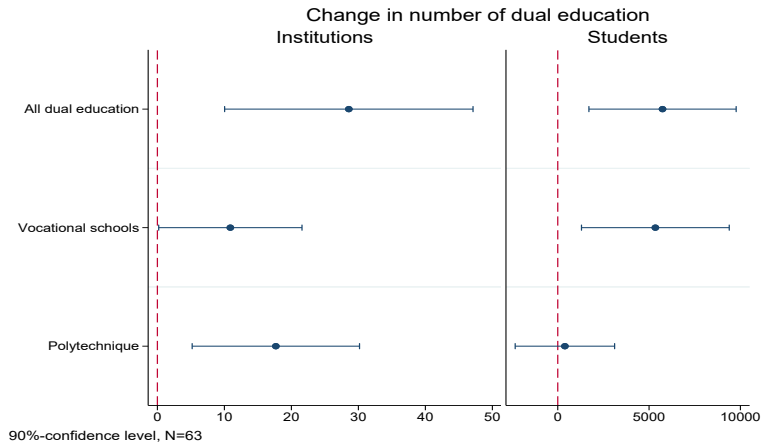
MECHANISM: HUMAN-CAPITAL ACCUMULATION

Effect of electricity on primary and secondary education

	Overall (1)	Reading (2)	Writing (3)	Math (4)	General (5)
A. Secondary education 1880-1900					
Δ Electricity pp 1880-1900	0.530* (0.306)	0.476 ⁺ (0.351)	0.667** (0.338)	0.064 (0.358)	0.713** (0.310)
B. Secondary education 1880-1910					
Δ Electricity pp 1880-1900	0.932** (0.449)	0.677* (0.353)	0.784* (0.404)	1.178* (0.696)	1.089** (0.449)
C. Primary education 1880-1900					
Δ Electricity pp 1880-1900	0.088 (0.316)	-0.353** (0.178)	0.154 (0.460)	0.037 (0.327)	0.310 (0.612)
D. Primary education 1880-1910					
Δ Electricity pp 1880-1900	0.158 (0.232)	-0.259 ⁺ (0.168)	0.246 (0.341)	0.517 (0.479)	0.129 (0.314)
Controls	Yes	Yes	Yes	Yes	Yes
<i>N</i>	178	178	178	178	178

- Increase in human-capital formation and endogenous economic growth (consistent with e.g. Romer 1990; Goldin & Katz 2001; Galor 2011).

MECHANISM: SUPPLY OF EDUCATION



► Detail ► Spending

MECHANISM: DEMAND FOR EDUCATION

	Effect of electricity on education demand					
	1902 (1)	1963 (2)	1964 (3)	1973 (4)	1973 (5)	1978 (6)
Δ Electricity pp 1880-1900	0.940 ⁺ (0.667)	0.168 ⁺ (0.117)	0.483 ^{***} (0.131)	1.790 ^{***} (0.674)	1.256 ^{***} (0.304)	1.171 ^{***} (0.274)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	178	178	178	178	178	178

- Exposure to new technology and local employment opportunities based on knowledge increased the demand for education.

MECHANISM: INNOVATION

Effect of early electricity adoption on innovation today

	All patents (1)	Before 2000 (2)	After 2000 (3)	City (4)	Town (5)	Rural (6)
Δ Electricity pp 1880-1900	0.111*** (0.033)	0.053*** (0.016)	0.057*** (0.021)	0.003 (0.009)	0.042** (0.020)	0.066** (0.029)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	178	178	178	178	178	178

- This translates into increased innovation, which drives further economic growth.
- Effect randomly allocated and larger in remote areas (< 10000)! Skilled employment and innovation in remote areas appears puzzling (see e.g. Eaton & Kortum 2002).

POLICY IMPLICATIONS

- Late 19th century electricity adoption led to structural change.
- Differences in economic development persist up to today.
- The main mechanism is human capital accumulation and future innovation (and complementary adjustment in infrastructure).
- Policy implications:
 - Long-run gains from adopting new technologies outweighing costs.
 - Complementaries between technological progress and education.
 - Similarities to intensive internet and mobile phone role-out in Estonia & Kenya and technological leapfrogging that is observable.

Thank You!

SUMMARY STATS

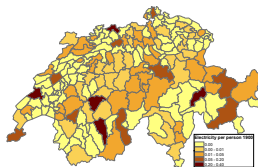
Summary statistics for the main variables used.

