AN EMPIRE LOST: SPANISH INDUSTRY AND THE EFFECT OF COLONIAL MARKETS ON PERIPHERAL INNOVATION

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ABSTRACT. This paper examines the impact of international market access on the trajectory of technical change using a historical trade shock that reshaped the Spanish textile industry in the late 19th century. Exploiting the effects of a trade policy change in 1891 that raised out-of-the-empire tariffs and forced the purchase of manufactured cotton goods from the metropole's producers by its colonies, I empirically document a significant increase in cotton textile innovation relative to other fabrics. Moreover, I demonstrate the presence of path dependence in innovation, as the disparity in textile innovation between cotton and other fabrics persisted even after the colonies' independence in 1898. Further analysis reveals that the relative prices of cotton fabrics and benefits accrued by cotton firms played a crucial role in stimulating cotton innovation. These results suggest that the innovation observed was not limited to the mere adoption of foreign technology but instead reflected local conditions in shaping incentives for local innovators to develop technologies tailored to specific local requirements. These findings contribute to the literature on the causal relationship between international trade, foreign markets, and the direction of technical change, shedding light on the possibility of innovation in peripheral countries.
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> "***Opening a new and inexhaustible market*** to all the commodities in Europe, it gave occasion to new division of labour and ***improvements of art***, which, in the narrow circle of the ancient commerce, could never have taken place for want of a market to take off the greater part of their product" - Adam Smith (1776), *An Inquiry into the Nature and Causes of the Wealth of Nations*

1. Introduction

The relationship between international trade, international markets, economic growth (Smith, 1776; Marshall, 1890), relative prices, and income distribution has long been a topic of interest among economists. Innovation and technological change are crucial mechanisms through which international markets contribute to economic growth. However, there needs to be more research on how privileged access to these markets can also influence the direction of technological change by shaping demand and prices faced by producers. This paper addresses the gap by utilizing historical patent data and collected price data and examining significant changes in international markets that impacted the 19th-century Spanish textile industry. Additionally, the findings of this study reveal that innovation is attainable even in less advanced economies, where local conditions play a crucial role in shaping incentives for developing technologies that fit specific local requirements beyond mere imitation of technological leaders' advancements.

The impact of international trade on technological change goes beyond its effect on the rate of innovation (see Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1991), and also extends to the type of technologies that innovators choose to develop (see Acemoglu, 2002; Gancia and Zilibotti, 2009; Gancia and Bonfiglioli, 2008). This paper contributes to the literature by examining how privileged access to foreign markets shapes the direction of technological progress. Building on previous empirical work by Hanlon (2015) that showed how shocks to input prices affect technological change, I provide evidence that shocks in output markets can have similar effects. Specifically, I study the impact of expanding markets on inventors' incentives and how these incentives influence their decisions on which sectors to introduce new machines. Using a unique historical experiment that transformed international trade patterns in the Spanish textile industry during the Spanish colonial period at the end of the 19th century, I investigate the extensive market integration between Spain and its colonies. The rise in external tariffs in 1891 effectively forced the Spanish colonies to buy cotton textiles, mainly from Spain, resulting in increased demand for cotton textiles and a change in relative prices of finished textiles. This change in market conditions led to increased incentives to innovate in the cotton sector, unlike other textile sectors. Importantly, even after the colonies gained independence in 1898, the relative increase in innovation in the cotton industry remained unchanged, suggesting that the initial boost in innovation due to captive markets persisted even after the original conditions disappeared.

In 1891, the Spanish cotton goods market witnessed an increase in size due to the Spanish authorities' implementation of an imperial protective tariff. The tariff system compelled colonies to purchase most cotton-manufactured goods from Spain, resulting in increased benefits for cotton producers in Spain. Unlike other sectors, this market expansion created stronger incentives for developing cotton-augmenting technology. However, these conditions were short-lived and lasted only a few years. Given the significant installed production capacity and the lack of a robust internal market, industrialists needed to seek new external markets after the colonies gained independence in 1898. Despite the loss of captive colonial markets, the initial boost in the cotton industry provided enough impetus for continued growth. The sector grew sufficiently to compete in international markets, and Spain focused on improving the quality of exported fabric to target wealthier markets. Notably, global consumers, particularly in Argentina, were more willing to pay for product quality than Spanish consumers (Markusen, 1986; Flam and Helpman, 1987; Hallak, 2006; Verhoogen, 2008). The cotton industry exhibited features of path dependence, as innovation remained high even after the loss of colonies, thanks to modifications in the conditions faced by producers during the captive market period.

I have found evidence in the patent data that supports the previous points: the two trade shocks affected inventors' incentives. Firstly, I have found that the colonial trade induced innovation in technologies used to produce cotton goods along all production stages. Secondly, after Spain lost its colonies, cotton innovation remained high for several periods despite the change in the initial conditions. Finally, I have documented the price changes induced by the shocks in the textile industry using novel archive price data from a major cotton firm (*La España Industrial*). This analysis helps to illustrate the strength of the induced technological change. Following the forced colonial integration, I have documented a temporary rise in cotton-finished textile prices relative to textiles made with other fibers. This evidence is consistent with a strongly directed technical change and substitutability between cotton and other fibers.

It is important to note one caveat when interpreting these results. The Spanish patent system allowed for two types of patents: invention patents, which protected new ideas and procedures, and introduction patents, which protected ideas developed and used in other countries but not yet implemented in Spain. This system was not unique to Spain, as many peripheral countries during the 19th century adopted similar systems to facilitate technological transfers (see Saíz, 2014). I utilize this feature to demonstrate that real innovation drives my results, not simply the effects of copying foreign technology.

The effects that I have found hold for both total and introduction patents, indicating that changes in trade structures indeed impacted incentives to create new production methods and ideas. This paper highlights that innovation is possible even in countries not at the forefront of technological advancements. In such countries, innovation is still necessary to adapt ideas to the specific needs and conditions of the local context. As per Mokyr (1990), there is a need for micro-inventions that involve minor additions and gradual improvements to existing technologies to bring new ideas developed in advanced countries into practical use. Therefore, local conditions still play a crucial role in determining incentives for developing new ideas and technologies. In this study, I focus on Spain and demonstrate that local conditions in Spain indeed influenced innovation.

My findings contribute to the literature on directed technical change, building on previous empirical studies investigating innovation behavior under different shock types (Popp, 2002; Hanlon, 2015; Aghion et al., 2016). I follow the previous literature, using a clean historical experiment to isolate causal effects. I take advantage of exogenous and surprising shocks generated by the increase in tariffs and the war on the Spanish industry. However, my paper distinguishes itself in one way ways. Unlike previous studies that primarily examined input shocks, I focus on shocks to the output market. The nature and implications of the shocks in my study are unique, providing novel insights into the relationship between trade structures, incentives for innovation, and technological change in the context of Spain during the period under study.

To my knowledge, this paper represents the first examination of how imperial possessions influenced technical direction. I study Spain's response to exogenous changes in trade relations with its colonies, drawing on the extensive literature on Western

European colonialism that explores the effects of this policy on both the colonized territories and the societies that engaged in colonization. In particular, I build on previous literature that questions how the Europeans obtained benefits from their colonial empires, as evidenced by studies such as those by (e.g. O'Brien and Escosura, 1998; Findlay, 1990; Butel and Crouzet, 1998). Slave trade profits (Williams, 1944) and expansion of colonial trade (Inikori, 2002) have been proposed as the main drivers of colonial benefits. However, despite the interest in the relationship between North Atlantic trade and growth (Davis, 1973), there is limited empirical evidence on the actual impact of trade on economic development in Western societies. As in previous work Davis and Huttenback (1982, 1986), I demonstrate that the benefits of the imperial enterprise did not uniformly distribute across all economic sectors. Even more, I provide formal empirical support for a previously unexplored channel: the effects of trade on innovation incentives. According to this literature, commerce created a unique price and wage structure that modified incentives and facilitated the technological breakthroughs observed in 18th-century Britain (Allen, 2009, 2011). This paper contributes to the existing literature by examining related mechanisms and broadening the analysis beyond the British Empire, investigating the effects of trade and innovation on the technological periphery. The findings suggest that colonial trade induced growth in specific economic sectors even in suboptimal institutional environments (Acemoglu, Johnson, and Robinson, 2005).

This paper contributes to the literature on trade and development by analyzing the behavior of exporting firms and their impact on technological advancement at aggregate levels. Unlike previous studies that focus on the effects of trade agreements or temporary trade protection on adopting new technologies (Bustos, 2011; Lileeva and Trefler, 2010; Juhász, 2018), this paper proposes that general trade competition also induces changes in industrial technology. By complementing existing literature, this paper provides evidence that trade leads to product and quality upgrading and increases the scope of technology used in producing goods, as supported by anecdotal evidence. These findings contribute to understanding how trade affects technological advancement in firms and highlight the broader implications of trade on industrial technology.

This paper contributes to the literature on quality improvements in trade, establishing that firms produce higher-quality goods to appeal to wealthier foreign consumers. Verhoogen (2008) formalized that firms decide to engage in quality upgrading to compete in global markets, and a growing body of literature has supported this empirical fact in various contexts. However, there is still an ongoing debate about the mechanism that explains this change, specifically whether firms are motivated by scale effects or quality choice (Verhoogen, 2021). In this paper, I provide supporting evidence for the latter, as the adjustment in quality stems from changes in demand characteristics rather than export volumes. The strong correlation between trade and quality production is evident in both direct measures of qualities, as observed in studies conducted in Egypt (Atkin, Khandelwal, and Osman, 2017) and France (Crozet, Head, and Mayer, 2011), as well as indirect measures based on prices and other indicators, as shown in Portugal(Bastos and Silva, 2010; Bastos, Silva, and Verhoogen, 2018), China (Manova and Yu, 2017), France (Martin, 2012), and (Görg, Halpern, and Muraközy, 2017). However, there is limited evidence on how innovation affects quality upgrading. This is the case in Spain after colonial independence. With a mature industry, Spanish producers could switch to the varieties needed to compete in international markets, thus offering insights into the relationship between innovation and quality improvements in trade.

2. Background

2.1. **Spanish cotton industry.** Cotton played a pivotal role in shaping the world's industrial history, particularly during the 18th century when European empires leveraged its importance to establish new industries, marking the beginning of the Industrial Revolution (Beckert, 2015, pp.xiv). Spain was no exception, as its cotton textile industry emerged as one of the relatively successful modern industries in the country. During the latter half of the 19th century, the cotton textile sector was among the first to undergo industrialization, characterized by adopting new ideas and technologies (Carreras, 2006). Regarding tax contribution, the textile industry accounted for 1.7% of the entire country's tax value[1] Moreover, cotton textile employment constituted around 4% of total employment and a significant 29% of total employment in the main industries.[2]

The Spanish cotton industry exhibited distinct features following the disruption in global markets due to the American Civil War. Firstly, the sector relied entirely on

[1]Based on the payments of industrial taxes Nadal (1987) in 1856. This value was not bigger than any other individual industry. Comparable industries were just half of this value.

[2]Based on the Giménez y Guited (1862)'s study of the primary industries in Spain in the most relevant provinces in 1860. The whole textile employment represented more than half of industrial jobs, including the wool industry (14% employment), silk industry (4.8%), and linen industry (3.5%).

raw material imports.[3] Secondly, despite its presence in different regions, the industry was concentrated in Catalonia due to geographical advantages and historical changes that occurred a century earlier.[4] Thirdly, most of the production was carried out in vertically integrated firms, where both spinning and weaving mills were under the control of the same entity.[5] Fourthly, although the market was dominated by large firms[6], the industry's size was relatively small compared to other European countries. Finally, firms utilized piece payment for spinning and weaving production, similar to technological leaders in England and North America. These payment methods remained unchanged during the latter part of the 19th century. Firms adjusted their output, work hours, or employment in response to external shocks Domenech (2008).

The Spanish cotton industry's internal market conditions directly influenced these distinct characteristics. The industry relied on a heavily protected agricultural output, which sustained internal demand but remained small and volatile. As a result, the industry could not support larger firms or achieve economies of scale, resulting in a relatively high cost structure compared to global market leaders (Nadal and Sudrià, 1993). To survive, firms in the Spanish cotton industry adopted a different strategy, which involved protecting the internal market and capturing external markets.

2.2. **Colonial markets, tariffs and the war.** After losing its continental possessions in America during the first half of the 19th century, Spain managed to maintain some territories, including Cuba, the Philippines, and Puerto Rico, albeit with difficulties. The first Cuban independence war (1868-1878) prompted the need to formulate the relationship between the metropole and the colonies. Two groups, Cuban sugar entrepreneurs and cotton industrialists, advocated for opposing trade policies concerning managing colonial trade. The former advocated a free trade policy to access global markets, while the latter sought trade restrictions to the colonial markets to protect themselves from larger international producers. Spanish authorities opted for a middle-ground solution to ease the tensions. Although the textile lobbies did not

[3] There was a minimal experience in raw cotton production, such as in Motril (Granada). Still, these enterprises could not meet the industry demand and disappeared during the second half of the century (Martín, 2018).

[4] An agrarian crisis in Catalonia between 1770-1775 led to capital moving towards cotton textile production due to increased agricultural wages and reduced rents. Moreover, rivers and mountains provided industrialists with a valuable power source to move mills without relying on other external energy sources such as coal (Nadal, 1975).

[5] According to Rosés (2009), in 1860, 60% of spinning production and 69% of weaving production came from integrated firms.

[6] Rosés (2009) estimated that in 1860 both spinning and weaving were dominant in over 60% of firms that produced more than 100 output tons per year.

achieve a high protective tariff,[7] they successfully induced a change in the trade policy towards the colonies. The *Ley de Relaciones Comerciales con las Antillas* in 1882 established a gradual yearly reduction of tariffs between the colonies and Spain over ten years, ultimately leading to the complete elimination of trade barriers between the two territories.[8] Although imperfect, this change provided Spanish textiles with a market to overcome the limitations of the internal market.

The rise of a protectionist tariff known as the Canovas Tariff in 1891 marked a real protection and market capture. Although initially intended as a starting point for negotiations to reduce French tariffs on Spanish wine, tariffs for industrial products remained high after negotiations failed (Sabeté-Sort, 1995), resulting in effective market integration through lowering barriers between the colonies and the imposition of extremely high tariffs after 1891. This system forced colonies to buy overpriced products from the metropole (Nadal and Sudrià, 1993).[9] However, the benefits of this policy did not last long as the Cuban independence movement gained strength in 1895 due to widespread disappointment with Spanish policies (Zanetti, 2013).[10] This movement ultimately resulted in the loss of the colonies and the subsequent loss of protected markets for Spanish cotton textiles after the quick intervention of the United States.[11]

Figure 1 shows the tariff evolution of textiles in Spain between 1878 and 1910, focusing on the protection of fabrics and clothing measured as the share of the tariff revenues of the total value of the imports. Throughout the period, cotton textiles had greater protection than other textiles such as linen, wool, and silk products. Before introducing the protective tariff in 1891, there was a downward trend in textile tariffs,

[7]The tariff system did not include a protective tariff for industrial products. It resulted from negotiations with other European powers in exchange for low tariffs on Spanish agricultural outputs such as wine and flour (Nadal and Sudrià, 1993).

[8]The law stipulated a yearly reduction of 5% in the original tariffs during the first three years, followed by a 10% reduction in the next four years, and finally a 15% reduction in the remaining three years until 1891.

