Does trade liberalization boost innovation? Evidence from French industrial sectors in the 19th-century

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Abstract

This study explores the role of trade liberalization on industrial decisions to innovate. To this end, I examine how French industrial producers responded to 19th-century trade liberalization in terms of adopting a key technology at the time: steam power. The identification strategy is based on a diff-in-diff approach, which combines industrial power-use statistics from the earliest French industrial censuses of 1843 and 1863 with industry-specific tariff-changes detailed in the Cobden–Chevalier Treaty of 1860. My preliminary findings show that trade liberalization had a positive and profound effect on technical change, which I argue was a direct response to increased foreign competition.

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1 Introduction

The effect of increased trade and trade-liberalization on domestic manufacturing performance is still debated. Growing international competition, not least from emerging economies like China, has raised important questions about the reaction of national firms to increased foreign trade. In particular, how do national producers react to increased foreign competition in terms of innovative activities and technical change? The literature, recently reviewed by Shu and Steinwender (2019), shows ambiguous findings. For example, Bloom et al. (2016) found that growing import-competition from Asia had a positive effect on technical change among European firms, while Dorn et al. (2020) conversely found a negative effect on innovative activity in the US.

My contribution draws lessons from the historical record. Multiple and continuous technological shocks nowadays make it difficult to capture the impact of trade on innovative activities. The far fewer and slower technical developments that happened historically eases the identification. Specifically, I estimate the role of trade liberalization on innovation during the 19th century, which saw declining costs of transportation and open-trade policies looming large on the national agendas (O'rourke and Williamson, 2002). I explore how trade-liberalization impacted the decisions to adopt the emerging general-purpose-technology at the time, steam power, which during the 19th-century gradually replaced the traditional technologies of water, wind, and animal power. In particular, I investigate the reaction of French industrial producers to the trade-liberalization described in the Cobden-Chevalier Treaty of 1860, an Anglo-French trade agreement that reduced import tariffs and eliminated trade protection on manufactured products between England and France. England at the time was a technologically-advance, highly-competitive economy with respect to other countries. France in contrast was industrialising much more slowly, and French firms moreover had benefited from tariffs and prohibitions against the import of British manufactured products in the period prior to the Treaty.

These conditions make 19th-century France a well-suited case for studying the effects of trade-liberalization and increased competition-exposure from an industrial-leader and global first mover. The trade openness shock contained in the Cobden-Chevalier Treaty only applied to certain industrial sub-sectors, affording a comparison of the technological advances made between sub-industries affected and unaffected by the trade agreement. Thanks to information recorded in the two earliest French industrial censuses, published in 1843 and 1863 in *Statistique Générale de la France*, I am able to construct an outcome-variable that I call steam-intensity. The variable indicates, at the local (district) sub-industry level, how much steam-power (the emerging technology at the time) was used relative to the traditional powers (wind, water, and animal). To estimate the causal effect of the reduction of trade-protection and import-tariffs, I apply a diff-in-diff approach.

My preliminary findings indicate that sub-industries exposed to trade-liberalization increased their steam-intensity by up to 51% more than sub-industries not exposed. Various specifications and robustness checks corroborate this finding. I also find that sub-industries located in areas potentially more exposed to British competition (captured by geographical proximity or good transport infrastructures) responded even more strongly to trade openness in terms of installing more steam power.

My study in this sense speaks directly to the recent literature on the effect of trade liberalization on innovation alongside the mechanism through which this occurred. I argue that the possible mechanism driving the positive effect of trade liberalization on innovation in 19th-century France was the rising foreign competition, consistent with the findings reported in Bloom et al. (2016) and Bombardini et al. (2017). My findings also link to the recent work of Juhász (2018), which finds a positive effect on innovation of the Napoleonic trade blockade on French infant textile industries. My study considers the wider industrial landscape, showing that when more established (non-infant) industries are included, the reaction to trade liberalization is to improve the adoption of new technology. This suggests that trade liberalization after a period of temporary protection calls for more innovation. I also contribute to the debate on the role played by the Cobden-Chevalier Treaty on the French economy at the time. While historically the new (open) trade policy was considered one of the causes of the slow French industrialization (Dunham, 1930), recent empirical studies offer a more positive perspective. For example, Becuwe et al. (2021) found a positive reaction on the export side after the trade liberalization of 1860. Confirming this positive reaction, my study shows improvements in technology diffusion in response to the Cobden-Chevalier Treaty.

My (preliminary) paper is organized as follows. Section 2 briefly discusses the background with a strong focus on technological adoption and trade policies in historical France. Section 3 describes the data used in the analysis, and Section 4 presents the empirical strategy and describes the results. I explain the proposed mechanism in Section 5 and conclude in Section 6.