	Mean	Std. dev.	25th Perc.	75th Perc.	Valid obs.
Change agricultural share 1880-1900	-0.07	0.07	-0.10	-0.02	178
Change manufacturing share 1880-1900	0.05	0.05	0.01	0.08	178
Change services share 1880-1900	0.02	0.04	0.01	0.03	178
Change electricity 1880-1900	0.02	0.05	0.00	0.01	178
Log water-power potential	0.23	0.40	0.00	0.24	178
Altitude (km)	0.96	0.56	0.53	1.22	178
Longitude	8.08	0.98	7.27	8.89	178
Latitude	46.98	0.45	46.62	47.37	178
Share agricultural employment (1880)	0.49	0.20	0.34	0.65	178
Population density (1880)	0.13	0.35	0.04	0.13	178
Average educ. grade (1880)	2.64	0.39	2.35	2.89	178
Mechanical waterpower per person (1880)	0.00	0.01	0.00	0.00	178

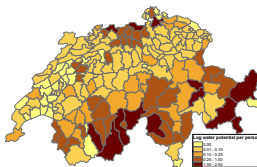
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ADDITIONAL MAPS

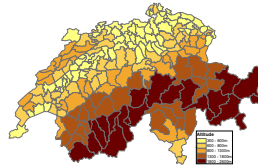
A) Electricity



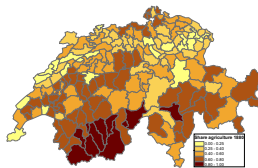
B) Potential



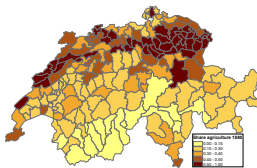
C) Altitude



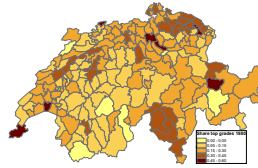
D) Agriculture



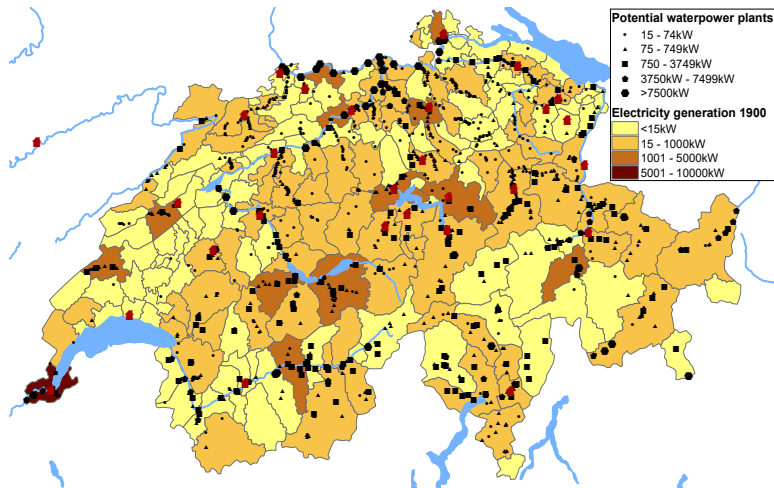
E) Manufacturing



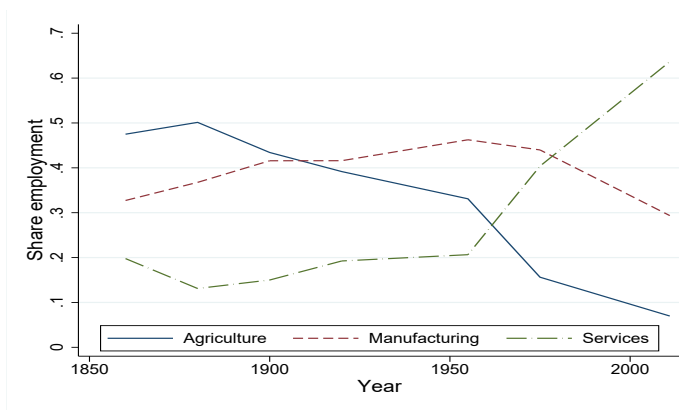
F) Education



MAP OF POTENTIAL AND GENERATED ELECTRICITY