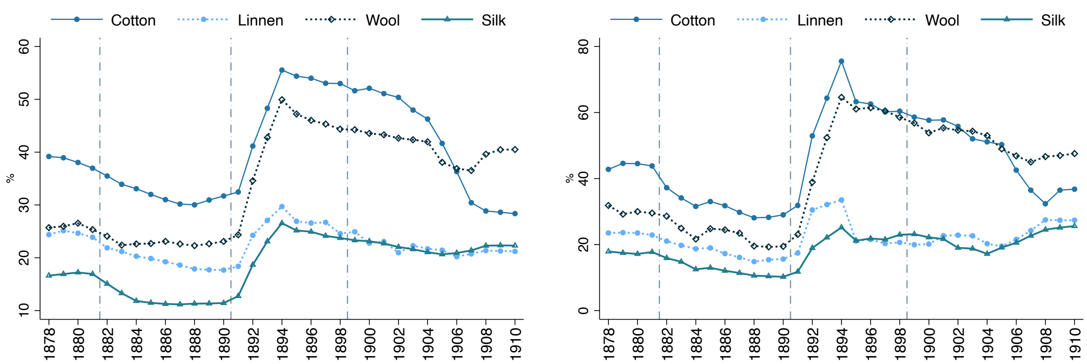
[9]This was not a unique feature of Spanish colonial policy. Other countries used similar strategies, such as England displacing Indian textiles from global markets in the late 17th century and Belgium benefiting from access to Dutch colonial markets in the Pacific during the Great Netherlands period (Beckert, 2015).

[10]Trade policy was not reciprocal, with the Spanish exporting a considerable amount of products to the colonies while the colonies' main market was not the metropole, as evidenced by Cuba's exports destination being predominantly the United States (82.5%) in 1878 (Zanetti, 1998).

[11]Despite some proposals of autonomy (which found opposition among the textile sector), after the United States intervention, Spain lost its last colonial possession in America and the Pacific. See Heraclides and Dialla (2017) for a detailed explanation of the United States' intervention in the Cuban and Philippine independence movement.

consistent with the literature that emphasizes the goal of protecting the agricultural sector during this period. However, this pattern changed in 1891 when authorities modified the tariff system, leading to almost doubling protection for all textiles types. For instance, cotton fabric protection increased from around 30% to 55%, and cotton clothing protection increased from approximately 35% to 65%.

FIGURE 1. **Textile tariffs**



A. Fabrics **B.** Clothing

Source: Dirección General de Aduanas (1876-1898, 1899-1911)
Notes: The tariff is the ratio of total tariff revenues to the total import value. Panel A of the figure presents tariffs for not made-up fabrics, without metal threads and not embroidered. Before 1906, cotton, linen, wool, and silk fabrics were classified into 7, 8, 8, and 8 product categories, respectively. However, after 1906, the number of product categories changed, with cotton fabrics including 11 categories, linen fabrics including 12 categories, wool fabrics including 9 categories, and silk fabrics including 8 categories. Panel B displays tariffs for manufactured cloth, categorized as embroidered or non-embroidered. Linen textiles also encompassed other vegetable fiber products such as jute, flax, or ramie. Appendix Figure B.2 provides information on the protection levels for each product, while Appendix Figure B.1 showcases tariff protection on other textile products, including raw materials, threads, and embroidered fabrics. The figure displays the one-year moving average of the raw numbers.

On the other hand, wool-manufactured products also experienced a significant increase in tariffs with this tariff reform. Despite achieving similar protection levels as cotton products, the tariff system did not result in a captured colonial market, mainly due to the weak demand for wool products in the colonies. The tropical location of the colonies created a need for breathable summer fabrics, which wool products lacked. Additionally, other textile materials such as linen and silk fabrics, which adapted to colonial market characteristics, did not receive a considerable increase in protection tariffs, even lower than the cotton protection before 1891. Producers could not use these tariffs to force the colonies to buy their products.[12] These findings highlight the limited effectiveness of tariffs in capturing colonial markets for certain textile products. In my analysis, I exploit this fact and use textiles made of linen, wool, silk, and other fibers as a "control" group to understand the behavior of textile industries without extensive market capture.

After its implementation, tariff protection persisted at elevated levels for an extended period. Notably, despite the loss of the empire in 1898, the tariff regime remained virtually unchanged until a subsequent modification in 1906, which solely changed the level of protection for cotton products. Following this amendment, the cotton product tariff reverted to levels similar to those witnessed before 1891. Intriguingly, the wool-manufactured fabrics industry emerged as the foremost beneficiary of the enhanced protective measures, garnering the highest level of tariff protection. In the realm of raw materials, I observe an opposite trend, as depicted in Appendix Figure B.1. Specifically, raw cotton faced relatively lower barriers than other materials, including wool and vegetable fibers, produced in Spain. This observation aligns with the notion that while not entirely shielded, the tariff policy did support the cotton industry, and the authorities did not intend to design the tariffs to have a detrimental impact on the industry.

Figure 2 illustrates how the tariff regimen impacted exports' volume and destinations. Prior to 1982, cotton production and exports were similar to linen. After the reduction in trade barriers that year, both cotton production and the share destined for exports grew similarly. The protective system in 1891 significantly increased the share of production destined for exports in both cotton and linen, with cotton reaching a maximum of 20% and linen around 8%. However, the behavior of exports differed between the two fibers, with cotton showing an increasing capture of the colonial market through new production.[13] Even before 1891 (and 1882), colonial markets represented more than 90% of total export markets in Figure 2 Panel B.[14] However, exports to these markets dramatically decreased after the loss of the colonies, with

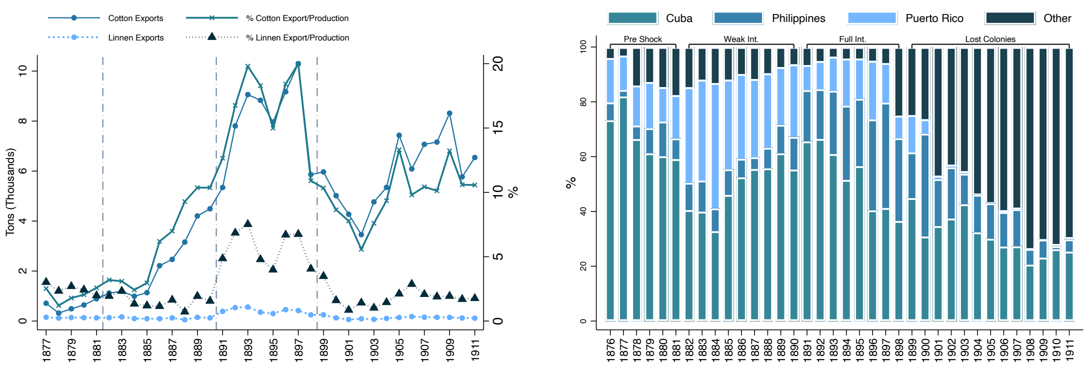
[12]For instance, translated in 1895, Cuba imported a minimal amount of wool and silk manufactures. In that year, Cuba received 11,796 tons of linen textiles and 4,932 tons of cotton textiles, 312 tons of wool textiles, and 19 tons of silk textiles (Dirección General de Hacienda, 1894-1895).

[13]Contrary to linen exports that did not increase in the same proportion, showing relative constant production levels and a replacement of the internal market. In 1895, the cotton imports in Cuba from Spain represented around 70% of the total imports weight while the linen imports from Spain amounted to only 31% of the total imports' weight (Dirección General de Hacienda, 1894-1895).

[14]The only change the 1891 tariff reform represented was a change in internal compositions. After 1891 there was an increase in exports to the Philippines.

values falling to around 20% ten years later in 1908.[15] This confirms the decision to use other textile industries as control groups, as they were less affected by trade policies than cotton.[16]

Figure 2. **Cotton textiles export**



A. Cotton textile production and exports **B.** Cotton textile destination

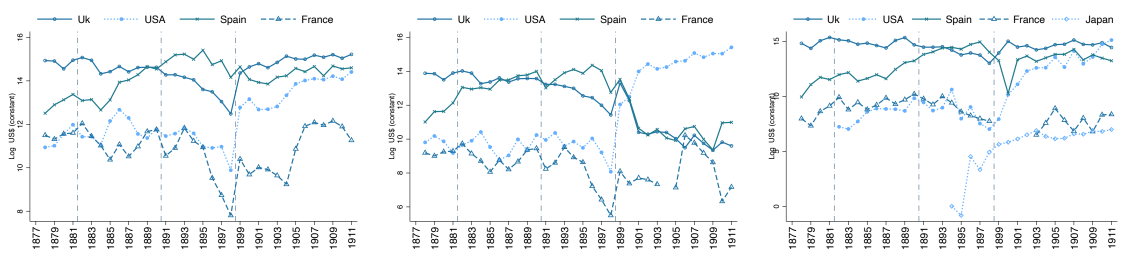
Source: Same as figure 1 and Ministerio de Agricultura, Pesca y Alimentación (1929-1935)
Notes: Panel A presents estimates of raw materials' weight based on the summation of average yearly cultivation yields from 1929 to 1935 with the total weights of raw imports for each corresponding year. I estimated textile production using this aggregated raw material weight, following the approach outlined by Sudrià (1983). To account for production losses, I assumed a reduction of 25% in weight across all production stages. The figure illustrates the two-year moving average of the raw data. In Panel B, the analysis focuses on the destination market share and the share of main colonies. Figure B.4 in the appendix, Panel A, provides a detailed breakdown of cotton textile export destinations, beyond the Caribbean and Pacific colonies.

The colonial cotton imports, as depicted in Figure 3, illustrate the changing dynamics of trade policies and their impact on the imports of cotton products in the three different colonies during various periods. Before the 1891 tariff reform, the United Kingdom was the primary provider of cotton products to the colonies. The reduction of trade costs between the colonies and the metropole in 1882 led to an increase in trade with Spain but without a decrease in other trade patterns, particularly in Cuba.[17] However, the increase in empire protection after 1891 resulted in a

[15]This is contrary to linen textile markets. The market share of colonial markets returned to the previous values at around 40% (See. Panel B appendix figure B.3).
[16]Actually, figure B.3 (Panel A) shows that none of the other textile sectors were comparable with any cotton product type when analyzing exports to colonial markets. Colonial trade of silk, wool, or linen was minimal in value, far below any cotton textiles category.
[17]The United Kingdom remained the primary source of cotton products in the colonies, although the increased participation of Spain achieved similar levels.

significant shift in the composition of cotton product providers. While imports from Spain increased, there was a reduction in imports from the United States, France, and, notably, the United Kingdom. Spain emerged as the leading source of cotton-manufactured products for all three colonies,[18] indicating a change in the trade composition patterns due to the altered trade policies and tariff regimens during that period.[19]

FIGURE 3. **Colonial imports of cotton manufactures**



A. Cuba **B.** Puerto Rico **C.** Philippines

Source: Same as figure 1 and Chief of the bureau of stadistics (1878-1911); London, H.M. Stationery Office. (1878-1911); Direction Général des douanes (1878-1896, 1897-1911); Yokohama City (1980)
Notes: This figure shows the evolution of the total value of cotton manufacturing imports in one of the three main Spanish colonies. The total value is expressed in logarithms of constant dollars of 1878. I exchange rates in Federico and Tena Junguito (2018a) to convert values to US dollars. The original sources provided data in pounds for the United Kingdom, Francs for France, Yen for Japan and pesetas for Spain. Before 1898 United Kingdom and France provided only aggregated trade statistics with Cuba and Puerto Rico (*Spanish Western Indies*). I used the share of trade between these two countries in 1898 and 1899 to assign the corresponding value to Cuba and Puerto Rico before the independence. Appendix figure B.5 provides the behaviour of other fibres manufactures imports and figure B.6 provide the behaviour of textile manufactures in Spain.

2.3. **Market lost.** After gaining partial trade freedom that was absent during the Spanish administration, the colonies experienced changes in their imports and trade partners' relevance. Following independence, the behavior of imports from the United

[18]This is different for other textiles such as linen or wool products (see Appendix figure B.5) where Spain never acquired a predominant place. For instance, Spanish linen products in Cuba never replaced United Kindom products as number one. In the case of Puerto Rico and wool and vegetable fibers, manufactured goods were before 1891 in similar conditions, and that did not change with the new tariff system.

[19]In the case of Cuba and Puerto Rico, this compositional change occurred almost immediately after the increase in tariffs, while in the case of the Philippines, the change happened after, and the reduction of imports from the UK was moderate.

States, the replacing colonial power, varied among the three colonies, largely influenced by their degree of freedom after 1898.[20] In Puerto Rico, the increase in imports from the USA came at the expense of trade with the United Kingdom, France, and Spain, which saw a significant and consistent decrease in their market share. In contrast, in the other two territories, the United Kingdom regained its role as a provider of cotton products, and France and Spain-manufactured products returned to the levels observed before 1891.[21]

The colonial break with Spain had a noticeable increase in trade values in the islands, suggesting that the metropole utilized its colonies to maintain high product prices compared to competitive international markets. As a result, the Spanish cotton industry faced challenges after the loss and had to adopt different strategies to overcome the adverse situation, considering the industry's specific characteristics.[22]

Adopting increased protectionism through higher tariffs and an expanded classification system in 1906 was a key strategy implemented in Spain to revive the textile industry after the 1898 war. According to Sabeté-Sort (1995), this policy resulted in a relative increase in tariffs for high-quality textiles compared to low-quality textiles. However, the industry's recovery began before this tariff system changed, indicating that other factors were at play. In this paper, I argue that the industry's recovery can be attributed to its insertion in global markets thanks to the already strong industry that enabled Spain to regain competitiveness.[23]

As Spain increased its protectionism through higher tariffs, firms also turned towards international markets to replace those lost after the war. Despite a slight export reduction in the initial post-war years, export volumes gradually increased and remained stable after 1891,[24] as shown in Figure 2. Two factors explain this growth.

[20] This is explained by the fact that the United States fully controlled Puerto Rico, and authorities in Washington introduced a differential tariff to benefit producers in the United States.

[21] Interesting is the case of Japan products that entered the Philippines' market and reached the same levels as France products.

[22] According to Nadal and Sudrià (1993) some characteristics were the constants of the industry during the first decade of the century: the significant presence of female and child labor and the wide variety of produced fabrics. Both were strategies to reduce costs and gain access to new markets. First, women and children were a cheaper labor source, and, according to Smith (1991), it was a deliberate strategy across the weaving sections to reduce costs. Second, the wide range of fabric types allowed the firms to reach more buyers despite the cost of productivity that it represented. Without specialization, large economies of scale were impossible. Moreover, the constant change in machines and techniques required more loom workers (Nadal and Sudrià, 1993).

[23] Moreover, the tariff scheme does not seem to have significantly impacted the levels of imports. Appendix figure B.6 shows that imports from the UK, France, and USA moved around the same values after 1898.

[24] This even though the peseta's value decreased after the instability caused by the war.

First, the search for alternative markets led to the establishment of replacement markets for cotton textile products in the American republics (Pane A, see appendix Figure B.4) and other European powers to a lesser extent. Second, there was a shift in the quality of exported fabrics. Spain ceased the export of white textiles and increased production and exports of higher value-added fabrics,[25] such as dyed, printed, double, and knitted fabrics[26] (Pane B, see appendix Figure B.4). Despite being on a smaller scale, Spanish industrialists aimed to compete in the global market with more specialized products.[27] This change in production by Spanish producers was made possible by the solidification of the industry during the colonial market capture period, accompanied by an increase in technological innovation during that time.