2 Background

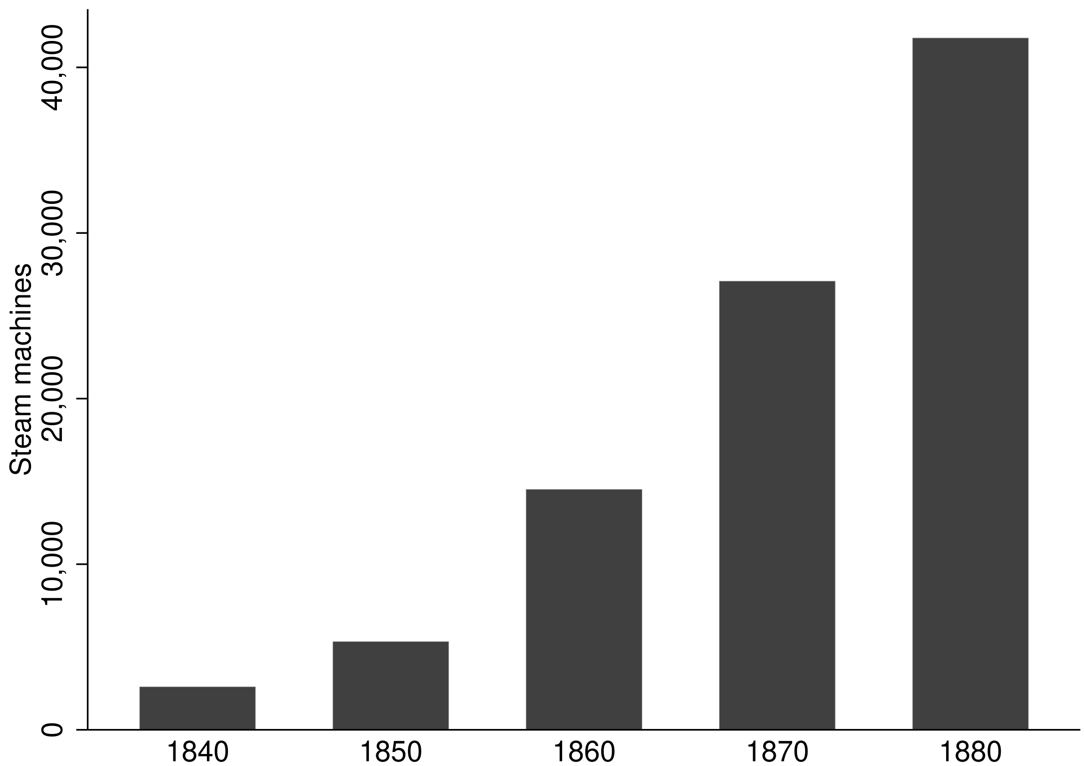
Nineteenth-century France's industrialization was traditionally viewed as less impressive than other European nations. Clapham (1921) was among the first to define the French transition to modernization as delayed and incomplete. This negative view, called in the literature retardation-stagnation hypothesis, interprets the slow French industrialization path with respect to the extraordinary performance of Britain as the main sign of French backwardness in the 19th century. However, this hypothesis underestimates the differences between the two countries, especially in terms of the endowment of natural resources. For this reason, the negative view has gradually been replaced by the optimistic revisionist hypothesis that considers 19th-century France was not as backward as originally thought (Crouzet, 2003). Perhaps, the backward French modernization path as an industrial follower could be more common to the other European countries than the British one. In terms of technological development, French industrialization was characterized by a strong adherence to water power and slow diffusion of steam power. In 1830 there were less than 1,000 machines in France, against the 30,000 installed in British industries (Jarrige and Hilaire-Perez, 2021). From the 1840s the french diffusion of steam power made several advances (figure 1), especially thanks to the introduction of high-pressure machines, capable of optimizing the resource endowments (Nuvolari, 2010). Despite these improvements, water power remained the primary source for lots of industries during the entire century. [1]

The status of industrial followers makes nineteenth-century France an interesting case to test the role of trade liberalization on innovation when a country removes trade barriers from a technological leader. In fact, on the 23rd January of 1860, France and England signed the so-called Cobden-Chevalier treaty, an agreement that reduced import tariffs between the two countries and removed prohibitions on British goods. Thanks to the "The Most Favorite Nation clause" the Treaty is considered the starting point of the first era of globalization, a period with declining costs of transportation and trade policies growing in importance on the national agendas (O'rourke and Williamson, 2002). In this context, several scholars paid attention to the role of the Anglo-French trade agreement of 1860 as an effective free-trade promoter. Particularly, the work of Accominotti and Flandreau (2008) fund that tariff rates started to decrease already in 1850 but, according to Lampe (2009) not in manufactured products. Looking at the tariff changes in the 1850s and after the Treaty, Tena-Junguito et al. (2012) show that import tariffs were lower in the 1860s but decrease intensively after the Treaty of 1860. Recently, the work of Becuwe et al. (2021) found evidence of French intra-industry trade post-1860, showing that France sustained its exports despite the increasing import due to the low tariffs.

To the best of my knowledge, little attention has been given by the literature to the specific effect on innovation.

[1] The strong adherence of French industries to water power is considered one of the main causes of the slow industrialization with respect to the other European countries. In fact, the work of Ridolfi et al. (2022) shows that the adoption of steam increased male wages only when steam power replaced water power, and not when steam is adopted jointly with water.

Figure 1: Number of steam machines in France 1840-1880



The graph shows the number of steam machines in each decade on French soil, including agricultural sectors and domestic ones. Railways and steamboats are excluded from these statistics. *Source*: Compte-rendu des travaux des Ingénieurs des Mines 1873-1875,1880.

3 Data

3.1 Industry-specific data

The industry-specific data used here come from the two earliest French industrial censuses published in *Statistique Générale de la France* and digitized by Chanut et al. (2000). The first census (hence 1843) covers the period 1843-1847 while the second one (hence 1863) started in 1861 and finished in 1865.[2]

The first industrial census describes plant-level data and originally was supposed to cover only establishments with more than ten employees. However, as mentioned by Chanut et al. (2000) and Doraszelski (2004), the source also recorded smaller establishments, usually aggregated in *collective* entities. The second industrial census covers all French industrial activities with a prevalence of collective entities.[3]

Both report data on the power used divided into steam, water, wind, and animal power in a number of machines for 1843 and in horse-power in 1863, plus a variety of other variables used in this analysis as controls as nominal wages and employment broken drown by male, female and child. For each observation, the surveys indicate the French district (*arrondissement*) of registration and the industrial sector to which it belongs. The survey contains a total of 373 districts but not all districts were recorded in both censuses. The first census does not report the entire department of Corsica, the districts belonging to the Departments of Savoie and Haute-Savoie, and the city of Paris. The second survey does not cover the city of Lyons.[4] Figure 2 shows the total number of sub-sectors by districts in 1843 and 1863 and the number of sub-sectors represented in both industrial censuses (balanced sample). The industrial classification cover 82 sub-sectors (table 8 in the appendix) that belong to 16 macro-sectors such as textile, food processing, chemical, etc. From the original dataset, I removed observations *a priori* with no sub-sectors or district information (0.4%) and State-owned plants (0.3%).