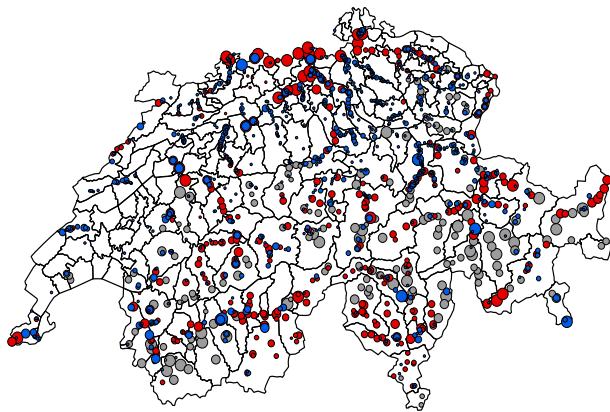


EMPLOYMENT ACROSS SECTORS



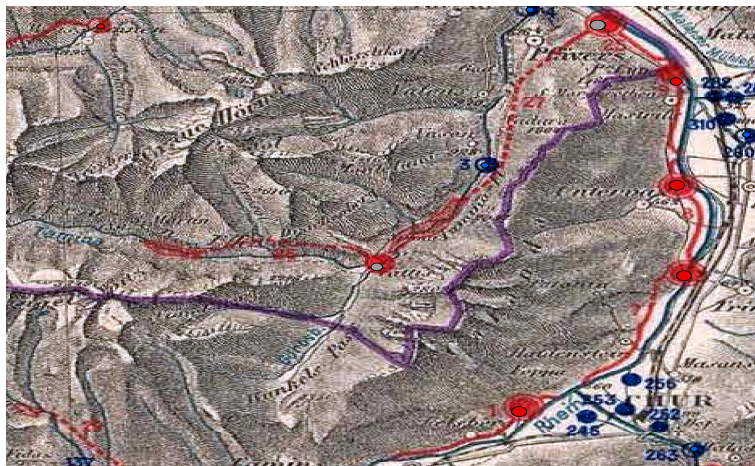
The figure depicts the share of employment in (i) agriculture, (ii) mining and manufacturing and (iii) services for 1860, 1880, 1900, 1920, 1955, 1975, and 2011. The share of employment reported is the average across the 178 districts in the sample.

DISTRIBUTION WATERPOWER



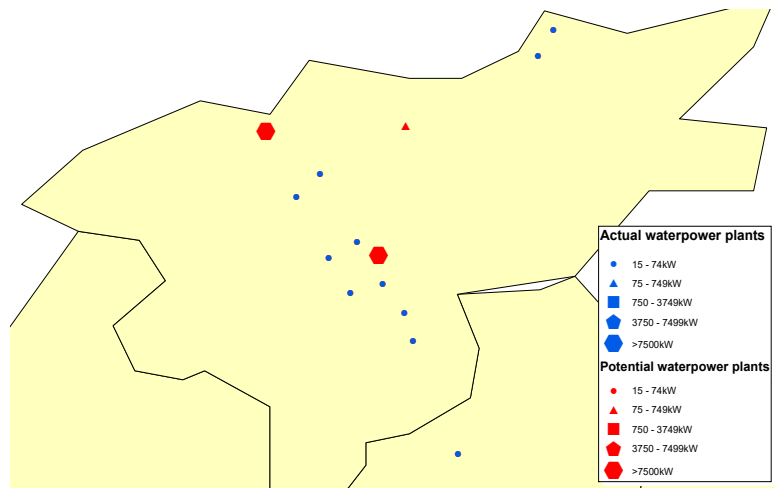
Blue dots exploited water-power, red dots potential water-power, grey dots require a dam. Size of circle representing (i) 20-99HP, (ii) 100-999HP, (iii) 1000-4999HP, (iv) 5000-9999HP and (v) above 10000HP. Source: Statistics of water-power of Switzerland 1914.

RAW DATA



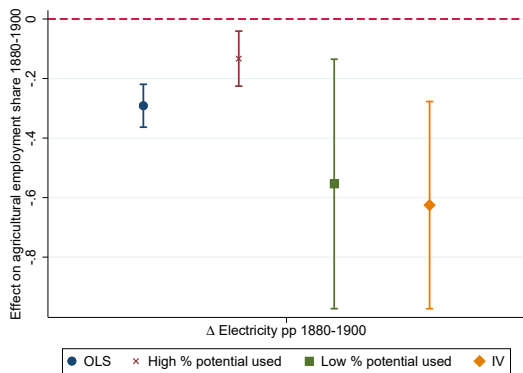
Blue dots exploited water-power, red dots potential water-power, grey dots require a dam. Size of circle representing (i) 20-99HP, (ii) 100-999HP, (iii) 1000-4999HP, (iv) 5000-9999HP and (v) above 10000HP.

EXAMPLE BASEL



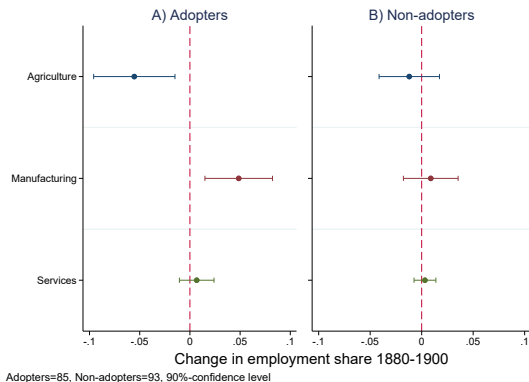
Waterpower plants and potential in the city of Basel. Most of the exploited waterpower is still watermills using mechanical energy.