3. Theoretical Framework

When technical change is endogenous, international markets affect the direction in which innovators develop new technology. Several authors have built theories of international trade and the effects on innovation (see Acemoglu, 2002; Gancia and Zilibotti, 2009; Gancia and Bonfiglioli, 2008). These are some of the critical features of the theory (see appendix section A for a complete review of the theory). The theory focuses on two sectors (they can represent cotton textiles and other fiber textiles, for instance). Intermediate goods and machines, combined, produced each one of the textiles, and both machines and intermediate goods are specific to each sector. Each sector uses raw fiber (cotton (Z) or other fibers (X)) endowments to produce intermediate goods depending on a unique sector cost structure. Ultimately, I am interested in the number of machines since they represent the available technology in each sector. A number of them (A_i for the numbers of machines in the sector i) measures each sector's innovation degree. Machine developers hold an infinite patent on machines and sell them in a monopolistic market to textile makers after producing them at a marginal cost. Developers must pay a fixed cost to enter the market and decide then in which sector to invest. Because each sector's market structure and demand for their machines affect investors' profits, those characteristics are essential

[25]Appendix B.3 also showed that imports to colonial markets did not disappear completely. The export values of sophisticated fabrics remained high, at the same level observed before the market integration periods.

[26]In 1895, most cotton textiles entering Cuba were low-quality textiles (around 50%). This count included textiles with a low number of threads and without any additional processing.

[27]This was not a unique Spanish feature. Beckert (2015) account recorded evidence in several countries with similar experiences. For instance, the Ottoman industry took advantage of cheap input products and catered to highly differentiated weaving output markets (p. 331 Beckert, 2015).

to determine in which sector a new machine should be introduced. Consequently, I will analyze how each trade shock affects first the market structure and the profits innovators can make in each sector and then the incentives to expand the sector machinery.

The Spanish patent law allowed the introduction of innovations already patented in other countries. That is, it allowed the imitation of foreign ideas. Under this framework, developers must consider the overseas technology. Gancia and Bonfiglioli (2008) show that even in this case, local conditions determine the technological levels adopted in the non-technological leader countries. Having this in mind, I argue that the conclusions about the effect international markets still apply to the Spanish context. First, because there was no perfect replication of foreign technology in Spain. Second, because even when there were no total barriers to overseas technological adoption, the Spanish markets' conditions were still affecting the decision of local innovators when they determined the type of innovation to develop.

In the case of the market integration shock, I assume that the change in innovation incentives is through the prices of intermediate goods. When Spain forced its colonies to buy cotton textiles, the prices of these manufactured goods increased after the production left the country to the colonies.[28] Since innovators were selling their machines in a monopolistic market, the increase in prices in the cotton sector also translated into an growth in the profits they can make selling the machines to this sector. This leaves the following prediction

Prediction **1.** *With fixed technology, cotton textile relative price increased after the protective tax and the market integration. Due to this rise in cotton textile relative prices, there was an increase in patented machines to process cotton (A_z) relative to the machines to process other fibers (A_x).*

4. Data

4.1. ***Patents.*** In this paper, I analyze the central concept of innovation using patent data obtained from the work of Saíz et al. (2008). These authors directly accessed the original documents containing historical patent applications,[29] which were sourced from the government office responsible for historical patent archives in Spain, known as the Oficina Española de Patentes y Marcas (OEPM). The data used in this study

[28]In terms of endowments, it meant that raw cotton relative to other fibers was scarcer in the integrated market as compared to Spain.

[29]In some cases, these authors only worked with administrative records since some inventors used to retire more detailed descriptive documents at the expiration period of their patents.

includes all patents registered in Spain[30] between 1878 and 1911.[31] To access the patents' basic characteristics, such as application date,[32] patent description, applicant's name, place of residence and occupation, patent duration, patent type,[33] and information on whether the patented idea was implemented, I scraped the OEPM website.

The dataset I used in this study classifies patents based on the International Patent Classification (IPC), which allows for the identification of the technology associated with each patent to some extent. The appendix table C.1 presents the technology classification of textile patents, highlighting all the technological subcategories that had at least one application between 1878 and 1911.[34] For the main analysis, I use one patent feature: whether the patent applies to cotton textiles. Patents are categorized as cotton-related if their main purpose, as mentioned in the patent description, is related to the process of general fibers and fabrics or cotton and fabrics made from cotton fiber. Non-cotton-related patents are those designed for different fibers and fabrics made exclusively from those fibers. In my analysis, I compare the behavior of 31 technologies destinated to the process of cotton against the 31 counterparts destinated to process other materials during the market integration and post-war periods.[35]

4.2. ***Machines.*** I gathered data on mechanization and machine acquisition from industry and business tax reports payments, as mentioned in Dirección General de

[30]I exclude any addition to previously registered patents from my analysis.

[31]There were no significant changes in patent legislation during this period. The Spanish patent system changed significantly in 1878. A law in this year modified the first patent law of 1826. It introduced, among other things: a new payment system based on progressive quotas, the possibility of patent protection extended to foreign inventors who had already patented the invention overseas, and a more rigorous procedure to verify that the protected idea was implemented. Besides some complementary laws orientated to regulate specific matters, there was a new significant law in 1902. However, this law did not change the previous regulation spirit significantly, and it only modified minor issues to adjust the system according to new realities. See Saíz (1995) for a detailed history of the Spanish patent system.

[32]I follow (Hanlon, 2015) using the date of the application since, as highlighted by this author, it allows me to focus on patents at the early stage of patenting and without any concern for differential speed during the granting process.

[33]That is if the patent was a patent of the invention or a patent of introduction

[34]Because the classification was created in 1970 and technologies changed over one hundred years, some patents do not fit into a single category or concept in the classification. I assigned the patent as a textile patent if one of these classifications was related to textile production. In the case of a textile patent categorized with several divisions, I assigned it to the classification of its primary purpose after reading its description.

[35]Appendix table C.2 shows a selection of the patent information I have: the average description and classification and different technologies classes of the patent are displayed.

Contribuciones (1879, 1893-1894, 1895-1896, 1900-1909). This data provides insights into the impact of innovation on mechanization patterns in various regions of Spain. However, there are certain limitations to this data. Firstly, the reports only cover part of the period of interest, and there are gaps in the data for specific years, such as 1879, 1893-94, 1895-96, and yearly from 1900 to 1909. Secondly, tax evasion and fraud were prevalent issues in Spain during the 19th and 20th centuries,[36] which means that the number of machines and taxes paid on them may not represent the total capital employed in these industries, and the analysis using this data provides only a lower bound estimate of the actual effect. It also assumes that there were no differential changes in evasion across industries.

The data collected from these sources include information on different machines used in three textile industries: cotton, wool, and linen (hemp).[37] The analysis compares the patterns of mechanization across 45 provinces[38] considering different fiber industries and stages of production. In 1879, most provinces had the presence of linen and wool industries, with only three provinces reporting no machines working with these fibers. However, cotton machines were present in 20 provinces, primarily on the coast (as shown in the appendix figure B.7). This situation changed over time, and the cotton industry expanded beyond its initial natural borders.[39] After 1900, several provinces reported the presence of cotton machinery, with only three provinces not reporting any cotton machines.

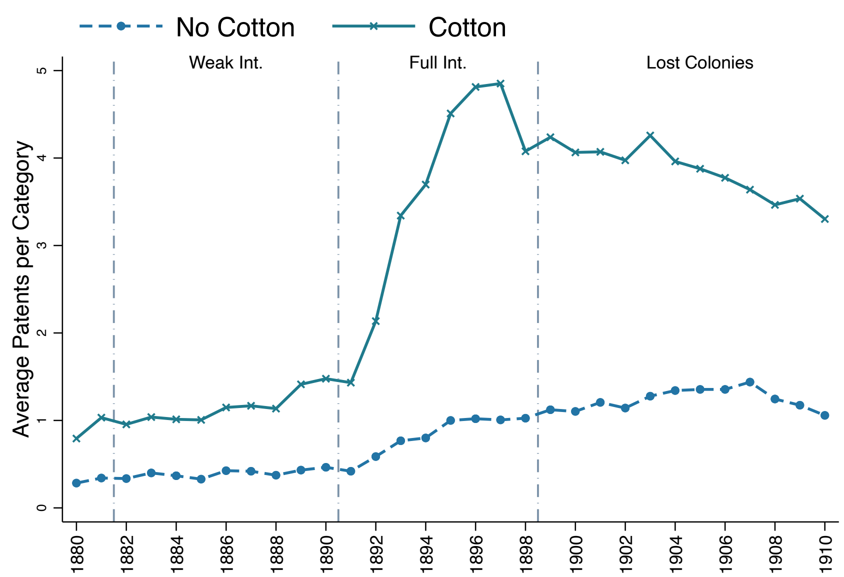
5. Technical Change

5.1. ***Empirical Strategy.*** The empirical work investigates the effects of colonial-metropolis market integration on cotton industry innovation. The study utilizes two dimensions of variation: the existence of textile industries unaffected by colonial market integration and the timing of integration between 1891 and 1898. The strategy

[36] Moreno Lázaro (2015) identified an extended fraud in flour mills. He estimates, on average, revenue losses of around 40% to 60%. See Comín (2018) for detailed information about this practice in Spain.
[37] I do not include information about machines used for mixed-material fabrics and stages in which it is impossible to identify the type of textile, such as textile bleaching.
[38] *Provincia* is an administrative division of Spain's territory. The system originated in 1833, and it did not have any significant change during the analysis period. The tax payment reports did not cover some territorial regions, such as the provinces belonging to the Basque Country (Vizcaya, Álava, and Guipúzcoa) and Navarra that were under a different tax system during my period of interest. Also, I do not include Canary Islands' regions since they never reported a machine in textile industries during these years.,
[39] A strong international orientation of cotton textiles and lack of good communication roads help to explain this location decision close to ports.

employed is a *difference-in-differences* approach. The approach compares the innovation patterns in the cotton industry before and after the colonial-metropolis market integration, taking into account the differences between textile industries that were and were not affected by the integration and the timing of the integration. I use data on patents in 31 technology categories related to all stages of textile production and two material categories (i.e., whether the patent is related to cotton or not). This approach allows for identifying the causal effects of colonial market integration on cotton industry innovation by isolating the effects of interest from other factors influencing the outcomes.

FIGURE 4. **Cotton related and no-cotton related textile patents**



Notes: This figure shows the evolution of textile patents for both cotton and non-cotton-related patents. The data is presented using a two-year moving average of the raw numbers.

Figure 4 shows the average number of cotton and non-cotton-related patents per technology category in all production stages between 1878 and 1911. Prior to the market integration in 1891, both categories exhibited similar behaviors, with no significant deviations in patent counts. However, after the integration, cotton-related patent counts experienced a sharp and sustained increase, peaking in 1897 at five times higher than pre-integration levels. This pattern of technological change in cotton textile production during the market integration period is consistent with theoretical predictions. Moreover, the fact that similar countries did not experience the same growth in textile patents during this period proves there were no external shocks coinciding with the increase in tariffs.[40] It provides further support for the impact of market integration on cotton industry innovation in Spain.

Formally, I estimated the following equation after aggregating the data into eight periods of four years each,[41] where subindex j denotes the technology-material category and subindex t denotes the period.

$$Pat_{jt} = \sum_{k \neq [1879-82]} \beta_k (\text{Period}_k \times \text{Cotton}_j) + \alpha_t + \alpha_j + \varepsilon_{jt} \tag{5.1}$$

where Pat_{jt} represents the count of patents in the technology category j at time period t. The variable Cotton$j$ is a dummy variable that takes the value of one for technology categories related to cotton, and α_t and α_j are time and technology-material fixed effects that capture time-invariant category characteristics and aggregate time shocks, respectively. The error term is denoted as ε_{jt}. The key coefficients of interest are denoted as β_k, which capture the differential change between each period k (e.g., weak integration, full integration, lost colonies)[42] and the baseline period (1879-82) in the number of cotton-related patents relative to the change in non-cotton-related patents.

The identification assumption in this analysis is that the number of cotton-related patents would have followed a similar pattern as the number of non-cotton-related patents in the absence of market integration. This assumption is supported when comparing the baseline period with the weak integration periods, where gradual tariff

[40]I calculated the textile new patents based on the total number of patents reported in Database (2015) and shares of textile innovation for that period registered by Nuvolari and Vasta (2015) for Italy and Andersson, Karadja, and Prawitz (2022) for Sweden. Figure B.8 shows that in the case of Italy and Sweden, new textile patents continued their growth without any substantial change in their trend. I do not observe this increase in innovation as in Spain in other similar countries. While Spain's GPD per capita in 2011 dollars was 2520$, it was 2796$ for Italy and 2359$ for Sweden.

[41]To address the challenges posed by the panel structure of the data, I adopt a similar aggregation strategy as suggested by Hanlon (2015). This strategy helps mitigate truncation problems, where some technology series exhibit zero patents in specific years, and serial correlation errors that can bias standard error estimates (Bertrand, Duflo, and Mullainathan, 2004). The presence of serial correlation in the data is confirmed in Table C.6 panel B, where a Q-stat biased corrected testBorn and Breitung (2016) applied to a yearly model (similar to Equation 5.1 in column 1) rejects the null hypothesis of no serial correlation of order 1 or 2. However, when using 4-year aggregated data (column 2), the evidence is ambiguous as the null hypothesis cannot be rejected. Nevertheless, using the LM portmanteau test for serial correlation developed by Inoue and Solon (2006), some evidence of serial correlation in the model persists. Four-year aggregated data eliminates some zero counts in the series while preserving the time structure that can be used to test for dynamic effects. Further details on this aggregation strategy can is available in Appendix C.6.

[42]The periods are weak integration (1883-86) and (1887-90); full integration (1891-94) and (1895-98); and lost colonies (1899-1902), (1903-06) and (1907-10).

reduction between colonies and metropolis should not result in effective integration as colonies were still allowed to trade with other foreign powers. Therefore, I expect the effect on cotton-related patents in this period to be close to zero.