To trace in time, I aggregated the data in local-sub-industry i.e. observations that belong to the same district and the same sub-industrial sector. A sub-industrial sector is not present in all districts, so I started with a sample of 10,693 observations from which I removed local-sub-industries observed only in one time period (50%) and without any type of power. This choice allows this work to overcome the issue that some firms were not inclined to innovate, because they were small or family-owned activities. I ended up with 2,626 observations. An

[2]The first census already started in 1839 and stopped in 1841 but the Prefects that had already prepared the report, designed a new updated version (see *Statistique de la France. Industrie. 1874, page 25*).

[3]In the case of collective entities, the censuses report the number of establishments aggregated.

[4]For more details see Chanut et al. (2000).

example of local-sub-industry for the flour milling sub-sector is reported in figure 3. The entire data set is used for further analysis and robustness checks. I also collected data from the census of 1873 that reports the same industry-specific data but by departments.

I measure technology adoption using what I call steam-intensity, defined as:

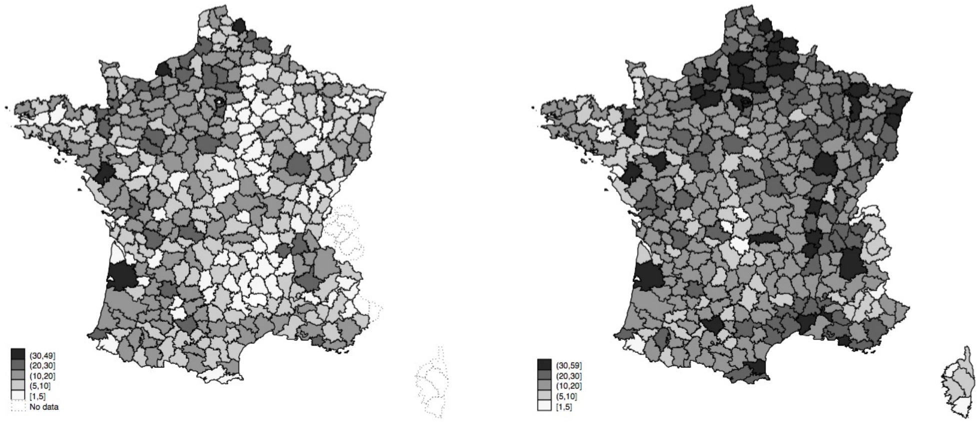
$$Steam\ intensity\ (outcome) = \frac{steam}{(steam + water + wind + animal)} \tag{1}$$

creating an index varying between 0 and 1 indicates how much steam power was used with respect to the traditional powers in both periods. A steam intensity equal to zero means that the local-sub-industries use only old powers; a steam intensity equal to one means that the local-sub-industry is only steam-powered while a number between 0 and 1 reflects how much steam was used with respect to the total powers. Table 1 describes the types of power (%) in the final sample. We can see that between the first and the second censuses, the percentage of local-sub-industries that use only steam as power increased from (13%) to (20%), while those only water-powered decreased from (37%) to (21%). The production with joint steam and water powers almost doubled in 1863. This last result is not surprising in the French context. In fact, it was not unusual to introduce steam to improve water power, being water less expensive than coal. As a general-purpose technology, steam power could be used in diverse sectors and for diverse functions, leading this work to consider an innovation also the introduction of steam jointly with water to improve the production method.

Table 1: Types of power used (%) in the final sample

	1843	**1863**
Power:		
Only steam	12.9	19.6
Only water	37	20.7
Steam and water	14	26.3
Only animal	10.6	6.1
Only wind	1.2	0.4
Other combination	24.3	26.9
	100	100

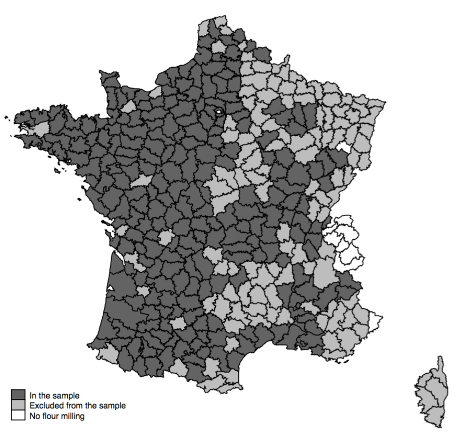
Figure 2: Number of sub-sectors by districts in 1843 and 1863



(a) 1843 (b) 1863

The These maps show the total number of sub-sectors by districts in 1843 and 1863. In figure 2a, the district with the highest number of sub-sectors represented is Nantes with 49 different industries followed by Lille with 38 sub-sectors. The districts of Ceret, Espalion, Nogent-sur-seine, Rochefort and Sancerre count only one industrial activity. The city of Paris and the district with dashed borders are not reported in the census of 1843. In the Map of figure 2b, Ville de Paris with 59 sub-sectors and Lille with 48 are the districts with the highest number of diverse activities while the districts of Calvi and Paimboeuf have only three sub-sectors represented. *Source*: Data elaboration from industrial surveys reported in *Statistique Générale de la France.*