EVIDENCE ON SOURCE OF BIAS IN THE OLS



This figure highlights that the downward bias in magnitude in the OLS is due to areas that utilize a large share of their potential for electricity generation ($> 20\%$) as they have a smaller marginal effect from adoption compared to those areas that are only able to utilize a small share ($< 20\%$). N=178; 66; 112; 178 [▶ Back](#)

REDUCED FORM ADOPTERS VS. NON-ADOPTERS



This figure presents the baseline reduced form estimates when the sample is split in districts that adopted any electricity by 1900 and those that did not. Adopters=85, Non-adopters=93. [▶ Back](#)

EXAMPLE WATERPOWER PLANTS

A) without embankment dam



Figure: Water-power plant in Gospel (1:10000). [▶ Back](#)

B) with embankment dam

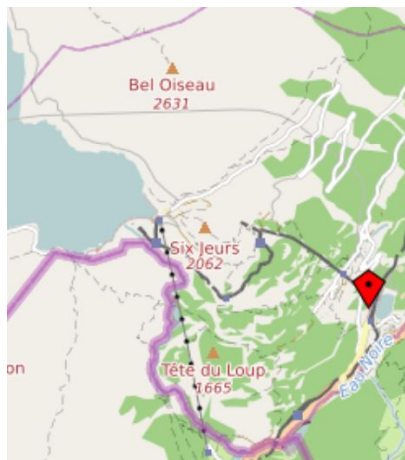
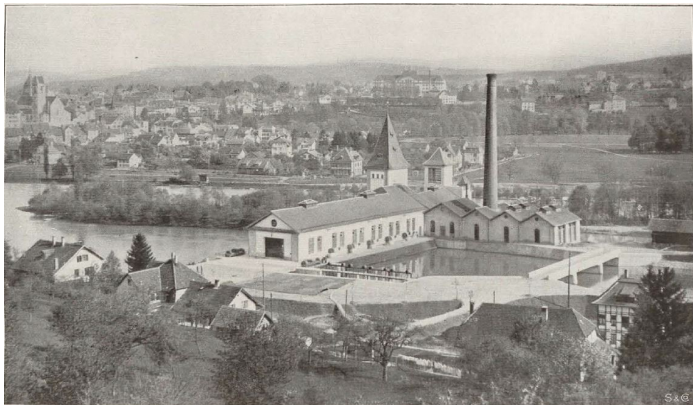


Figure: Water-power plant in Barberine (1:1000000).

EXAMPLE 1



Waterpower plant in Aarau and Gösgen build in 1894 and extended in 1912 owned by the municipality of Aarau with an average electricity production of 940HP. Concession till 1990. Source: Statistics of water-power of Switzerland, 1914.

EXAMPLE 2



Waterpower plant in Prés du Chanet build in 1895 and extended in 1914 owned by the municipality of Neuchâtel in the Boudry district with an average electricity production of 3000HP. Concession till 1989. Source: Statistics of water-power of Switzerland, 1914.

TREATMENT ASSIGNMENT

Comparison areas with and without electricity potential

Variable	Control		Treatment		Diff	P value
	Mean	N	Mean	N		
Panel A. Difference between no-potential vs. any potential						
Share agricultural employment (1880)	0.53	29	0.49	149	0.041	
Share manufacturing employment (1880)	0.35	29	0.40	149	-0.047	
Share services employment (1880)	0.14	29	0.13	149	0.006	
Altitude (km)	0.75	29	1.00	149	-0.246	**
Longitude	7.55	29	8.19	149	-0.633	***
Latitude	46.93	29	46.99	149	-0.064	
Panel B. Difference between no-potential vs. top 33% of potential						
Share agricultural employment (1880)	0.53	29	0.57	61	-0.041	
Share manufacturing employment (1880)	0.35	29	0.31	61	0.038	
Share services employment (1880)	0.14	29	0.14	61	-0.001	
Altitude (km)	0.75	29	1.27	61	-0.522	***
Longitude	7.55	29	8.23	61	-0.680	***
Latitude	46.93	29	46.79	61	0.136	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

T-test between means in treatment and control for instrument.

RANDOM ALLOCATION

Random distribution waterpower potential

	Population density 1880		Share employment 1880 in					
	(1)	(2)	Agriculture (3)	(4)	Manufacturing (5)	(6)	Services (7)	(8)
A. Geography								
Potential kW per km ²	0.004 (0.002)	0.004 (0.002)	-0.000 (0.000)	0.000 (0.001)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Altitude (km)		-0.098*** (0.032)		0.082 (0.061)		-0.064 (0.054)		-0.018 (0.024)
Longitude		0.034 (0.033)		-0.011 (0.029)		0.005 (0.025)		0.006 (0.007)
Latitude		-0.026 (0.056)		-0.148* (0.079)		0.180** (0.075)		-0.032 (0.019)
B. Population								
Potential kW per person	-0.056** (0.020)	-0.019 (0.022)	0.102** (0.044)	0.060 (0.043)	-0.101** (0.037)	-0.061 (0.037)	-0.001 (0.011)	0.000 (0.008)
Altitude (km)		-0.108*** (0.033)		0.056 (0.062)		-0.037 (0.057)		-0.019 (0.024)
Longitude		0.036 (0.031)		-0.016 (0.027)		0.010 (0.024)		0.006 (0.006)
Latitude		0.035 (0.046)		-0.148* (0.075)		0.176** (0.071)		-0.027 (0.018)
N	178	178	178	178	178	178	178	178