The inference process in this analysis poses additional challenges due to the limited number of observations and panel units. As a result, standard inference approaches that rely on asymptotic assumptions are unreliable. I employed a randomized test to draw conclusions to overcome this challenge. The approach involves two steps. First, one group in each pair of technology categories is assigned randomly as the treated cotton-related technology. Second, the periods are randomly shuffled and assigned to the treated period.[43] This process is repeated for 20,000 different realization combinations of these randomizations, and placebo coefficients are estimated. Under the null distribution of no effect on cotton-related patents and the assumption of same-time effect on both material categories, the specific assignment of treatment and time does not affect the observed outcomes. To derive conclusions, I constructed both p-values and confidence intervals. I assess confidence intervals using an efficient search algorithm proposed by Garthwaite (1996).[44]

5.2. ***Results.*** I present the results of equation 5.1 in Figure 5. The findings confirm the observations in Figure 4, indicating an increase in the number of cotton-related patents during the market integration period compared to patents related to other fibers. Prior to the protectionist tariff and during incomplete market integration, the point estimates move closer to zero, aligning with the theoretical expectation that only under complete integration would there be sufficient incentives to shift towards more expensive cotton textiles. The results are statistically significant at a 95% confidence level starting from the second half of the market integration period.[45] Based on these results, during the 1895-1898 period, there were, on average, 13.5 more cotton-related

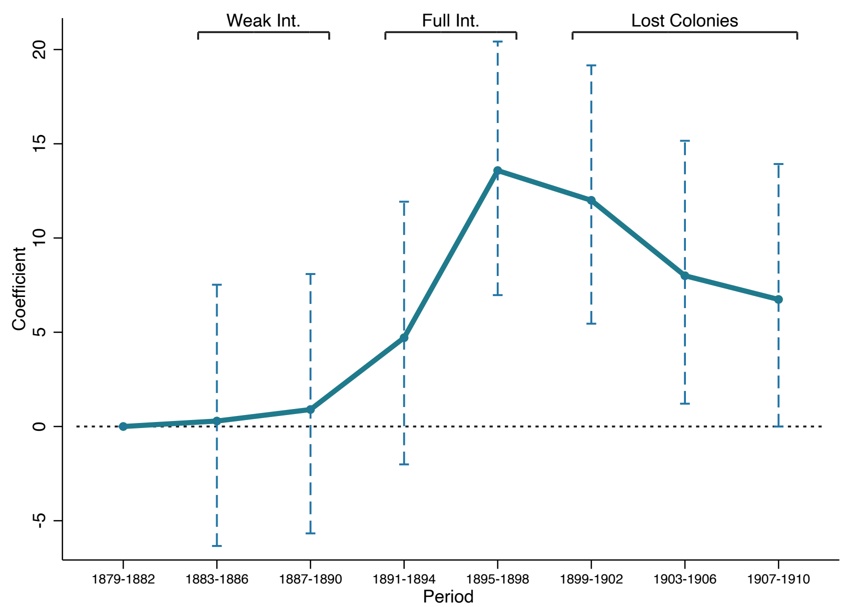
[43]This is a similar approach used by Hanlon (2015). However, I also randomized over the period. This method allowed me to test the hypothesis that differences in the pre-shock periods do not drive the estimated effects.

[44]Randomization tests have the advantage of relying on a few distributional assumptions; however, finding CI is computationally costly. In theory, the calculation involves searching over a grid of possible treatment effects using randomization distributions to calculate a p-value under the null hypothesis that the treatment is equal to each value in the grid. Then the calculation involves choosing the lowest and highest value in the grid with a p-value of 0.05. Garthwaite (1996) proposed an efficient search process independently for each endpoint of the confidence interval. This procedure reduces the search dimensionality. Instead of using the whole randomization distribution for every possible effect, the algorithm uses a single randomization in each search step. I follow the author's suggestions regarding the starting point and the length of the search.

[45]Figure B.10 in the appendix shows the convergence path for the confidence interval estimation and the distribution of placebo coefficients for each one of the coefficients plotted in Figure 4.

patents per technology category compared to non-cotton-related patents. Although the effect begins to fade in the periods following the American-Spanish war and the loss of colonies, it remains statistically significant.[46]

FIGURE 5. **Event study: Effect market integration on cotton patents**



Notes: This figure displays the coefficients β_k obtained from regression 5.1, along with their corresponding 95% confidence intervals. The inference is based on a randomized approach following the algorithm proposed by Garthwaite (1996) using 20,000 randomization allocations. Total number of observations 496.

5.3. **Robustness.** In addition to the results presented using a 4-year aggregation, I also estimate a yearly panel from 1878 to 1911 of equation 5.1, as shown in Appendix Figure B.11. Given the data structure with a more extended time series, I use a more restrictive form of estimation that includes differential trends by technology category.[47] To account for serial correlation, I calculate Newey-West standard errors with a lag length of 3, following Greene's rule-of-thumb lag length of $T^{1/4}$ rounded upwards. Additionally, I estimate double cluster standard errors at the group and year levels to address the presence of cross-sectional dependence.[48] These additional

[46]This pattern would evidence the path dependence on innovation (like the one theorized in Acemoglu et al. (2012))

[47]Exactly I estimate the following equation: $Pat_{jt} = \sum_{k \neq [1881]} \beta_k (\text{Year}_k \times \text{Cotton}_j) + \sum_{g \in \text{Tech}} \alpha_g \times t + \alpha_t + \alpha_j + \varepsilon_{jt}$ where $\alpha_g \times t$ are the technology group differential trends.

[48]Table C.6 shows the presence of some cross-sectional dependence between units. Pesaran's test with a statistic of 7.881 and p-value of 0.

estimation approaches provide robustness to the results obtained and strengthen the reliability of the findings.

The results obtained from the yearly panel estimation confirm the observations made in the previous analysis. Before 1891, the estimated difference between cotton and non-cotton patents was almost zero, indicating no significant divergence in innovation between cotton and other textile industries. However, after 1891, there was a significant increase in the estimated difference until 1898. Nevertheless, even after the loss of the colonies, the difference remained statistically significant in all years, indicating the presence of small path dependence in innovation.

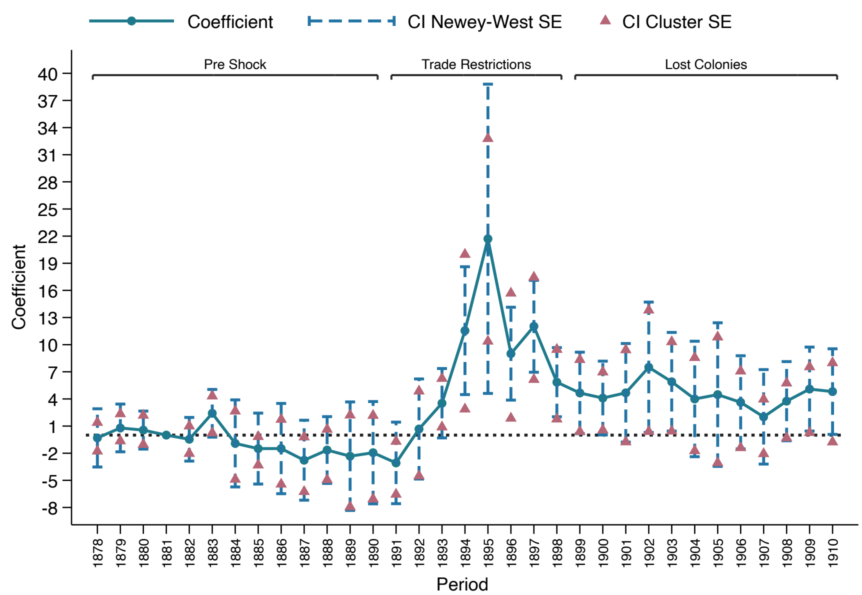
The peak point was observed in 1895 when, on average, there were five more cotton-related patents per technology category than other textile-related patents. This suggests that market integration motivated more innovation in the cotton industry due to the changes in the price of the final textile determined in the integrated market. Furthermore, the coefficient remained significant even during the first period of trade restrictions, from 1891 to 1894, indicating that the divergence between cotton and non-cotton patents started after the tariffs increased. Despite concerns about the reactivation of the Cuban independence movement and the possible loss of colonies (Heraclides and Dialla, 2017), cotton innovation continued to increase. On average, there were two more cotton patents during this period, indicating that the positive effect persisted, albeit at a smaller magnitude.

The previous result might result from a different shock unrelated to the increase in the protective tariff. To override this hypothesis, I test if there is a relation between the effective tax that each patent category receives each year (τ_{jt})[49] and the number of patents using the following model:

$$Pat_{jt} = \sum_{k \neq [1881]} \beta_k [\text{Year}_k \times \text{Ln}(\tau_{jt})] + \text{Ln}(\tau_{jt}) + \sum_{g \in \text{Tech}} \alpha_g \times t + \alpha_t + \alpha_j + \varepsilon_{jt} \tag{5.2}$$

[49]The process of assigning tariff products to patent categories involved several steps. First, I classified the products reported by the Spanish authorities based on their closest match to the categories in the World Customs Organization's Harmonized Commodity Description and Coding System in 2002 (HS). I performed this classification at different levels of precision, ranging from 4 to 6 digits of disaggregation depending on the product. It is worth noting that some products could be classified under multiple codes. Second, I aggregated the total values of imports into Spain and the revenues collected from tariffs for each HS classification. This provided information on the overall economic activity associated with each classification. Third, using the crosswalk provided by Lybbert and Zolas (2014) I assigned the proportions of each product to cotton-related and non-cotton-related patent categories. Finally, I calculated the protection level for each patent category as the share of tariff revenue collected from the respective patent classification divided by the total value of the products in that classification. In cases where no product is directly related to a patent category, I assumed a protection level of 0.

FIGURE 6. **Event study: Effect market integration on cotton patents using yearly panel and tariff for each patent category**



Notes: This figure displays the coefficients β_k obtained from regression 5.2, along with their corresponding 95% confidence intervals. 95% confidence intervals use Newey-West standard errors with a lag length of 3, based on Greene's rule-of-thumb lag length of $T^{1/4}$ rounded upwards. Double cluster standard errors are also applied at the group and year levels to account for cross-sectional dependence. Figure B.11 presents the estimation results of a Difference-in-Difference model with differential technology group trends using yearly panel data from 1878 to 1911.

The estimation in Figure 6 reveals that the coefficients β_k, which captures the differential effect of protection on the number of patents, indicate that tariff protection spurred innovation, particularly after 1893 when the increase was significant enough to capture the colonial market. Furthermore, this effect persisted even after Spain lost its colonies, albeit with a smaller magnitude. These findings provide compelling evidence to conclude that the increase in tariffs was the driving factor affecting innovation, rather than other specific shocks that may have impacted the cotton industry during that period and were not taken into account in the analysis. For example, in 1897, a 25% increase in tariffs would have translated into 2.6 more patents, further supporting the positive relationship between tariff protection and innovation in the cotton industry.[50]

[50]Coefficient in this year β_{1897} was 11.8, so $2.6 = 11.8 \times \ln(1.25)$

The previous results may not fully capture the changes in the industry due to market integration between Spain and its colonies or the loss of these captive markets. External forces from innovating countries that sought to allocate production beyond national frontiers could influence the effects observed after 1891. To address this concern, I conducted an additional analysis using only patents registered by Spanish residents, excluding those registered by foreign residents. This exercise was possible because Spanish patent law protected ideas from non-resident individuals if they planned to implement the technology in the country. This is particularly relevant as cotton advancements and machinery from England began to be used in other continental European countries, with British engineers establishing manufacturing facilities to circumvent export restrictions (Allen, 2009). The results, shown in the appendix in Figure B.15, indicate that the conclusions reached in my previous analysis remain unchanged. Specifically, during the integration period between 1894-1898, there was an increase of 9.5 cotton patents per technological category from Spanish residents compared to other textile industries. Even after the loss of colonies, there was a gradual reduction in differential cotton textile innovation, but it remained statistically significant for several years thereafter. These results suggest that any shocks related to capital reallocation do not drive the main results, supporting the conclusion that the increase in tariffs was the main driver of innovation in the cotton industry during the study period.

It is possible that my findings capture the impact of new countries demanding new textiles after 1891 and 1898. For instance, during this same period, Argentina experienced an economic boom that increased the demand for industrial goods.[51] To formally test whether Argentina's conditions could explain my results, I estimated equation 5.1 while controlling for Argentinian exports. I included a new set of variables allowing interaction between material-technology fixed effects and Argentina's total yearly import values.[52] The results of this analysis, shown in Appendix Figure

[51]Argentina became one of the most important markets for Spanish cotton fabrics. Between 1905 and 1910, the Argentinean market represented 15% of total cotton Spanish exports, far above other important markets such as France (6.9%), Turkey (4.9%), Uruguay (4.7%), and Colombia (4%). However, economic conditions in Argentina started to improve several years before the American-Spanish War. By 1895 the railroad system was already developed, and it connected several inland cities, and the import values were high (see Fajgelbaum and Redding, 2021). That means the Argentinean market was already available to Spanish producers by the end of the 19th century.

[52]I estimate this new equation $Pat_{jt} = \sum_{k \neq [1879-82]} \beta_k(\text{Period}_k \times \text{Cotton}_j) + +\alpha_t + \alpha_j + \alpha_j \times \ln(\text{Arg Imp}_t) + \varepsilon_{jt}$, where $\ln(\text{Arg Imp}_t)$ is the natural logarithm of import values in Argentina measured in constant Argentine *peso moneda nacional* (source Dirección General de la Estadística de la Nación, 1916)

B.13, exhibit similar behavior to the main results. Specifically, there was a significant positive increase in cotton innovation after 1895, with 12.5 more patents per category in the cotton industry compared to other textile industries during the following four-year periods. Thus, these possibilities do not fully explain my results, supporting the conclusion that the increase in tariffs was the primary driver of innovation in the cotton industry during the study period.

Lastly, differences in patent quality do not drive my results. I employed two approaches to account for potential disparities in the quality of patent applications. According to Spanish law, an inspection was required to verify that the applicant had utilized the patented innovation within the first two years of the application process. Appendix Figure B.14 displays the results when considering only the counts of these high-quality patents, which were utilized in the industry's production lines. Notably, during the period of market integration (mainly from 1895 to 1898), there was an increase in high-quality cotton patents compared to non-cotton patents. Additionally, during the initial stage of market integration (1891-1894), there was a significant but modest increase in high-quality cotton patents. Subsequently, after the loss of captive markets, there was a decline in the patent differential, although it took several years to return to pre-shock levels.

Secondly, Spanish law allowed for the introduction of innovations and ideas that were already in use in other countries but have yet to be in Spain. Appendix Figure B.15 presents the results when excluding these types of patents, focusing solely on new ideas and innovations. Notably, even after 1898, there was an increase in new patents related to cotton weaving, indicating that the implemented innovations were not mere copies of foreign inventions.In conclusion, my main results are robust to different specifications and account for high-quality improvements in cotton textiles across all production stages between 1891 and 1898.

6. Machinery

6.1. **Imports of machinery.**

I assess whether differential changes influence my findings in technological pioneer nations. It is plausible that the apparent increase in patent numbers could simply be due to the importation of new machinery rather than genuine innovation. As illustrated in Figure 7, the total value per capita of exports from the United Kingdom[53] to Spain[54] declined after 1891, which persisted at lower levels during colonial market capture. Interestingly, following the 1898 war, there was a resurgence in UK exports to Spain, returning to pre-war levels. This finding challenges the notion that the earlier observed increase in innovation was linked to technologies adopted by more technologically advanced countries.

Moreover, these findings further support my results, suggesting that the observed improvements were significant enough to partially replace foreign technology. To assess this possibility, I analyzed other countries to isolate general trends in the United Kingdom's (UK) exports. Specifically, I employed a synthetic control method (SCM) to create a synthetic Spain that reflects the country's behavior without imposing increased tariffs. Following the seminal approach, I constructed this synthetic Spain as a weighted combination of other countries, such that total UK machinery exports' behavior resembles that of Spain before 1891. The weights for this artificial Spain were derived using the methodology outlined by Abadie and Gardeazabal (2003); Abadie, Diamond, and Hainmueller (2010) to minimize differences in pre-intervention trends in UK machinery exports, the balance of trade, and GDP per capita in 1870.[55] This approach allows for a rigorous assessment of the causal effect of market capture on the industry and the importation of foreign technologies in Spain.

In Figure 7, the behavior of the synthetic control unit is depicted,[56] along with estimating the probability area that accounts for various sources of uncertainty using Cattaneo, Feng, and Titiunik (2021) method. This analysis reveals that the decline in machinery exports from the United Kingdom (UK) to Spain is statistically significant.

[53]The choice of British machinery is not surprising. According to Floud (1976) British machine tool industry specialized in the creation of minor modifications of tools for all the existing machines that adapted to the particular necessities of each customer. Even more, during the second part of the XIXth century, they were the primary machinery providers to European firms without big competition from the United States.