Figure 3: An example of the existence of a local-sub-industry: flour milling



Local sub-industries of flour milling sub-sector located in light grey areas are excluded from the sample because they are observed only in one time period or they have no power at all. The remaining 240 local-sub-industries in dark grey are included in the sample, while in white districts there are no flour milling activities reported in the censuses. *Note:* Each industrial sub-sector has a different distribution across districts. *Source*: Data elaboration from industrial surveys reported in *Statistique Générale de la France.*

3.2 Trade liberalization

England's gradual adoption of trade liberalization started forty years before the Treaty with the Huskisson reforms, while France made a decisive step toward free trade only in 1860. Before that, public opinion and the more conservative party hindered any kind of cut in tariff duties, manifesting the fear that British competition would decrease employment and wages. It seems that the only way to decrease duties was a secret negotiation by the Emperor (Dunham, 1930). The Cobden-Chevalier Treaty was signed on the 23rd of January 1860 and promoted by Napoleon III. The English Cobden and the French Chevalier secretly negotiated the tariffs, believing -as free traders- that the agreement could prevent wars and that both countries could benefit in development. This Anglo-French trade agreement removed trade barriers by reducing duties and replacing prohibition with an *ad valorem* tariffs of 15 or 30 per cent. The new tariff duties exposed french industries to higher competition with the British ones, offering more export opportunities to the latter, with the exception of the wine product, whose import costs from France decreased due to the Treaty. [5]

I used the original table duties of the Cobden-Chevalier treaty described by Lack (1861) to estimate tariff changes before and after the Anglo-French trade agreement. This source lists the British products involved in the Treaty and reports the old and the new tariff duties. In the case of prohibited goods, the old tariff is substituted with the word: prohibited. I aggregated products by industrial sub-sectors and I matched tariff and industrial data. It turns out that 58 out of 82 sub-industrial sectors reported in the industrial data had a reduction in import tariff or a lifting of the prohibitions greater than 40%. Local-sub-industries that belong to these 58 sub-sectors are used in the baseline analysis as the treated group while the remaining are the non-treated group. As already mentioned, the negotiation of the tariff was secret and without any kind of lobby interests, being the Treaty aimed to implement a period of peace between the two countries. Table 2 shows that there is no statistical difference in mean between sectors with trade-liberalization (treated) and without tariff changes (control) in 1843 in steam intensity or other characteristics such as size, production, and geographical advantages.

However, to deal with the diverse intensity of trade-liberalization I also estimated the tariff changes as: [6]

$$Tariff\ reduction\ = \frac{Tariff_{1860} - Tariff_{1859}}{Tariff_{1859}} * (-1) \tag{2}$$

[5]See Lack (1861) and Dunham (1930) for more details.

[6]Tariffs were specific and *ad valorem*. If the old tariff was specific and the new one *ad valorem* (or viceversa) I transformed the tariff in specific using the value of products reported in the *Tableau général du commerce de la France avec ses colonies et les puissances étrangères*. For prohibitions, I used an old tariff of 200 *ad valorem*.

Table 2: Differences in mean between Treated and Controls *before* treatment by sub-sectors

	Mean		
Pre-treatment variables	Treated	Control	$p > \|t\|$
Steam intensity	0.29	0.37	0.273
Steam machines	30.35	30.5	0.990
Total workers	16812	9201	0.205
Male workers	10285	7209	0.440
Male wage	214	208	0.588
Value of production	46	61	0.653
Distance from waterways	7.02	7.011	0.859
Distance from customs	80.18	87.54	0.357
Coal price	3.23	3.19	0.723

The table includes all the data from the Industrial census of 1843 aggregated by industrial sub-sectors. Geographical variables are calculated as the mean.

I also used lots of other data collected from diverse sources reported in the summary statistics in table 3.

Table 3: Summary statistics restricted sample

Variable	**Mean**	**Std**	**Min**	**Max**
Steam intensity 1843	0.22	0.35	0	1
Steam intensity 1863	0.39	0.41	0	1
Treated y/n	0.58	0.49	0	1
Trade liberalization	0.43	0.40	0	1
Prohibited before 1860 y/n	0.46	0.49	0	1
Total workers 1843	486	1636	1	32500
Male workers 1843	297	867	0	15411
Male daily wage 1843 (centimes)	202	69	70	650
Coal price 1843	3.23	1.15	0.69	6.19
Railways 1860 y/n	0.70	0.50	0	1
Distance from customs (km)	96.76	64.52	0	225.5
Distance from waterways (km)	8.30	7.51	0.02	37.84
Distance from London (km)	545	236	149	1037
Machine sector in the district 1843 y/n	0.03	0.16	0	1
Value of production 1843 (Francs)	2228594	5052144	900	638000007

4 Empirical strategy and results

To test the role of trade liberalization on innovation, I use a panel data-set of 1313 local-sub-industries observed in 1843 (pre-treatment) and 1863 (post-treatment). I applied a diff-in-diff approach:

$$Y_{it} = \alpha_i + \delta_t + Treated_i * Post_t + \epsilon_{it} \tag{3}$$

where Y_{it} steam intensity in local-sub-industry i, i = sub-sector × district; α_i local-sub-industry *fixed effect* ; δ_t time shock; $Post_t Treated_i$ is the diff-in-diff coefficient where *post* and *treated* are equal to one if the year is 1863 and the sub-sector is involved in the Cobden-Chevalier Treaty.