PRE-TREND

	Agriculture		Manufacturing		Services	
	(1)	(2)	(3)	(4)	(5)	(6)
A. 1860-1880						
Δ Electricity pp 1880-1900	0.087 (0.552)	0.388 (0.400)	-0.348 (0.436)	-0.210 (0.260)	0.260 (0.320)	-0.177 (0.193)
B. 1860-1870						
Δ Electricity pp 1880-1900	0.298 (0.400)	0.340 ⁺ (0.232)	-0.458 (0.369)	-0.061 (0.165)	0.227 (0.203)	-0.257 ⁺ (0.194)
C. 1870-1880						
Δ Electricity pp 1880-1900	-0.215 (0.293)	0.048 (0.223)	0.111 (0.126)	-0.149 (0.201)	0.035 (0.225)	0.079 (0.202)
F-stat (1st stage)	37.76	18.39	37.76	18.39	37.76	18.39
Controls	No	Yes	No	Yes	No	Yes
N	177	177	177	177	177	177

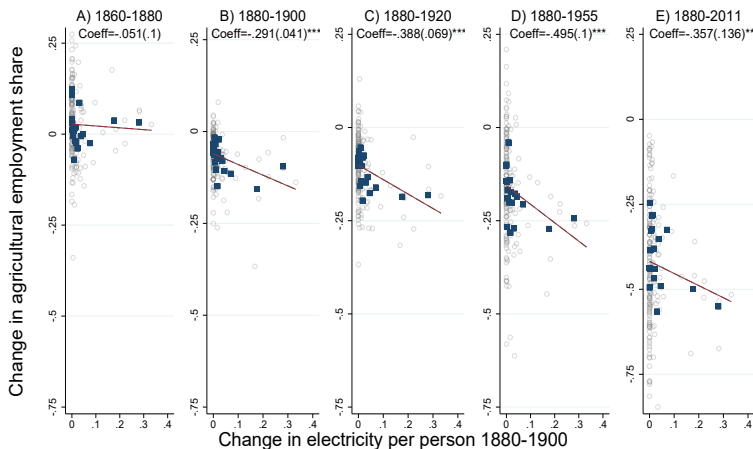
Pre-trend effect of electricity adoption 1880-1900 on development 1860-1880, 1860-1870 and 1870-1880. 1860 initial controls.

A. OLS	Additional human characteristics					Additional geographic controls					All
	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Electricity	-0.305*** (0.042)	-0.298*** (0.047)	-0.305*** (0.046)	-0.288*** (0.044)	-0.280*** (0.033)	-0.294*** (0.038)	-0.284*** (0.040)	-0.291*** (0.044)	-0.290*** (0.044)	-0.273*** (0.049)	-0.269*** (0.052)
Share math	-0.104 ⁺ (0.065)										-0.067 (0.083)
Share Cath.		0.008 (0.022)									0.016 (0.030)
Share Jew		-0.914 (0.792)									-0.360 (0.781)
Share Rom.			-0.070 ⁺ (0.046)								0.013 (0.029)
Share Ital.			-0.012 (0.040)								0.054 (0.053)
Share Fr.			-0.017 (0.022)								-0.009 (0.049)
Liberal				0.016 (0.016)							0.092 ⁺ (0.056)
Sonderbund				0.031 ⁺ (0.019)							0.199*** (0.049)
Canton FE					Yes ✓						Yes ✓
Cropland						0.085*** (0.020)					0.035 (0.030)
River							-0.017** (0.006)				-0.006 (0.008)
Water flow								-0.001*** (0.000)			-0.001*** (0.000)
Alpine									-0.007 (0.016)		-0.004 (0.022)
Po Basin									0.055*** (0.004)		0.073*** (0.012)
Rugged										-0.093* (0.047)	-0.096 (0.086)