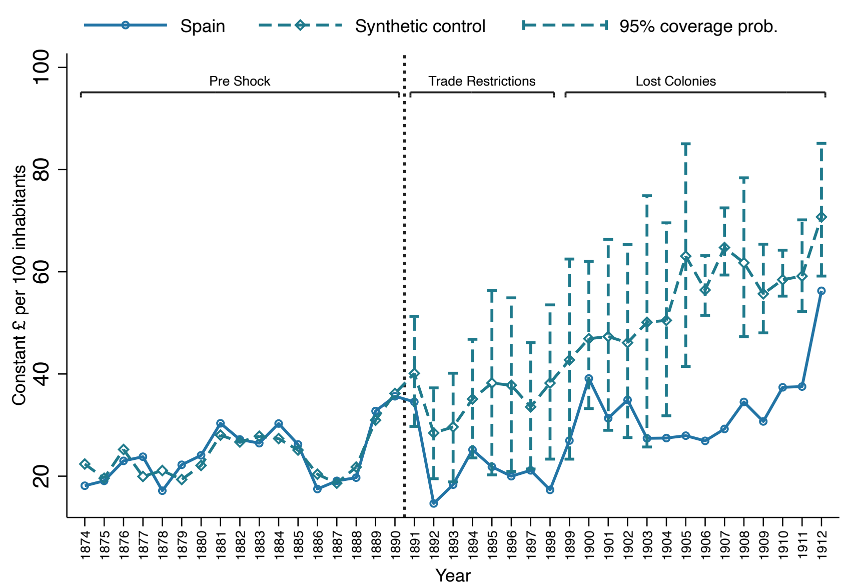
[54]Unfortunately, the United Kingdom did not provide a desegregate account of the value of textile machinery exported to different countries before 1891. Appendix figure B.17 shows the behavior of these exports and the estimation before using 1891 share of textile machinery on total machinery between 1989 and 1910.

[55]Trade data from Federico and Tena Junguito (2018b) and GDP per capita and population data from Bolt and van Zanden (2020).

[56]To evaluate the confidence of this estimation, I present several pieces of evidence. First, the positive weights to construct the estimation seem reasonable: France (45.3%), Turkey (40.7%), Egypt (9.4%), Uruguay (3.5%), Italy (0.7%) and (0.4%). Also, appendix graph B.16 shows the estimation of the trade balance of both Spain and the constructed one showing a similar behavior between these variables and far away from the different values in the set of countries used in this exercise. The population of synthetic Spain was 23 million, while the real Spain was 26.1 million inhabitants. The real GDP per capita for synthetic Spain is $2098 2011 dollars, and real Spain $2070.

After 1891, fewer machines entered Spain than expected if Spain had not captured the colonial markets. Moreover, it appears that the displacement of this machinery lasted after the loss of the colonies, indicating a potential relationship between colonial market capture and machinery exports and innovation.

FIGURE 7. **Synthetic control analysis - UK machinery exports to Spain**



Notes: The graph illustrates the behavior of machinery exports from the United Kingdom to Spain, along with the estimated synthetic control unit constructed using a pool of 27 donor countries before 1891. The estimation of the synthetic control unit includes a 95% coverage probability that follows Cattaneo, Feng, and Titiunik (2021) methodology.

Several additional exercises support the robustness of these findings. First, even when considering only textile machinery, similar patterns emerge. While with slightly less precision, there is still a significant decrease in textile machines exported from the technological leader to Spain, as evident in Appendix graph B.17. Second, I did not find that the war in 1898 was a plausible explanation for the divergence in Spain's machinery imports. When I used 1898 as the initial divergence date, I found no significant difference between Spain and the counterfactual. This exercise suggests that the change in the industry commenced within the eight years when Spain could sell its products in the islands at high prices, as depicted in Appendix graph B.18. Furthermore, when examining other measures of technology transfer, such as the number of spin orders by Spanish firms from the UK, a consistent pattern of a significant decrease in machinery after 1891 is observed, as shown in Appendix graph B.19. This pattern aligns with the notion that tariff protection incentivized local innovations within the cotton textile sector, which persisted even after the initial incentives ceased.

The analysis of patents provides further insight into the nature of innovation during the period studied. The most commonly used terms in the innovations are often associated with improvements and changes to existing machinery and techniques, as evident in Appendix Figure B.9 and Appendix Table C.3. For instance, the term "procedure" is the most frequent word, indicating mechanical and chemical modifications to existing devices.[57] Moreover, the analysis of word correlations, as shown in Appendix Table C.4, reveals that these improvements were associated with various production stages, such as spinning, weaving, bleaching, and printing. These findings suggest that the innovation focused primarily on small changes that displaced the machinery and its parts from England, aligning with the notion of concentrated innovation on incremental improvements to existing technology.

6.2. **Innovators.** To investigate whether the increase in tariffs caused a displacement of English producers in Spain, I analyzed changes in the number of professionals dedicated to the machine tool industry in Spain. To assess whether career decisions and the creation of human capital reflected these changes in incentives, I compared the percentage change in the number of experimental sciences and industrial engineering students with students in other knowledge areas not involved in creating minor technological improvements. To estimate the effect, I used a *difference-in-differences* model and data from students[58] grouped into seven categories:

$$\Delta \ln \text{Students}_{jt} = \sum_{k \neq [1881]} \beta_k [\text{Year}_k \times \text{Ind Inn}_t)] + \text{Eng}_t \times t + \alpha_t + \alpha_j + \varepsilon_{jt} \tag{6.1}$$

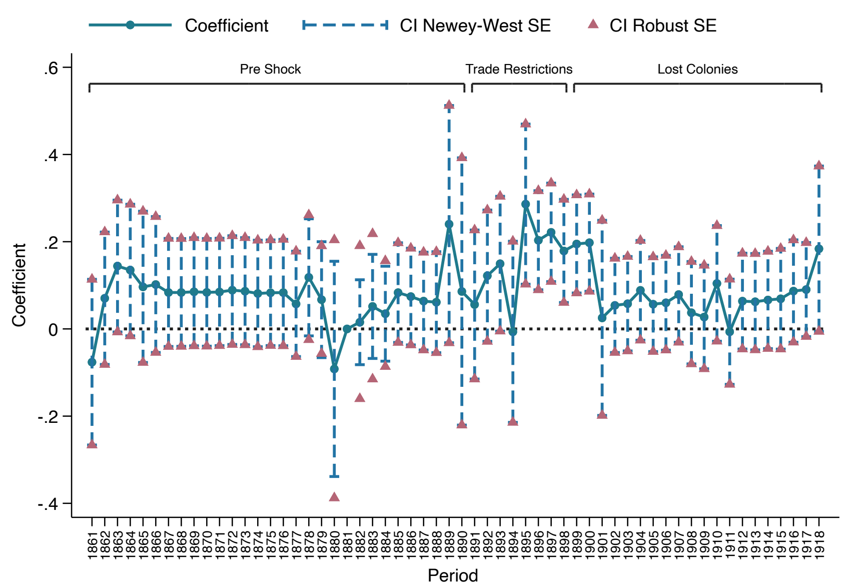
where subindex j denotes the student type, and subindex t denotes year. The variable Students_{jt} is the total number of students at year t and career group j, and Ind Inn_t is a dummy that takes the value of one if the career is involved in the creation of industrial innovation (e.g., experimental sciences and industrial engineers vs. health sciences, humanities, social sciences, infrastructure engineers and natural resources engineers). Finally, $\text{Eng}_t \times t$ captures a differential trend of engineers' careers. The

[57]Indeed, this is not an uncommon feature of textile patents. During the same period, these three words were in the top 5 of the more frequent terms used in the patents descriptions in the universe of patents.

[58]The data source is Nuñez (2006)

key coefficients are β_k, which capture the yearly differential change in those students for industrial innovators compared to 1881. The hypothesis is that there would be a positive change in the total number of students resulting from increased incentives for this type of qualified worker.

FIGURE 8. **Differential change industrial engineers and experimental scientist students**



Notes: This figure displays the coefficients β_k obtained from regression 6.1, along with their corresponding 95% confidence intervals. Yearly panel form 1861-1918 estimation of Difference-in-Difference model including differential engineering trend. 95% Confidence Intervals using Newey–West standard error with a lag length of 3, based on Greene's rule-of-thumb lag length of $T^{1/4}$ rounded upwards. Double cluster standard errors at group and year.

I present the exercise results to analyze changes in the number of professionals dedicated to the machine tool industry in Spain in Figure 8. The point estimates show no significant differences in the preferences between industrial and non-industrial-related careers before 1891. However, after the increase in tariffs and the capture of colonial markets for a short period, there was a boost in engineering careers, resulting in an increase of around two percent in the number of students between 1895 and 1900. This finding aligns with the sector's greater innovation activities, thanks to the cotton industry. This exercise is another evidence that strengthens the argument that local innovators developed these improvements and not just copied foreign machines. It shows that the creation of human capital reflected increased incentives for industrial innovators.

6.3. **Machines' adoption.** Next, I focus on the installed capital and how technological advancements translated into adopting machinery in different textile industries across several Spanish regions. To this end, I investigate the behavior of installed machines in different processes of cotton, wool, and linen industries. Specifically, I employ a *difference-in-differences* model to compare the cotton machines with wool and linen machines:

$$\begin{aligned} Y_{ptm} =& \beta_1(\text{Integration}_t \times \text{Cotton}_m) + \beta_2(\text{Early lost}_t \times \text{Cotton}_m) \\ &+ \beta_3(\text{Late lost}_t \times \text{Cotton}_m) + \alpha_m + \alpha_{tp} + \varepsilon_{ptm} \end{aligned} \tag{6.2}$$

where subindex p denotes the province, m denotes the material, and subindex t denotes the period. The dependent variable is Y_{ptm}, which measures the number of one type of machine per 10,000 inhabitants. I introduce a dummy variable, Cotton_m, which takes the value of one if the machine was used in the cotton industry. Additionally, I include Integration_t, which takes the value of one during the integration period, i.e., for the years 1893-94 and 1895-96, and two dummy variables, Early lost_t and Lost lost_t, which take the value of one after the colonies were lost between 1900 and 1904 and between 1905 and 1909, respectively. Province-year and material fixed effects, α_m and α_{tp}, are included to capture any time-invariant category characteristics. Since a province with a cotton industry differs from provinces with other industries, I estimate differential trends using province-year fixed effects α_{tp}. The error term, ε_{jt}, is clustered at the province-year level, and I control for correlation between industries in the same province at the same year.[59] The key coefficients are β_1, β_2, and β_3, which capture the differential change in machines between each period and the baseline period of 1879.[60]

Table 1 presents the results of the empirical estimates of the equation model 6.2, which investigated the usage of machines in various production stages, including spinning, cloth weaving, and other mechanical processes of fabrics like shearing and raising. The table's odd columns compare the behavior of cotton machines with wool and linen machines. In contrast, the even columns compare the cotton industry with only the wool industry to obtain robust results. Panel A shows that the use of cotton mechanical looms per capita significantly increased, even after Spain lost its colonial possessions, with all three point estimates being similar. This suggests

[59]I only have a small number of provinces (45 provinces). Therefore, I followed Imbens and Kolesár (2016), and I calculated HC2 standard errors tested against a t-distribution.

[60]Again, the standard identification applies here. Without market integration, the machines used to create cotton textiles would have behaved similarly to wool and linen machines.

that the innovation initiated in 1891 had a lasting impact on the mechanization of the cotton industry. The results are also consistent with the innovation findings, which indicate that increased patents at the weaving stage led to more mechanical and jacquard looms operating in cotton fabric production.

Table 1. Response of cotton industry to colonial markets capture

Cotton x ...	Dependent Variable: Variable per 10.000 Inhabitants							
	Mechanical Spindles		Mechanical Loom		Jacquard Loom		Mechanical Raising	Mechanical Shearing
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Machines								
... x Trade Restrictions	73.80	117.70	10.01*	9.14*	0.26*	0.26	0.02	0.03
	(174.49)	(141.34)	(5.65)	(5.33)	(0.16)	(0.24)	(0.10)	(0.09)
	[0.370]	[0.410]	[0.000]	[0.010]	[0.450]	[0.770]	[0.550]	[0.280]
	[[0.347]]	[[0.587]]	[[0.093]]	[[0.170]]	[[0.927]]	[[0.845]]	[[0.650]]	[[0.682]]
... x Early colonies lost	−49.04	−4.12	11.22***	10.38**	0.84**	0.88**	0.04	0.08
	(96.23)	(85.27)	(4.22)	(4.05)	(0.33)	(0.36)	(0.10)	(0.08)
	[0.500]	[0.410]	[0.000]	[0.010]	[0.020]	[0.140]	[0.300]	[0.000]
	[[0.151]]	[[0.371]]	[[0.006]]	[[0.032]]	[[0.443]]	[[0.875]]	[[0.366]]	[[0.867]]
... x Late colonies lost	−107.70	−5.35	12.13***	11.09***	0.84***	0.94***	0.07	0.07
	(90.90)	(66.37)	(4.35)	(4.16)	(0.26)	(0.30)	(0.10)	(0.08)
	[0.170]	[0.140]	[0.000]	[0.000]	[0.010]	[0.170]	[0.070]	[0.010]
	[[0.164]]	[[0.358]]	[[0.011]]	[[0.082]]	[[0.125]]	[[0.400]]	[[0.429]]	[[0.698]]
Panel B: Firms								
... x Trade Restrictions	0.07	0.05	0.08	0.04	−0.00	−0.01	0.02	0.03
	(0.08)	(0.09)	(0.05)	(0.03)	(0.02)	(0.05)	(0.05)	(0.07)
	[0.060]	[0.130]	[0.090]	[0.100]	[0.960]	[0.970]	[0.280]	[0.160]
	[[0.347]]	[[0.587]]	[[0.093]]	[[0.170]]	[[0.927]]	[[0.845]]	[[0.650]]	[[0.682]]
... x Early colonies lost	0.08*	0.06	0.14**	0.10**	0.02	0.01	0.01	0.06
	(0.04)	(0.07)	(0.06)	(0.04)	(0.02)	(0.04)	(0.05)	(0.07)
	[0.030]	[0.070]	[0.000]	[0.000]	[0.450]	[0.700]	[0.550]	[0.020]
	[[0.151]]	[[0.371]]	[[0.006]]	[[0.032]]	[[0.443]]	[[0.875]]	[[0.366]]	[[0.867]]
... x Late colonies lost	0.07*	0.06	0.14**	0.09*	0.04*	0.03	0.02	0.05
	(0.04)	(0.07)	(0.06)	(0.05)	(0.02)	(0.04)	(0.05)	(0.07)
	[0.060]	[0.140]	[0.000]	[0.000]	[0.210]	[0.390]	[0.200]	[0.040]
	[[0.164]]	[[0.358]]	[[0.011]]	[[0.082]]	[[0.125]]	[[0.400]]	[[0.429]]	[[0.698]]
Observations	1716	1144	1716	1144	1716	1144	1144	1144
Material fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Time x Province fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Comparison Cotton vs.	W and L	W	W and L	W	W and L	W	W	W

Notes: W stands for wool, and L for linen and hemp. Columns 1, 3, and 5 compare the cotton industry with the wool and linen (hemp) industry, and columns 2, 4, 6, 7, and 8 compare the cotton industry only with the wool industry. Comparison period 1979. P-values from a randomized test using 1000 allocation in squared brackets. P-values from a test based on HC2 standard errors tested against a t-distribution are in double-squared brackets. I followed the correction proposed by Imbens and Kolesár (2016). Standard errors in parentheses are clustered on the province-year level. * is significant at the 10% level, ** is significant at the 5% level, and *** is significant at the 1% level.