In addition, to explore whether there are differences in the effect itself between industries more and less exposed to the new competition, I added an interaction in equation 4 using railways and closeness to London.

$$Y_{it} = \alpha_i + \delta_t + Treated_i * Post_t + Treated_i * Post_t * interaction_i + \epsilon_{it} \tag{4}$$

where $interaction_i$ is the interaction term; $Post_t Treated_i$ show the effect of trade liberalization for local-sub-industries far from British markets; $Post_t Treated_i * interaction_i$ is the difference between local-sub-industries more and less exposed to the British competition.

4.1 Preliminary results

Table 4 reports the results of equation 3. The coefficient of trade liberalization in column (1) is positive and statistically significant, meaning that the treated group had a predicted mean of steam intensity 11 percentage points higher than the control group. This implies that local-sub-industries with a tariff reduction or lifting prohibitions increased the use of steam by 51 % more than the local-sub-industries without tariff-changes (figure 4a). [7]

4.2 Robustness

The census of 1843 is the first industrial census existing in France, so I use diverse robustness checks to address the issue of a missing parallel trend. Firstly, in columns (2-8) of table 4,

[7] The percentage is calculated by dividing the diff-in-diff coefficient (0.114) by the average of steam intensity in 1843 estimated using the margins command (0.224).

I control for *pre*-treaty factors that rendered some local-sub-industries more inclined to innovate such as male wages, coal prices, presence of railways and machine sector in the district, distance from customs and from waterways. The coefficient of trade liberalization is still positive and statistically significant, even when I included all the controls together in column (8), where the treated-group increased steam-intensity 47% more than the control group. [8]

Table 5 reports the results of matched and split samples to take into account the initial differences in *pre*-steam intensity. In columns (1-2), the sample is matched using a propensity score matching with the nearest-neighbour procedure. The number of observation is 2,142 because unmatched observations are excluded. Here the effect of trade liberalization is 40%.[9] Table 5 columns (3-8) splits the sample into local-sub-industries that had or did not already have steam engines in 1843. The effect of the treatment is positive and statistically significant which implies that rising import competition increased both the adoption and the use of steam. Particularly, the sample restricted to non-steam local-sub-industries in 1843 (62% of the total sample) offers a good way to look at the pre-trends. In this case, both the treated and control groups start with the same level of steam power, which is zero from the first introduction of the steam engine in the 1730s to 1843 (figure 4b). In 1863, the local-sub-industries that start with no steam not involved in the Cobden-Chevalier treated use 13% of steam, while those involved ended with 32% (column 3). [10] For the local-sub-industries that have already steam in 1843, the coefficient of trade liberalization is still positive and statistically significant, showing an effect of 20% (column 6) and 19% when only-steam powered local-sub-industries in 1843 are excluded (column 8). [11]

To address the concern that sub-sectors may have a diverse intensity of the treatment; I also use as treatment-variables in table 6: only prohibited sub-sectors; the tariff-reduction; and tariff-reduction for only treated-sub-textile-industries. The results show that lifting prohibitions or moving to higher import-tariff-reduction both contributed positively to innovation. The results are also corroborated when I add the census of 1873 (figure 4d) confirming the high impact of trade liberalization and the slow adoption of the control group.

[8] The percentage is calculated by dividing the diff-in-diff coefficient (0.106) by the average of steam intensity in 1843 estimated using the margins command (0.224).

[9] The percentage is calculated by dividing the diff-in-diff coefficient (0.100) by the average of steam intensity in 1843 estimated using the margins command (0.252).

[10] The coefficient of *Post* in table 5 column (3) is equal to 0.129.

[11] For table 5 column (6) the percentage is calculated by dividing the diff-in-diff coefficient (0.075) by the average of steam intensity in 1843 estimated using the margins command (0.382). In the same way, in column (8) the trade liberalization coefficient (0.105) is divided by 0.542.

Table 4: The role of trade liberalization on innovation: baseline

	Steam intensity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Trade liberalization	0.114***	0.114***	0.114***	0.108***	0.109***	0.112***	0.114***	0.106***
	(0.012)	(0.021)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.021)
Male wage in 1843		0.005						-0.023
		(0.029)						(0.032)
Coal price in 1843			-0.030					-0.019
			(0.025)					(0.024)
Railway y/n in 1860				0.083***				0.077***
				(0.021)				(0.022)
Machine sector in the district y/n in 1843					0.117†			0.106
					(0.072)			(0.074)
Distance from customs						-0.009		-0.004
						(0.007)		(0.009)
Distance from waterways							0.003	0.005
							(0.009)	(0.009)
r2	0.181	0.181	0.182	0.190	0.183	0.183	0.181	0.192
N	2626	2626	2626	2626	2626	2626	2626	2626

† p<0.15, * p<0.10, ** p<0.05, *** p<0.010. Clustered standard errors in parentheses.

Trade liberalization is a dummy equal to one if the sub-sector has a tariff reduction of lifting prohibition due to the Cobden-Chevalier Treaty. *Pre* treaty controls are equal to zero if year=1843. Male wage is the logarithm of male daily nominal wage; Coal price is the logarithm of coal price in 1843 by the department. Railway and Machine sector variables are dummies while the distance from customs and waterways are transformed in log(x+1). *Time* and *local-sub-industry* fixed effects are included.