B. IV

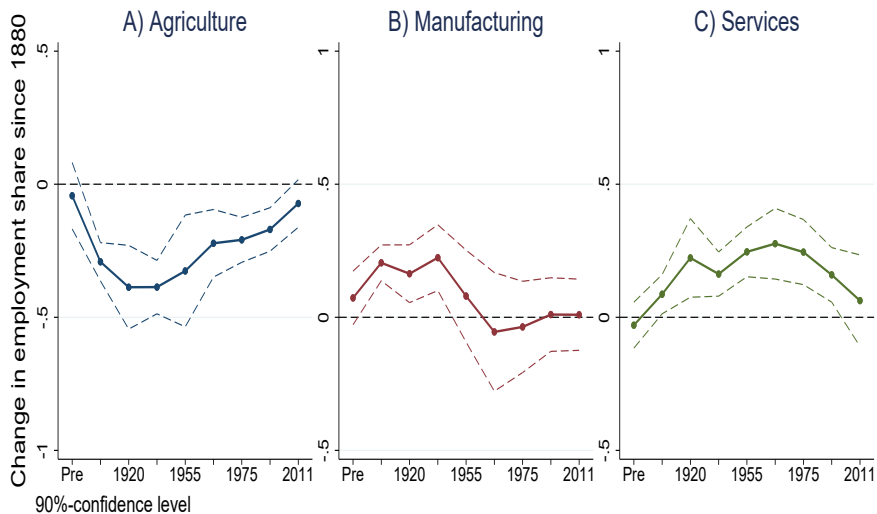
Electricity	-0.661*** (0.240)	-0.575*** (0.211)	-0.595*** (0.178)	-0.585*** (0.224)	-0.497* (0.281)	-0.600*** (0.211)	-0.512*** (0.193)	-0.546*** (0.194)	-0.635*** (0.210)	-0.601*** (0.221)	-0.406* (0.210)
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Electricity adoption and transition out of agriculture



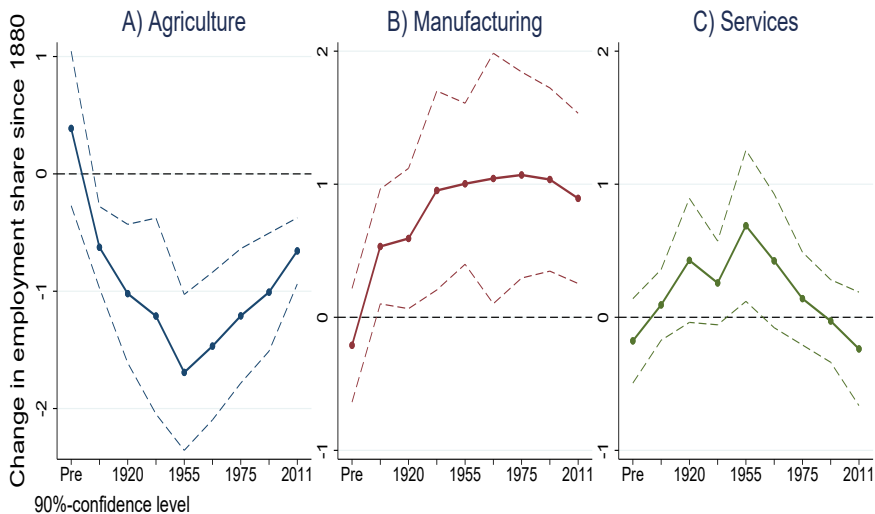
LONG-RUN RESULT OLS

Effect of early adoption electricity on structural change



LONG-RUN RESULT IV - NO ADDITIONAL CONTROLS

Effect of early adoption electricity on structural change



ELECTRICITY ADOPTION 1900-1920

Electricity adoption and industry employment 1900-1920

	Elec. (1)	Con. (2)	Metal (3)	Chem. (4)	Text. (5)	Food (6)	Others (7)
Δ Electricity pp 1900-1920	0.006*** (0.000)	-0.001 (0.004)	-0.001 (0.004)	0.001 (0.002)	0.002 (0.004)	-0.001 (0.001)	-0.002+ (0.001)

▶ Back Approach

▶ Back Results

MECHANISM: ELECTRICITY USE

Long-run differences in electricity use

	Electricity use in kW per		
	District (1)	Firm (2)	Employee (3)
A. 1929			
Δ Electricity pp 1880-1900	6017.18 (8775.68)	141.92 (526.02)	-6.92 (15.90)
B. 1955			
Δ Electricity pp 1880-1900	20655.16 (30241.94)	25.24 (38.77)	-0.45 (7.03)
Controls	Yes	Yes	Yes
<i>N</i>	178	178	178

- Due to expansion of electricity grid no persistent differences in use of electricity (inconsistent with e.g. Comin & Mestieri 2018)
- Later expansion of electricity generation only affect employment in this sector [▶ Generation 1900-1920](#) [▶ Back](#)

MECHANISM: POPULATION AGGLOMERATION II

Effect of electricity on employment growth

	Employment growth rate		
	1880-1900 (1)	1900-1920 (2)	1920-1941 (3)
A. Overall			
Δ Electricity pp 1880-1900	1.242*** (0.456)	0.986* (0.542)	-0.040 (0.313)
B. Male			
Δ Electricity pp 1880-1900	1.549*** (0.464)	-0.369 (0.576)	-0.298 (0.322)
C. Female			
Δ Electricity pp 1880-1900	0.021 (0.202)	2.105** (0.966)	0.653 (0.728)
Controls	Yes	Yes	Yes
<i>N</i>	178	178	178

- First male than female employment growth.
- But employment growth stagnates as local labour reserves are exhausted.