Furthermore, Panel B of Table 1 suggests a positive effect on the distribution of machinery inside firms across all production stages analyzed. There was an increase in the number of firms that reported and paid taxes on mechanized tools, indicating that to increase competitiveness, firms changed their technology and acquired existing machines in the country. Conversely, there was no significant change in the number of firms reporting jacquard looms, implying that existing firms with this technology introduced more of these looms.[61]

In addition, the behavior of non-mechanized tools in the same production stages as before was analyzed in the appendix table C.7. The results indicate a positive effect on manual sharing tools, suggesting some innovation in the finishing stages of production. However, the innovation did not translate into mechanization. While there was contradictory evidence in the case of looms, with some positive effect of the tax increase on this type of machinery when compared with the wool and linen industry, there was also some evidence of a reduction in manual looms after 1891 when compared to the cotton industry. Finally, evaluating the number of firms reporting manual machinery in all production stages shows evidence of an increase in the cotton industry. Altogether, the evidence suggests that the initial tariff rise positively affected the cotton industry, leading to the adoption of more machines and mechanization. This effect lasted even after the incentives disappeared, indicating that the innovation had a lasting impact.

7. Mechanism

7.1. **Finished textile prices after market integration:** The market integration between Spain and its colonial markets affected the relationship between the price of finished cotton and other fiber fabrics. Spain's export of its cotton manufacturing production to its colonies led to an increase in the price of this product in the internal market, which increased the incentives for innovators to develop new mechanisms for cotton textile production. This mechanism explains the increase in innovation in the cotton sector. This is because an increase in the price of cotton products would have made cotton manufacturing more profitable and increased the demand for cotton machinery. To evaluate the validity of this hypothesis, I estimated the behavior of the price of a cotton-finished fabric.[62] I compared it to the price of the finished fabric

[61]This fact helps me overcome the possibility that introducing textile patterns and not improving existing technology explained the innovation change I found.

[62]I use *Percalina Lisa Superior* price. The source of this information is the inventory ledgers of *La Espanña Industrial*. This fabric is the only fabric that the firm constantly produced between

of linen and wool.[63] Formally I estimate the following model:

$$\ln(P^F_{jt}) = \left[\sum_{k=1889}^{1898} \gamma^F_k \times \text{Years}_k \times \text{Cotton}_j\right] + \gamma^F_{99-10} \times \text{Colonies Lost}_t \times \text{Cotton}_j \tag{7.1}$$
$$+\alpha_j \times t + \alpha_t + \alpha_j + \varepsilon_{jt}$$

where P^F_{jt} is the textile price of material j at time t. The Years_k variables represent dummy indicators for each year, and Colonies Lost_t is an indicator for the years following the Spanish-American war. The Cotton_j variable is a dummy indicator for whether the textile material is cotton. I include a differential time trend in the regression to account for the differences in trends before the market integration.[64] The coefficients γ^F_k capture changes in the cotton prices relative to other textiles while comparing the market integration years with the years before this shock.

I expect an increase in cotton fabric prices after the integration period due to the increased price of cotton manufacturing products in the internal market. However, with the adjustment of innovation, I anticipate these values to resume pre-shock levels. To evaluate this hypothesis, I compare the behavior of the price of cotton-finished fabric to the price of the finished fabric of linen and wool. Appendix figure B.20 shows evidence of this behavior, especially when comparing wool prices. After 1891, both cotton and wool fabric prices decreased. However, the price drop was more pronounced for the wool-finished textile price. Moreover, the reduction trend reverted to wool fabrics, suggesting that cotton fabrics became relatively cheaper after 1895.

Figure 9 depicts the relative price of cotton-finished textiles compared to other fiber fabrics between 1890 and 1900. The graph shows an increase in the relative cotton finished textile price that started in 1893 and remained high for three years, and after 1895, the increasing trend reverted, and the price ratio experienced a fall. This behavior suggests that the initial trigger that motivated the cotton innovation was the increase in cotton relative price, which is consistent with the theory that predicts innovation adjustments to revert this tendency and push the price ratio to the levels before the initial shock. Moreover, the estimated coefficients allow me to calculate the elasticity of substitution between cotton fabrics and other fiber products. The

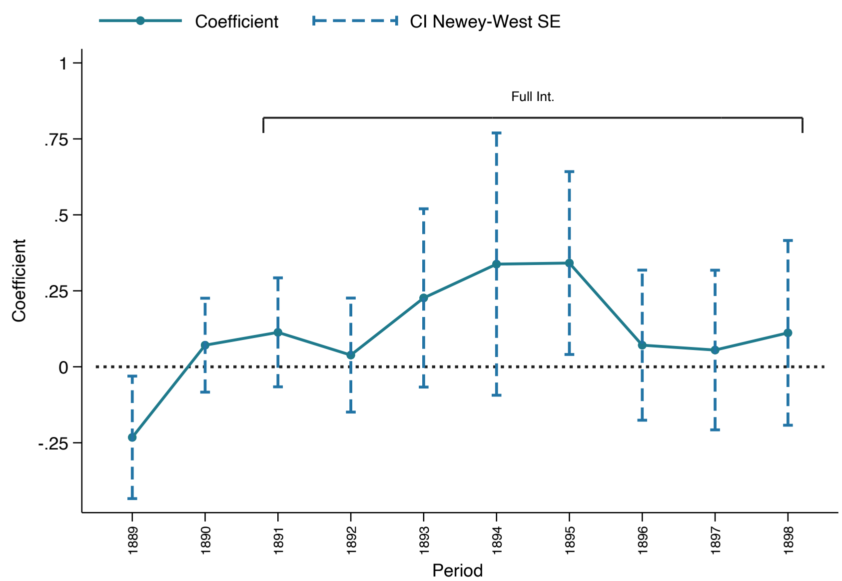
1878 and 1907. Therefore, when analyzing this price variety, I do not have concerns about possible changes in textile quality.

[63]Price is the average manufactures price for imported goods from England to Spain. The data was gathered by Nadal Ferreras (1978) in pounds and converted to pesetas using historical exchange series provided by Federico and Tena Junguito (2018a). All prices are measured as constant pesetas per meter.

[64]Including that the colonies lost dummy allows me to isolate the effect from the change coming to the insertion of Spain in international markets.

point estimate in 1895 implies an elasticity of substitution between cotton textiles and other textiles ($\epsilon^{z,x}$) of 1.07, assuming that the price changes observed in 1895 have not absorbed any adjustment on technologies yet.[65]

FIGURE 9. **Behavior of textile prices**



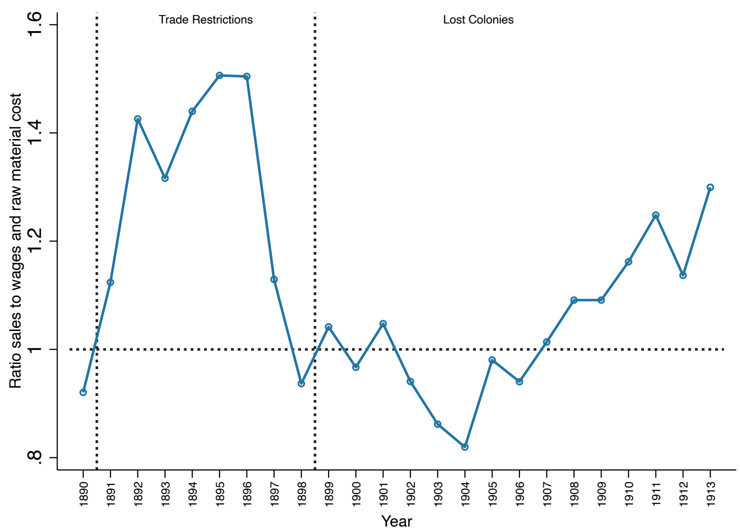
Notes: This figure shows the coefficients γ_k^F from regression 7.1 for each year starting from 1889 to 1898. 95% confidence intervals using Newey-West standard errors with three lags. Annually data from 1877 to 1907. Total number of observations 99.

7.2. **Textile firms benefits:** In addition to the evidence on cotton prices and innovation, another observation that supports my argument is the relationship between cotton prices and the profitability of a major cotton firm in Spain. As shown in Figure 10, the increase in cotton prices resulted in a rise in the sales-costs ratio of this firm,

[65]See appendix section A for more details. If prices do not yet reflect innovation adjustments γ_{1895}^F is equal to $1/\epsilon^{z,x} \ln \lambda$. I can estimate λ using the observed ratio increase in patents in each sector. Before 1891 the cotton-other fibers patent ratio was 3.18; in 1895, this ratio was 4.51. These numbers imply that λ is equal to 1.4. Finally, given that γ_{1895}^F is 0.33, I estimate an elasticity of substitution of 1.07. Also, I estimate the ratio of available raw materials in Spain, both isolated and with the integrated market. For three fibers (cotton, linen-hemp, and wool), I assess the availability in continental Spain by adding internal production and imports after subtracting exports. In the case of cotton and linen, I estimate internal production using the cultivated area in 1929. In the case of wool, I estimate internal production using the 1890 cattle census and assuming an average yearly production of 2 kg per sheep and a reduction of 0.57% after scour. I calculated an availability in 1895 of 72,940 tons of cotton, 9,126 tons of wool, and 21,081 tons of linen (hemp). Jointly, these numbers implied a ratio of cotton to other fibers of 2.4 in continental Spain, and with $\lambda = 1.4$, a ratio of 1.7 in the whole integrated market.

indicating an improvement in profitability after the colonial market protection. This trend persisted for most of the period until a decline in 1897, bringing profitability back to the pre-colonial level. The behavior of the cotton firm's profits aligns with the pattern observed in cotton prices. It is consistent with the theory that the price changes in the cotton market triggered innovation in cotton production.

FIGURE 10. **Cotton firm benefits**



Notes: This figure shows the ration between total sales and cost of production (raw materials and total wages) of the *La España Industrial*. The source is the balance sheets of the company between 1890 and 1913.

8. CONCLUSION

This paper examines the effects of international markets on the direction of technological progress using a natural experiment that occurred at the end of the 19th century in the Spanish textile industry. Specifically, gaining access to protected foreign markets positively affected the industry, as it created incentives to develop cotton-augmenting technologies. Furthermore, the study reveals signs of path dependence, indicating that even after the independence of the colonies and the loss of colonial markets, there is a significant difference in cotton innovation compared to other textile industries.

This research fills a gap in the literature that has primarily focused on analyzing the effects of input shocks on innovation and provides an answer about the impact of trade and foreign markets on innovation. The study shows that trade shocks can affect the relative prices of the final product, thereby influencing the incentives to develop new technology. Moreover, the findings underscore the importance of understanding the features of trade policies and their ability to change relative prices when examining the consequences of opening and closing foreign markets.

The study also sheds light on innovation behavior in peripheral countries, filling a literature gap that predominantly focuses on the most technologically advanced countries. Although the innovations in the Spanish textile industry were not radical breakthroughs that completely transformed the industry, they were improvements that met the country's specific needs. The research shows that changes in market conditions for cotton textiles led to increased innovation designed to meet those new conditions.

The study's findings suggest that trade with colonies was a crucial benefit for European empires and could be a potential explanation for Western Europe's industrialization during the 18th and 19th centuries. The research emphasizes the importance of understanding how trade shocks improve other sectors to identify the potential spillover effects of trade shocks and new technology on economic growth. Understanding innovation clusters and the importance of agglomeration economies in knowledge will be critical to comprehend the possible multiplicative effects of trade on economic growth.

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ONLINE APPENDIX

Appendix A. A MODEL OF TRADE AND INNOVATION

A.1. **Cotton and other fibers textiles.** In this section I show a model of innovation between two sectors: cotton textile and other fibers textiles.

A.1.1. *Set up and assumptions.* There is an unique final produced good (apparel), produced competitively using cotton textiles (Y_z) and other textiles (Y_x) as inputs, according to the following aggregate production function

$$Y_f = \left[Y_z^{\frac{\epsilon - 1}{\epsilon^{z,x}}} + Y_x^{\frac{\epsilon^{z,x} - 1}{\epsilon^{z,x}}} \right]^{\frac{\epsilon^{z,x}}{\epsilon^{z,x} - 1}} \tag{A.1}$$

where $\epsilon^{z,x} \in (0, +\infty)$ is the elasticity of substitution between the two inputs. Then the producers of textiles $k \in \{Z, X\}$ maximize their production Y_k under a regular inputs constraint giving the relative demand function:

$$\frac{P_z}{P_x} = \left(\frac{Y_z}{Y_x} \right)^{-\frac{1}{\epsilon^{z,x}}} \tag{A.2}$$

Where P_z and P_x are the prices of the two textiles[66]. Textiles Y_z and Y_x are produced using a continuum of sector specific intermediates ($y_z(i)$ and $y_x(i)$ respectively). Where A_z and A_x is the measure of machines and innovation in each sector[67].

$$Y_z = E_z \left[\int_0^{A_z} y_z(i)^\alpha di \right]^{\frac{1}{\alpha}} \quad \text{and} \quad Y_x = E_x \left[\int_0^{A_x} y_x(i)^\alpha di \right]^{\frac{1}{\alpha}} \tag{A.3}$$

Both textile producers sell in competitive markets and they maximize profits taking intermediate goods prices $p_z(i)$ and $p_x(i)$ as given. This gives the following demands functions for each intermediate good

$$y_z(i) = Y_z \left(\frac{A_z^{2\alpha - 1}}{p_z(i)} \right)^{\frac{1}{1-\alpha}} \quad \text{and} \quad y_x(i) = Y_x \left(\frac{A_x^{2\alpha - 1}}{p_x(i)} \right)^{\frac{1}{1-\alpha}} \tag{A.4}$$

and the following relative demand equation

$$\frac{y_z(i)}{y_z(j)} = \left(\frac{p_z(j)}{p_z(i)} \right)^{\frac{1}{1-\alpha}} \quad \text{and} \quad \frac{y_x(i)}{y_x(j)} = \left(\frac{p_x(j)}{p_x(i)} \right)^{\frac{1}{1-\alpha}} \tag{A.5}$$

The production function for each intermediate input is linear in the type of material employed ($y_z(i) = \frac{Z(i)}{\phi_z}$ and $y_x(i) = \frac{X(i)}{\phi_x}$. Where ϕ_z and ϕ_x measure the cost in terms of the material needed to produce the intermediate good. This production is subject to resource constraints $\int_0^{A_z} z(i)di \leq Z$ and $\int_0^{A_x} x(i)di \leq X$. The intermediate

[66] Y_f is the numeràire.