Table 5: The role of trade liberalization on innovation matched and restricted sample by *pre* intensity

	Steam intensity							
	Matched sample		*pre* intensity =0		*pre* intensity >0		0 <*pre* intensity <1	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Trade liberalization	0.102***	0.100***	0.191***	0.153***	0.065*	0.075*	0.116***	0.105**
	(0.026)	(0.026)	(0.023)	(0.022)	(0.038)	(0.039)	(0.042)	(0.044)
Male wage in 1843		-0.042		0.077***		-0.099*		0.045
		(0.037)		(0.030)		(0.059)		(0.090)
Coal price in 1843		-0.022		-0.093***		0.025		0.015
		(0.030)		(0.029)		(0.041)		(0.043)
Railway y/n in 1860		0.051**		0.105***		0.064		0.038
		(0.026)		(0.022)		(0.052)		(0.052)
Machine sector in the district in 1843		0.114†		0.464***		0.055		0.014
		(0.075)		(0.095)		(0.064)		(0.085)
Distance from customs		-0.013†		-0.044***		0.0045		0.003
		(0.008)		(0.009)		(0.009)		(0.010)
Distance from waterways		0.006		-0.002		0.017		0.023
		(0.010)		(0.009)		(0.017)		(0.020)
r2	0.180	0.191	0.353	0.435	0.031	0.042	0.261	0.266
N	2142	2142	1622	1622	1004	1004	664	664

† p<0.15, * p<0.10, ** p<0.05, *** p<0.010. Clustered standard errors in parentheses.

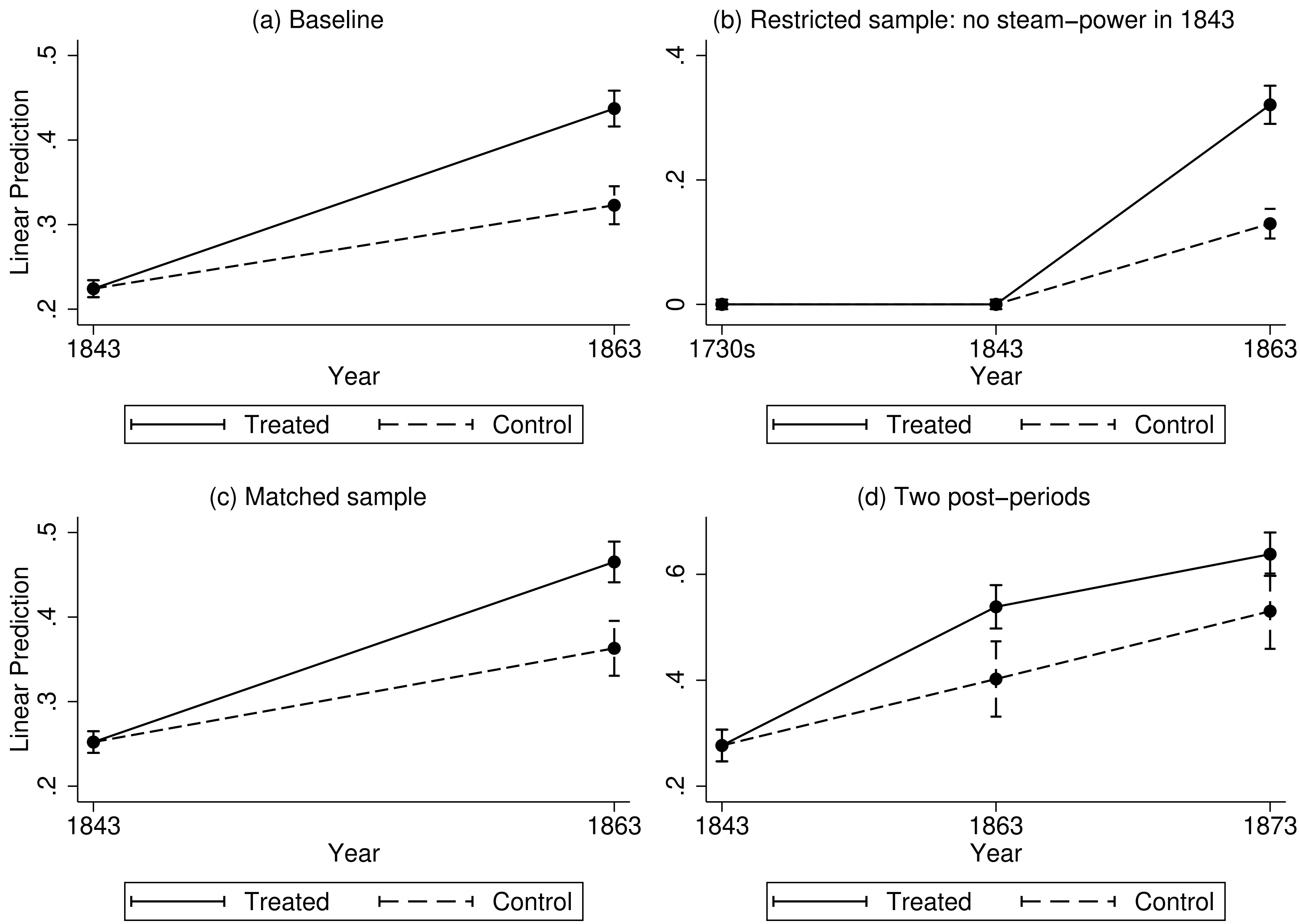
Trade liberalization is a dummy equal to one if the sub-sector has a tariff reduction of lifting prohibition due to the Cobden-Chevalier Treaty. *Pre* treaty controls are equal to zero if year=1843 and are the same of table 4. In columns (1-2) the sample is restricted to only matched observation using propensity score matching with the nearest-neighbour matching procedure. *Time* and *local-sub-industry* fixed effects are included.