CURRENT OUTCOMES

Effect of early electricity adoption on current outcomes

	<i>Income</i>		<i>Education</i>	
	<i>Average</i> (1)	<i>Median</i> (2)	<i>Secondary</i> (3)	<i>Tertiary</i> (4)
Δ Electricity pp 1880-1900	42.543* (25.777)	26.922* (14.460)	0.405*** (0.146)	0.196*** (0.036)
Controls	Yes	Yes	Yes	Yes
<i>N</i>	178	178	178	178

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EDUCATION SPENDING

Effect early electricity adoption on education spending

Dependent Variable: Change in education spending 1887-1900

	Primary		Secondary	
	Pupils	Expenditure	Pupils	Expenditure
Change electricity 1880-1900	0.804 (0.630)	0.730* (0.406)	0.059 (0.107)	9.846** (4.951)
Controls	Yes	Yes	Yes	Yes
<i>N</i>	25	25	25	24

Robust standard errors in parentheses

+ $p < 0.20$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table: Column 1 and 3 share of pupils in the total population. Column 2 and 4 municipal and cantonal spending per pupil.

VOCATIONAL EDUCATION

Effect early electricity adoption on vocational education

Dependent Variable: Change in dual education institutions 1880-1910

	All (1)	Polytechnic (2)	Vocational (3)
Panel A. All districts			
Change electricity 1880-1900	1.199 (1.332)	1.041 ⁺ (0.771)	0.158 (0.723)
<i>N</i>	178	178	178
Panel B. Cantons			
Change electricity 1880-1900	42.662** (17.823)	14.682*** (3.070)	27.980 ⁺ (17.256)
<i>N</i>	25	25	25
Panel C. Population centres			
Change electricity 1880-1900	17.319** (8.632)	9.564** (4.037)	7.756 (6.504)
<i>N</i>	63	63	63
Panel D. Students in 1910			
Change electricity 1880-1900	5737.043** (2450.812)	392.076 (1654.997)	5344.967** (2458.889)
<i>N</i>	63	63	63

All specifications:

Controls	Yes	Yes	Yes
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⁺ $p < 0.20$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

MECHANISM: FISCAL CAPACITY I

Effect of electricity on fiscal capacity

	Spending (1)	Revenue (2)	Taxes (3)	Debt (4)
Δ Electricity pp 1880-1900	-0.873 (1.248)	2.738 (2.519)	0.120 (0.494)	-1.358 (3.490)
Controls	Yes	Yes	Yes	Yes
<i>N</i>	50	50	50	47

- Government spending, income, taxes & debt per person for a set of large municipalities in 1920. Statistically insignificant, but economically significant (e.g. about 5% decrease in municipal spending for the average municipality). Also higher (non-tax) revenue (e.g. from water-concession & municipal power plants).

MECHANISM: FISCAL CAPACITY II

Effect of electricity on tax-referendums

	1885 (7)	1915 (8)	1917 (9)	1922 (10)	1923 (11)	1930 (12)
Δ Electricity pp 1880-1900	-0.902 (0.747)	-0.209 (0.168)	0.640 (0.606)	0.537*** (0.179)	0.601 (0.369)	0.839*** (0.323)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	178	178	178	178	178	178

- Referendums: Alcohol-tax 1885, War-tax 1915, Stamp-tax 1917, Wealth-tax 1922, Alcohol-tax 1923, Alcohol-tax 1930. Potentially the effect of education on nation-building as cohorts after 1880 become more important (Bandiera et al. 2019).

MECHANISM: COMPLEMENTARY INFRASTRUCTURE I

Effect of electricity on infrastructure today

	Operation points (per km^2) (1)	Tunnels (per km^2) (2)	Train journeys (per person) (3)
Δ Electricity pp 1880-1900	0.262* (0.151)	0.056* (0.030)	3.762*** (1.253)
Controls	Yes	Yes	Yes
<i>N</i>	178	178	178

- Infrastructure network adjusts and better integrates previously remote areas (see also Dell & Olken 2020).

MECHANISM: COMPLEMENTARY INFRASTRUCTURE II

Effect of electricity on infrastructure demand

	1877 (7)	1891 (8)	1897 (9)	1927 (10)	1945 (11)	1987 (12)
Δ Electricity pp 1880-1900	-0.696 (0.605)	-0.608 (0.547)	0.091 (0.703)	0.483* (0.265)	1.178*** (0.361)	1.699*** (0.411)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	178	178	178	178	178	178

- This is also reflected in a change in local perceptions.