[67] Terms $E_z \equiv (A_z)^{\frac{2\alpha-1}{\alpha}}$ and $E_x \equiv (A_x)^{\frac{2\alpha-1}{\alpha}}$ are two externality terms that assures the existence of a balanced-growth path.

good sector is monopolistic since the producer owns a patent for this product. The monopolist face a demand curve with the constant price elasticity $1/1-\alpha$ and the optimal price in each sector is:

$$p_z(i) = \frac{w_z \phi_z}{\alpha} \quad \text{and} \quad p_x(i) = \frac{w_x \phi_x}{\alpha} \tag{A.6}$$

Where w_z and w_x is the price of each raw material Z and X. This implies that the profits of these firms is equal to a fraction $(1-\alpha)$ of the total sales

$$\pi_z(i) = (1-\alpha)\frac{p_z(i)z(i)}{\phi_z} \quad \text{and} \quad \pi_x(i) = (1-\alpha)\frac{p_x(i)x(i)}{\phi_x} \tag{A.7}$$

Using the market clearing conditions on the raw materials I can write the production function as $Y_z = \dfrac{A_z Z}{\phi_z}$ and $Y_x = \dfrac{A_x X}{\phi_x}$. Using these equations in the relative demand function (A.2) I found the relative price function equation

$$p \equiv \frac{P_z}{P_x} = \left(\frac{A_z Z}{A_x X}\frac{\phi_x}{\phi_z}\right)^{-\frac{1}{\epsilon^{z,x}}} \tag{A.8}$$

Using (A.4) I can rewrite intermediate prices as $P_z A_z = p_z(i)$ and $P_x A_x = p_x(i)$ and the relative profits of monopolistic in each sector as

$$\frac{\pi_z(i)}{\pi_x(i)} = \frac{p_z(i)z(i)}{p_x(i)x(i)}\frac{\phi_x}{\phi_z} = \left(\frac{A_x}{A_z}\right)^{\frac{1}{\epsilon^{z,x}}}\left(\frac{\phi_x Z}{\phi_z X}\right)^{\frac{\epsilon^{z,x}-1}{\epsilon^{z,x}}} \tag{A.9}$$

Using this same condition I can write the raw materials prices ratio as

$$\omega \equiv \frac{w_z}{w_x} = \left(\frac{A_z}{A_x}\frac{\phi_x}{\phi_z}\right)^{1-\frac{1}{\epsilon^{z,x}}}\left(\frac{Z}{X}\right)^{-\frac{1}{\epsilon^{z,x}}} \tag{A.10}$$

A.1.2. *Endogenous technological change.* Introduction of new machines has a fixed cost μ as units of the numeràre. Each innovator decide between designing machines for one of the two sector. Patents are infinitely lived and therefor at the balanced growth path the discounted value in each sector (V_z and V_x) of the profit stream cannot exceed the innovation cost. This implies that innovators are indifferent between the two technologies. That is $V_z = V_x = \mu$ or $\frac{\pi_z}{\pi_x} = 1$. Using this condition jointly with A.9 I find the the technology direction that is compatible with balanced growth.

$$\frac{A_z}{A_x} = \left(\frac{\phi_x Z}{\phi_z X}\right)^{\epsilon^{z,x}-1} \tag{A.11}$$

Also on balanced growth the textiles price ratio and and the endowments payment ratio can be written as

$$p^{**} = \left(\frac{\phi_x Z}{\phi_z X}\right)^{-1} \quad \text{and} \quad \omega^{**} = \left(\frac{\phi_x}{\phi_z}\right)^{\epsilon^{z,x}-1} \left(\frac{Z}{X}\right)^{\epsilon^{z,x}-2} \tag{A.12}$$

A.1.3. *Market Integration.* In this section now I develop the effect of market integration. Now consider Spain with endowments Z^S and X^S get integrated with its colonies that have endowment Z^C and X^C. The endowments of materials in the market are defined as the sum of both the metropolis and the colonies endowments (i.e. $Z^I = Z^S + Z^C$ and $X^I = X^S + X^C$.). Then the relative price equation (A.8) from the integrated market is

$$p^I \equiv \frac{P_z}{P_x} = \left(\frac{A_z(Z^S + Z^C)}{A_x(X^S + X^C)} \frac{\phi_x}{\phi_z}\right)^{-\frac{1}{\epsilon^{z,x}}} = \lambda^{1/\epsilon^{z,x}} p \tag{A.13}$$

Colonies copy technology from the metropolis without any differential cost. Adjusting technology equation (A.9) becomes

$$\frac{A_z^I}{A_x^I} = \left(\frac{\phi_x Z}{\phi_z X}\right)^{\epsilon^{z,x}-1} \lambda \tag{A.14}$$

Where $\lambda \equiv \dfrac{1 + X^C/X^S}{1 + Z^C/Z^S}$. If I assume that cotton is relative more abundant in Spain compare with its colonies (i.e. $\frac{Z^S}{X^S} > \frac{Z^C}{X^C}$) then $\lambda > 1$. Or what is the same a market integration produce an increase on innovation on the relative more abundant product (i.e. cotton). Also when technology is allowed to adjust the price ratio becomes equal to the levels before the market integration

$$p^{I**} = \left(\frac{\phi_x Z}{\phi_z X}\right)^{-1} = p^{**} \tag{A.15}$$

A.1.4. *Change on textile prices.* Coefficients γ_k^F in equation 7.1 identify the relative change between other fibers and cotton (p) before and after the integration, that is $\ln(p^I/p^{**})$ that can be expressed as:

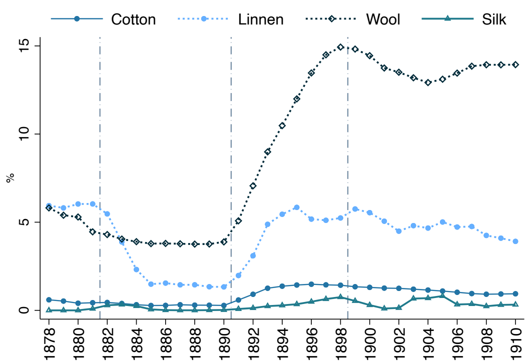
$$\ln\left(\frac{p^I}{p^{**}}\right) = \frac{1}{\epsilon^{z,x}} \ln \lambda \tag{A.16}$$

finally the increase on the technology after the market integration can be expressed as

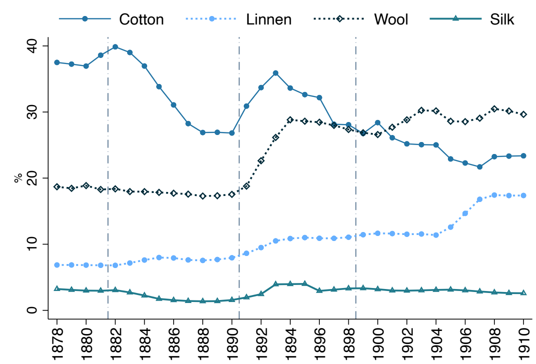
$$\frac{A_z^I/A_x^I}{A_z/A_x} = \lambda \tag{A.17}$$

Appendix B. Figures

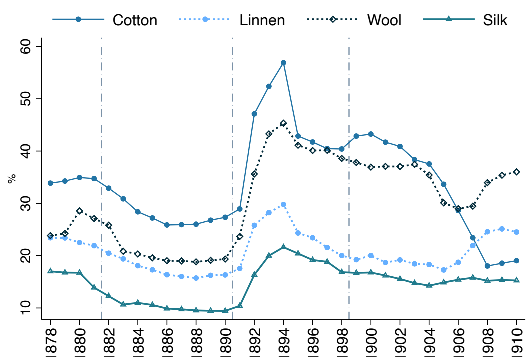
Figure B.1. **Textile tariffs (other products)**



A Raw materials



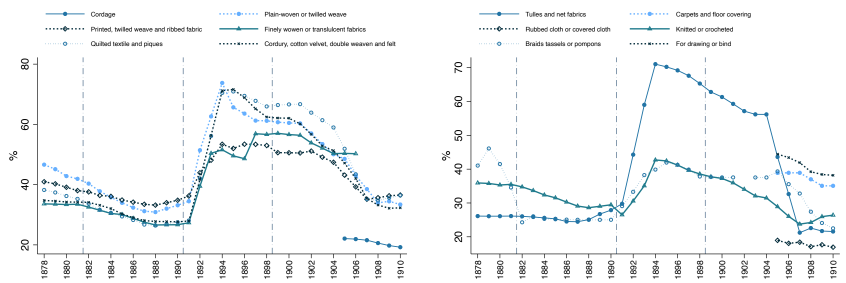
B Threads



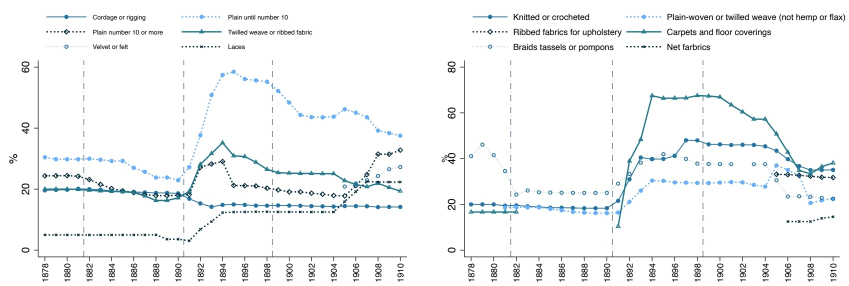
C Embroidered

Source: Dirección General de Aduanas (1876-1898, 1899-1911)
Notes: The tariff is the ratio of total tariff revenues to the total import value. Panel A of the figure presents tariffs for shows the protection of the raw materials, including different categories of intermediate partialized processed materials. Panel B displays tariffs for threads, including different quality types. Panel C displays tariffs for embroidered (or with metal threads) fabrics. The figure displays the one-year moving average of the raw numbers.

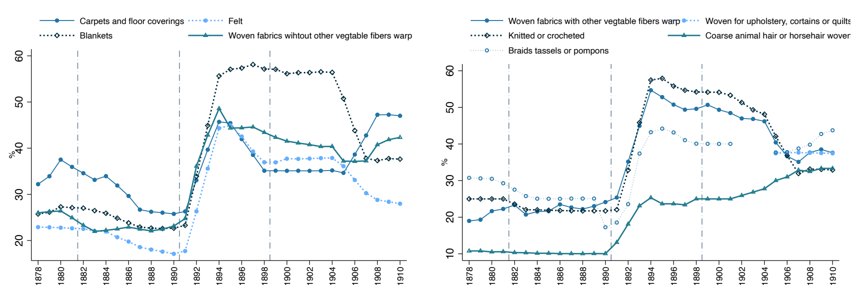
FIGURE B.2. **Textile tariffs (fabrics categories)**



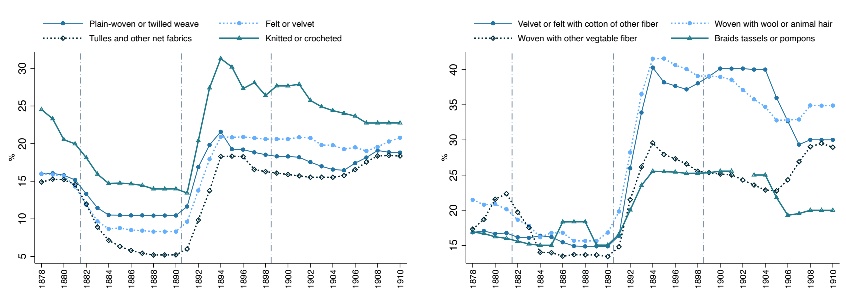
A. Cotton



B. Vegetable fibres



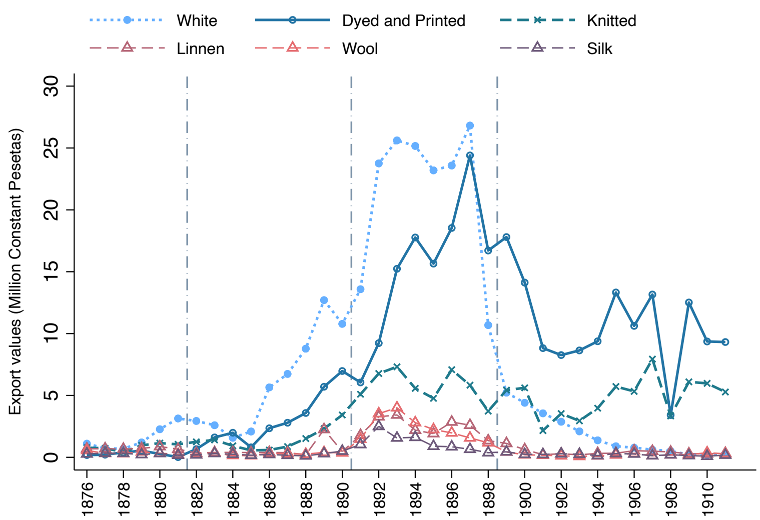
C. Wool



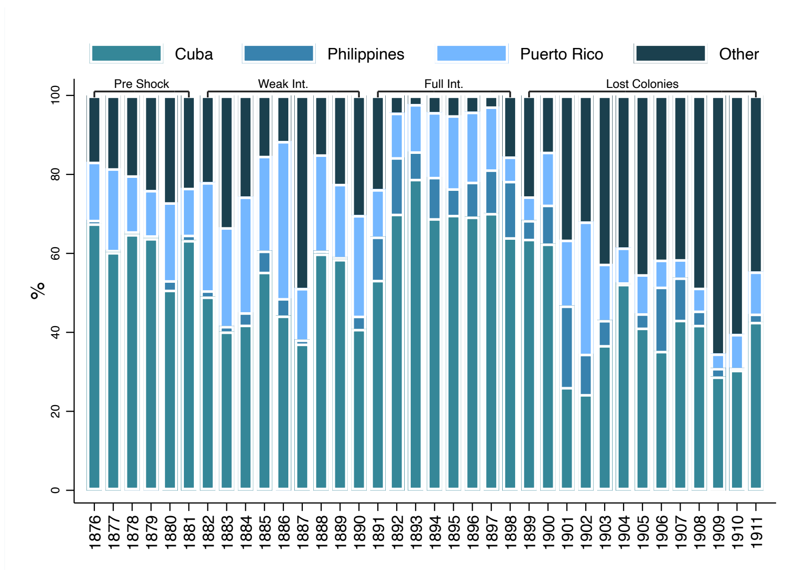
D. Silk

Source: Dirección General de Aduanas (1876-1898, 1899-1911)
Notes: The tariff is the ratio of total tariff revenues to the total import value. The figure displays the one-year moving average of the raw numbers.

Figure B.3. **Textiles exports to colonies**



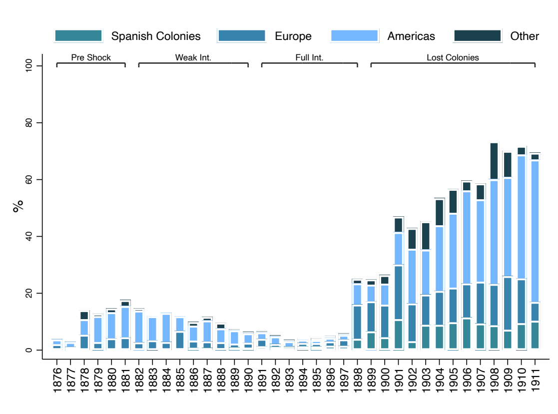
A Textile trade value to colonies



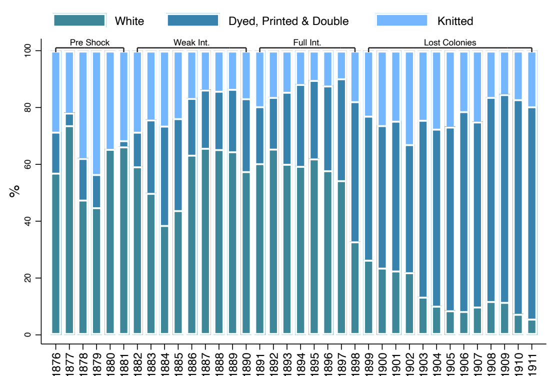
B Linen exports by destination

Source: Same as table 1
Notes: This graph presents data on textiles imports to colonies and the share of colonial markets in total linen exports. Panel A displays the value of imports by type of material using constant pesetas. I categorized cotton fabrics into three different types to capture the quality differences among them, despite the limitations of this type of measure (Sudrià, 1983). Panel B illustrates the share of colonial markets in the total linen exports.