Table 6: The role of trade liberalization on innovation: *alternative* treatment

	Steam intensity					
					Only textile	
	(1)	(2)	(3)	(4)	(5)	(6)
Prohibited y/n	0.122***	0.111***				
	(0.021)	(0.022)				
Tariff reduction			0.139***	0.127***	0.257**	0.264**
			(0.025)	(0.026)	(0.124)	(0.122)
			*0.126****	*0.115****	*0.281***	*0.288***
Male wage in 1843		-0.006		-0.005		0.077**
		(0.031)		(0.032)		(0.034)
Coal price in 1843		-0.025		-0.014		-0.013
		(0.026)		(0.025)		(0.038)
Railway y/n in 1860		0.080***		0.075***		0.089**
		(0.022)		(0.022)		(0.042)
Machine sector in the district in 1843		0.090		0.109†		0
		(0.076)		(0.075)		(.)
Distance from customs		-0.007		-0.005		0.0221
		(0.007)		(0.007)		(0.016)
Distance from waterways		0.006		0.007		-0.029*
		(0.009)		(0.009)		(0.017)
r2	0.187	0.201	0.180	0.192	0.224	0.258
N	2314	2314	2529	2529	534	534

† p<0.15, * p<0.10, ** p<0.05, *** p<0.010. Clustered standard errors in parentheses. Standardized coefficients in Italics.
Prohibited is a dummy equal to one if the sub-sector has a lifting prohibition due to the Cobden-Chevalier Treaty. *Tariff reduction* is the tariff growth rate multiplied by (-1). *Pre* treaty controls are equal to zero if year=1843 and are the same of table 4. Treated without prohibitions are excluded from the sample in columns (1)-(2). The number of observations in columns (3)-(4) is lower than the main analysis because of missing tariffs, while in the last two columns (5-6) the sample is restricted to only treated in textile sectors. The machine sector variable in column (6) is missing because no textile industries were located in the district with the machine sector in 1843. *Time* and *local-sub-industry* fixed effects are included.

Figure 4: Steam intensity pre and post-trade liberalization



95% CI.

Graph (a) shows the result of the baseline analysis reported in 4 column (1) while graphs (b) and (c) refer to table 5 columns (3) and (1). In graph (d) I added the industrial census of 1873 and the local-sub-industries are at the department level.

5 Mechanism

In the previous section, I showed that removing foreign trade barriers had a positive impact on the introduction and use of new technology in domestic industrial activities. This could happen via various channels.[12] In historical France, import competition may be the most prominent channel driving the positive effect of trade liberalization on innovation. Producers could increase the use of new technology to face the potential reduction of domestic demand caused by the increasing foreign-competition. According to this statement, producers that fear more intensively British competition because closer to British should be more motivated to attempt to increase output or reduce cost through technical change. In fact, when I interact the effect of trade-liberalization with railways and closeness to London in table 7 - I found that treated-local-sub-industries more exposed to foreign competition had an effect on innovation higher than those treated but located in more remote areas.

Table 7: Trade liberalization interacted with exposition to trade

	Steam intensity			
	(1)	(2)	(3)	(4)
Effect × railways (yes)	0.087***	0.075**		
	(0.032)	(0.033)		
Effect × closeness to London			1.786*	1.444†
			(0.919)	(1.006)
			*0.068**	*0.055†*
Effect	0.051*	0.054*	-0.670*	-0.527
	(0.030)	(0.030)	(0.404)	(0.441)
Controls	no	yes	no	yes
r2	0.187	0.189	0.184	0.194
N	2626	2626	2626	2626

† p<0.15, * p<0.10, ** p<0.05, *** p<0.010. Clustered standard errors in parentheses. Standardized coefficients in Italics. *Time* and *local-sub-industry* fixed effects are included. *Effect* is a dummy equal to one if the sub-sector has a tariff reduction of lifting prohibition due to the Cobden-Chevalier Treaty and it is zero if year=1843. *Closeness to London is the log-inverse of distance from London. Pre* treaty controls are equal to zero if year=1843 and are the same as table 4.

[12]See Shu and Steinwender (2019) and Geng and Kali (2021) for details on the recent literature on trade and innovation and the channels.

6 Conclusion

My study considers the impact of trade liberalization on technical change by looking at the effect of the Cobden-Chevalier Treaty on the adoption and intensive use of steam power in 19th-century France. I find that steam-power use rose up to 51 % more if the industry was exposed to the trade-liberalization contained in the Treaty than otherwise. Industries with no import-tariff-changes, or industries that were located in areas far from London or were difficult to reach in terms of transportation, were relatively more anchored to old technologies. I thus propose that the differences in technical change were ultimately caused by more or less exposure to competition from the British producers.

How do these findings relate to studies in more recent times? First, my study expands on the existing literature that debates the effect of import-competition on innovation. It supports the finding of Bloom et al. (2016) in the 20th-century Europe context and Bombardini et al. (2017) in the Chinese one, suggesting that producers respond to foreign competition by improving their technology (*escape-competition-effect*). Hence, my data do not support the negative so-called *Schumpeterian* effect of trade on innovation observed for example in Dorn et al. (2020). However, conclusions on the effect of trade liberalization on innovation usually differ because of diverse outcomes, trade partners, initial characteristics, and historical context. I pay attention to general-purpose-technology already adopted by technological leaders - as for example in Bloom et al. (2016) - and on industries that already used at least one type of technology (old or new-one).

In addition, my study is related to the work of Juhász (2018), which highlights the positive effect of trade-protection due to the Napoleonic wars on French technology adoption. The different roles of trade observed here could be explained by the sample choice. While Juhász observes technological changes in infant-industries of cotton spinning, I consider a wider industrial landscape, finding that after a temporary trade restriction, trade openness is needed to boost innovation.