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GEOGRAPHICAL DISTRIBUTION

Dependent Variable: Share employment 2011

Panel A. Potential water-power

	(1)	(2)	(3)
	Agriculture	Manufacturing	Services
Log potential waterpower (1km)	-0.017*** (0.000)	0.004*** (0.000)	0.013*** (0.000)
Log potential waterpower (1-5km)	-0.014*** (0.000)	-0.000 (0.000)	0.014*** (0.000)
Log potential waterpower (5-10km)	0.003*** (0.000)	0.000 (0.000)	-0.003*** (0.000)
adj. R^2	0.026	0.001	0.016
N	206359	206359	206359
District FE	No	No	No

Panel B. Potential water-power with District FE

	(1)	(2)	(3)
	Agriculture	Manufacturing	Services
Log potential waterpower (1km)	-0.018*** (0.000)	0.005*** (0.000)	0.013*** (0.000)
Log potential waterpower (1-5km)	-0.013*** (0.000)	0.002*** (0.000)	0.011*** (0.000)
Log potential waterpower (5-10km)	0.001** (0.001)	0.001** (0.000)	-0.002*** (0.001)
adj. R^2	0.126	0.009	0.098
N	206359	206359	206359
District FE	Yes	Yes	Yes

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

POWER-STATIONS

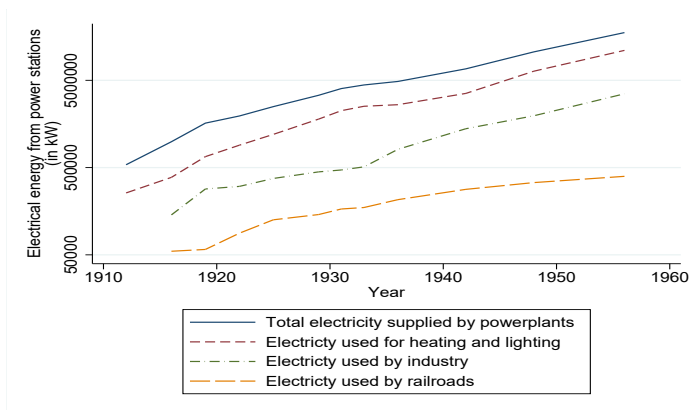
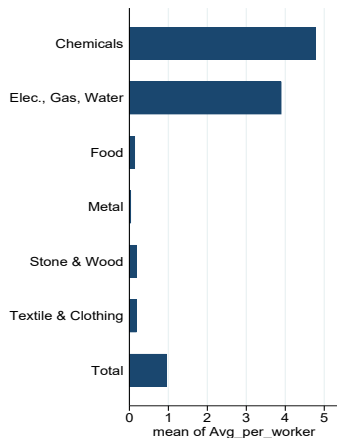
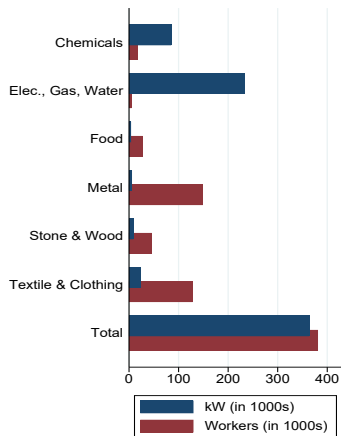


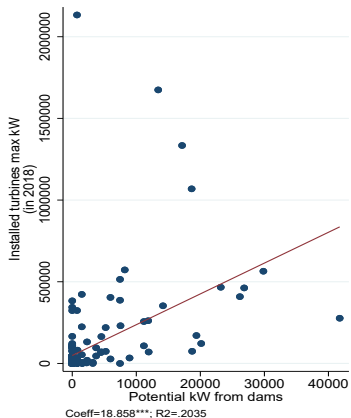
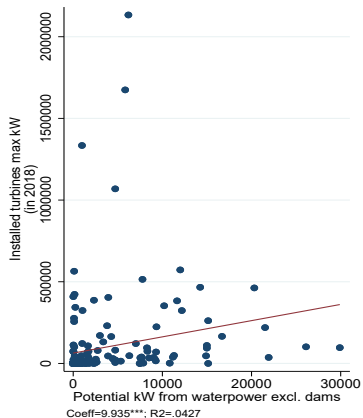
Figure: Electricity produced by power stations for general supply in log Megawatt from 1912 to 1956 and the share of general electricity produced provided to industry and railroads. Source: Historical Statistics of Switzerland.

ENERGY INTENSITY



Usage of waterpower and employment in 1918 by industry categories. Source: Statistical Yearbook 1918.

CURRENT PRODUCTION WATER-POWER



N=178

The relationship between maximum potential power production of installed turbines in 2018 and the waterpower potential.

MIGRATION AS SHARE OF POPULATION

Effect of access to electricity on migration

Dependent Variable: Change in share of locals and migrants

	(1)	(2)	(3)	(4)
	Municipality	Canton	Swiss	Foreign
Change electricity 1880-1900	-0.103 (0.193)	-0.126 ⁺ (0.095)	-0.027 (0.045)	0.257 ⁺ (0.171)
Controls	Yes	Yes	Yes	Yes
<i>N</i>	178	178	178	178

Robust standard errors in parentheses are clustered at the cantonal level

⁺ $p < 0.20$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Change share of population born in municipality of residence, same canton, in Switzerland, and abroad 1880-1900.