References

Accominotti, Olivier and Marc Flandreau, "Bilateral treaties and the most-favored-nation clause: the myth of trade liberalization in the nineteenth century," *World Politics*, 2008, *60* (2), 147–188.

Becuwe, Stéphane, Bertrand Blancheton, and Christopher M Meissner, "The French (Trade) Revolution of 1860: Intra-Industry Trade and Smooth Adjustment," *The Journal of Economic History*, 2021, *81* (3), 688–722.

Bloom, Nicholas, Mirko Draca, and John Van Reenen, "Trade induced technical change? The impact of Chinese imports on innovation, IT and productivity," *The review of economic studies*, 2016, *83* (1), 87–117.

Bombardini, Matilde, Bingjing Li, and Ruoying Wang, "Import competition and innovation: Evidence from china," *Researchpaper: http://www7. econ. hitu. ac. jp/cces/trade_conference_2017/paper/matilde_bombardini*, 2017.

Chanut, Jean-Marie, Jean Heffer, Jacques Mairesse, Gilles Postel-Vinay, Frédéric Boccara, Pierre Sicsic, A Strauß, and Patrick Verley, *L'industrie française au milieu du 19e siècle: les enquêtes de la statistique générale de la France*, Ed. de l'EHESS, 2000.

Clapham, John Harold, *The economic development of France and Germany, 1815-1914*, University Press, 1921.

Crouzet, François, "The historiography of French economic growth in the nineteenth century," *The Economic History Review*, 2003, *56* (2), 215–242.

Doraszelski, Ulrich, "Measuring returns to scale in nineteenth-century French industry," *Explorations in Economic History*, 2004, *41* (3), 256–281.

Dorn, David, Gordon H Hanson, Gary Pisano, Pian Shu et al., "Foreign competition and domestic innovation: Evidence from US patents," *American Economic Review: Insights*, 2020, *2* (3), 357–74.

Dunham, Arthur Louis, *The Anglo-French treaty of commerce of 1860 and the progress of the industrial revolution in France*, Vol. 9, Ann Arbor: University of Michigan Press, 1930.

Geng, Difei and Raja Kali, "Trade and innovation: Unraveling a complex nexus," *International Journal of Innovation Studies*, 2021, *5* (1), 23–34.

Jarrige, François and Liliane Hilaire-Perez, "La machine à vapeur démythifiée," *L'Histoire. Les collections*, 2021, (91), 24–31.

Juhász, Réka, "Temporary protection and technology adoption: Evidence from the napoleonic blockade," *American Economic Review*, 2018, *108* (11), 3339–76.

Lack, H Reader, *The French Treaty and Tariff of 1860: With an Historical Sketch of the Past Commercial Legislation of France*, Cassell, Petter and Galpin, 1861.

Lampe, Markus, "Effects of bilateralism and the MFN clause on international trade: Evidence for the Cobden-Chevalier Network, 1860-1875," *The Journal of Economic History*, 2009, *69* (4), 1012–1040.

Nuvolari, Alessandro, "The theory and practice of steam engineering in britain and france, 1800-1850," *Documents pour l'histoire des techniques. Nouvelle série*, 2010, (19), 189–197.

O'rourke, Kevin H and Jeffrey G Williamson, "When did globalisation begin?," *European review of economic history*, 2002, *6* (1), 23–50.

Ridolfi, Leonardo, Carla Salvo, and Jacob Weisdorf, "The impact of mechanisation on wages and employment: evidence from the diffusion of steam power," 2022.

Shu, Pian and Claudia Steinwender, "The impact of trade liberalization on firm productivity and innovation," *Innovation Policy and the Economy*, 2019, *19* (1), 39–68.

Tena-Junguito, Antonio, Markus Lampe, and Felipe Tâmega Fernandes, "How much trade liberalization was there in the world before and after Cobden-Chevalier?," *The Journal of Economic History*, 2012, *72* (3), 708–740.

Appendix A. Data

Table 8: Industry classification

Macro sector	Sub-sectors
Textiles	Hosiery Lace embroidery Cardery, crushing, combing of wool Hemp Cotton spinning Woolen mill Melangee spinning Linen spinning Silk spinning and milling Cotton spinning and weaving Wool spinning and weaving Impressions Passamanerie Dry cleaning Mixed or unspecified weaving Cotton weaving and blends Wool weaving Vessels Silk weaves Various textile
Mining and quarrying	Iron mines Fuel Land and quarries Non-ferrous metals Salt
Iron and other metals	Iron and steel industry Non-ferrous metallurgy
Iron products	Arms Boiler making Clouterie & hardware Cutlery & sharpening steels Tooling Machinery Locksmith-hardware Various metal object
Leather	Leather industries
Wood products	Saw mills Cooperage Rotating wooden oobjects Basketry,plaster,stoppers
Ceramics	Faience, porcelai & pottery Glass,crystal, mirrors
Chemicals	Acid Matches Colour Distillation of wood Animal charcoal, glue and fertilizer Soda and soaps Various chemical products
Building materials	Manufacture of binders Tiles and bricks Various materials
Lighting	Wax and candles Gas
Furniture	Wall paper Various furnishing articles
Clothing	Brushware Hats Slippers and shoes Gloves Various article of clothing
Food processing	Brewery Canning Distillery Oil mills Flour mills Biscuits and pasta Sugar refinery Sweets Various food products
Transport equipment	Saddlery & body Shipbuilding
Paper, printing, pens	Watchmaking Printing-typography Musical instruments Optical Paper and board mill Writing materials Currencies and other
Luxury items	Jewellery and orfevrerie Tabletterie Various articles from Paris

Note: Industrial classification from original dataset provided by Chanut et al 2000.