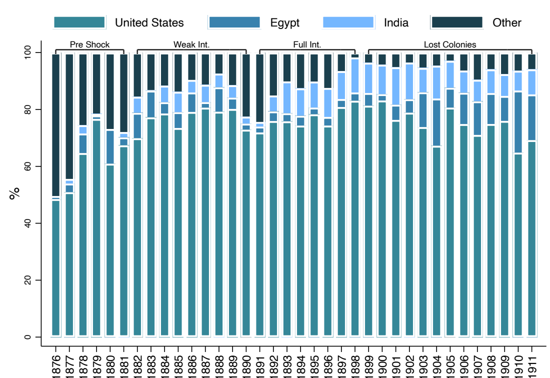
FIGURE B.4. **Cotton textiles exports and imports**



A Cotton textile by destination (Others)



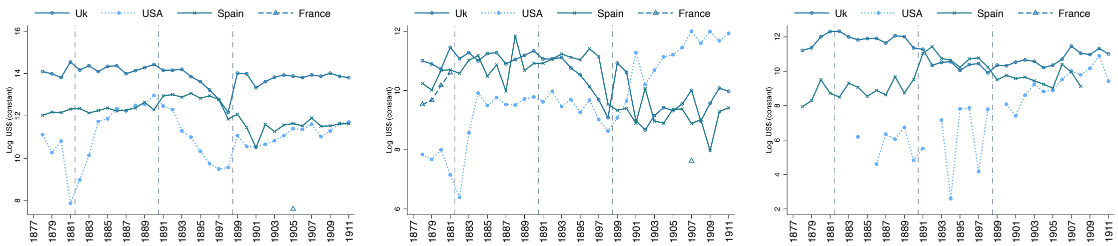
B Cotton textile exports by type



C Raw cotton imports by origin

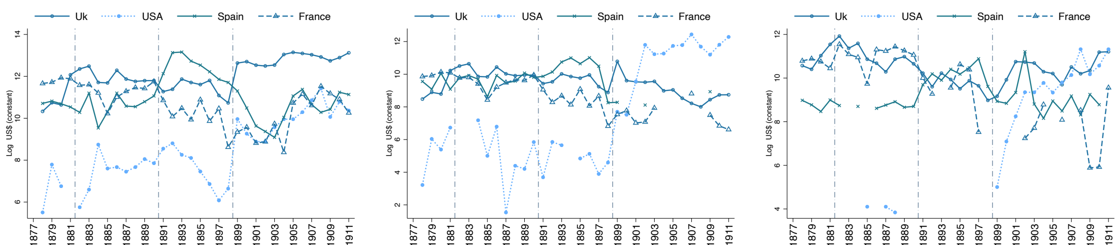
Sources: Same as table 1
Notes: This graph displays the breakdown of cotton textile destinations in Panel A, categorized into four groups based on country location: American republics, Europe, other Spanish colonies, and other regions. In Panel B, I show the distribution of exports based on the textile type, using the Spanish authorities' categorization system. Finally, Panel C presents the shares of raw cotton by country of origin.

FIGURE B.5. **Colonial imports of textile manufactures**



A Cuba **B** Puerto Rico **C** Philippines

A. Vegetable fibres



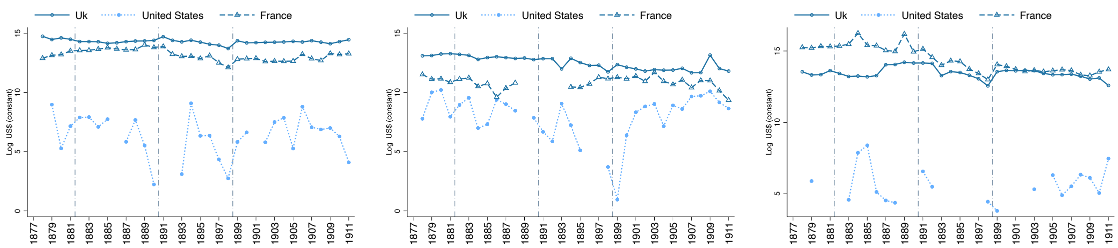
D Cuba **E** Puerto Rico **F** Philippines

B. Wool

Source: Same as figure 1 and Chief of the bureau of stadistics (1878-1911); London, H.M. Stationery Office. (1878-1911); Direction Général des douanes (1878-1896, 1897-1911)

Notes: This figure shows the evolution of the total value of vegetable fibres and wool manufacturing imports in each of the three main Spanish colonies. The total value is expressed in logarithms of constant dollars of 1878. I exchange rates in Federico and Tena Junguito (2018a) to convert values to US dollars. The original sources provided data in pounds for the United Kingdom, francs for France and pesetas for Spain. Before 1898 United Kingdom and France provided only aggregated trade statistics with Cuba and Puerto Rico (*Spanish Western Indies*). I used the share of trade between these two countries in 1898 and 1899 to assign the corresponding value to Cuba and Puerto Rico before the independence.

FIGURE B.6. **Spain imports of textile manufactures**

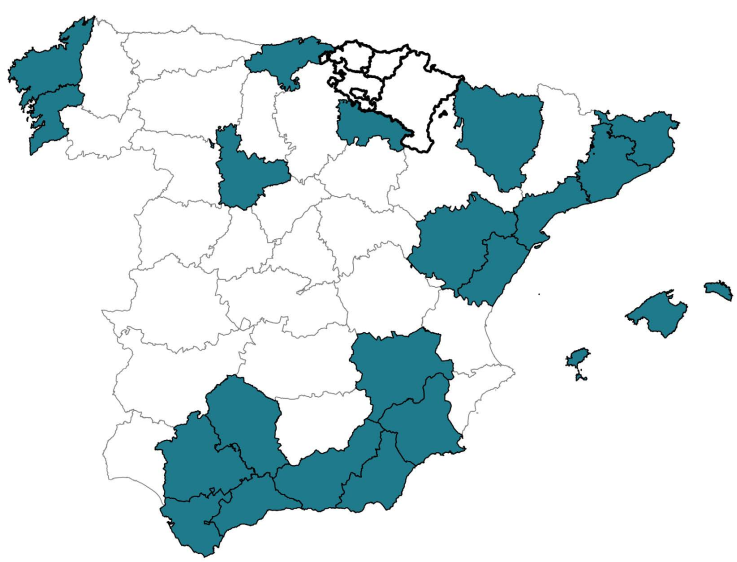


A Cotton **B** Linen **C** Wool

Source: Chief of the bureau of stadistics (1878-1911); London, H.M. Stationery Office. (1878-1911); Direction Général des douanes (1878-1896, 1897-1911); **?**

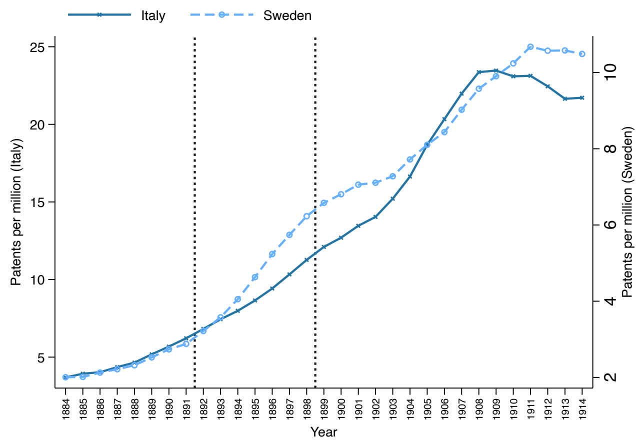
Notes: This figure shows the evolution of the total value of textile manufacturing imports in Spanish. The total value is expressed in logarithms of constant dollars of 1878. I exchange rates in Federico and Tena Junguito (2018a) to convert values to US dollars. The original sources provided data in pounds for the United Kingdom, francs for France and pesetas for Spain. Trade includes both movements towards Spain and the Canary Islands.

FIGURE B.7. **Cotton textile industry location 1879**



Notes: The map illustrates the distribution of the cotton industry in 1879 based on the presence of spindles or looms. The thick lines represent the provinces in the Basque Country and Navarra for which no information is available. The Canary Islands are excluded from the map.

FIGURE B.8. **International textile patents**



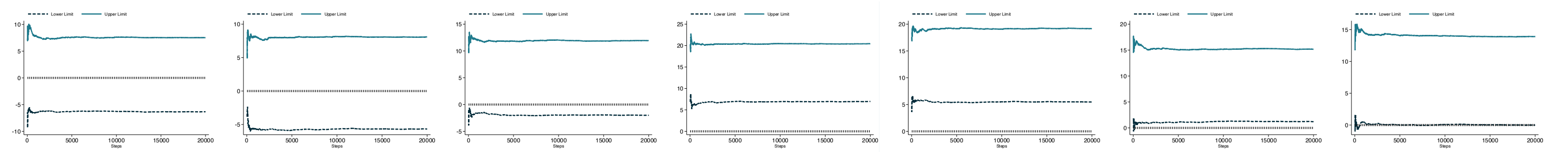
Notes: The graph displays the estimated textile patents for Italy and Sweden from 1850 to 1950. The data is based on historical patent data provided by Database (2015). The number of textile patents for each country is assessed based on the shares reported in Nuvolari and Vasta (2015) for Italy and Andersson, Karadja, and Prawitz (2022) for Sweden.

FIGURE B.9. **Textile patents word cloud**

Notes: The world cloud shows the two hundred fifty most frequent words used on Spanish textiles patents between 1878-1911. Font size of the word is proportional to its frequency in the description of the patent.

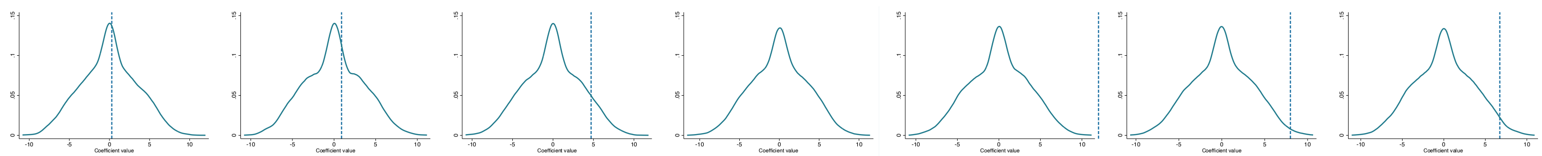
FIGURE B.10. **Randomization Inference Event Study**

Panel A: Lower and Upper Bounds Confidence Interval Convergence



a) Cotton x 1883-1886 **b)** Cotton x 1887-1890 **c)** Cotton x 1891-1894 **d)** Cotton x 1895-1898 **e)** Cotton x 1899-1902 **f)** Cotton x 1903-1906 **g)** Cotton x 1907-1910

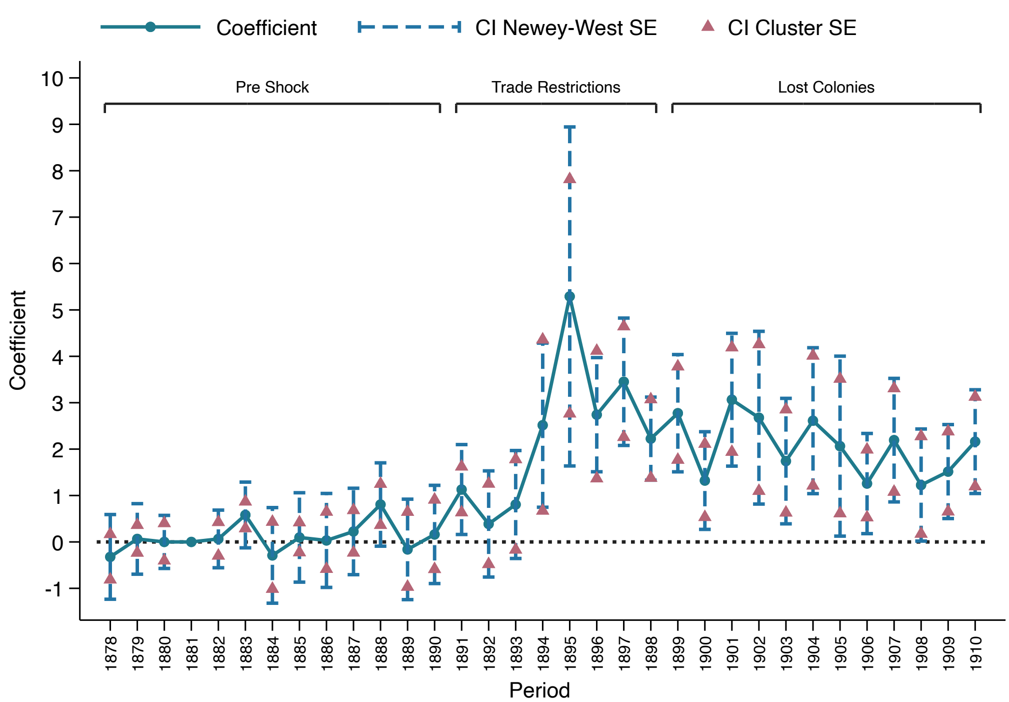
Panel B: Placebo Coefficients Distribution



a) Cotton x 1883-1886 **b)** Cotton x 1887-1890 **c)** Cotton x 1891-1894 **d)** Cotton x 1895-1898 **e)** Cotton x 1899-1902 **f)** Cotton x 1903-1906 **g)** Cotton x 1907-1910

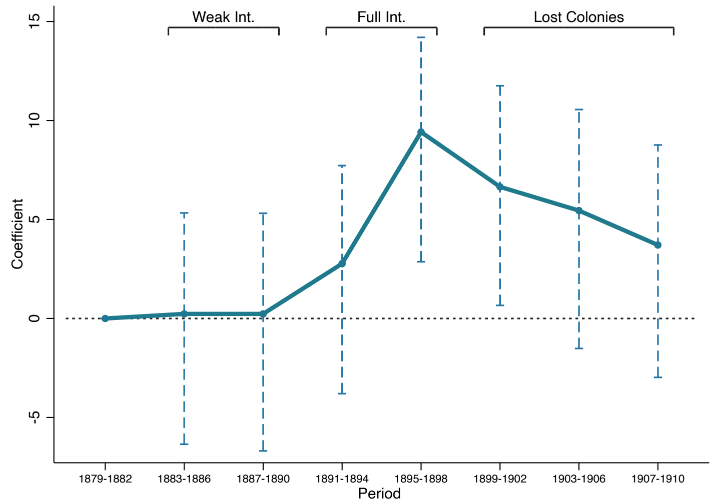
Notes: Panel A shows the convergence path of confidence interval lower and upper bounds presented in Figure **??** using the algorithm proposed by Garthwaite (1996). The convergence is based on 20,000 randomization allocations. Panel B shows the distribution of placebo coefficients and the position of the coefficient presented in Figure **??**. To estimate the placebo coefficients, I used 10,000 randomization allocations.

FIGURE B.11. **Event study: Effect market integration on cotton patents using yearly panel**



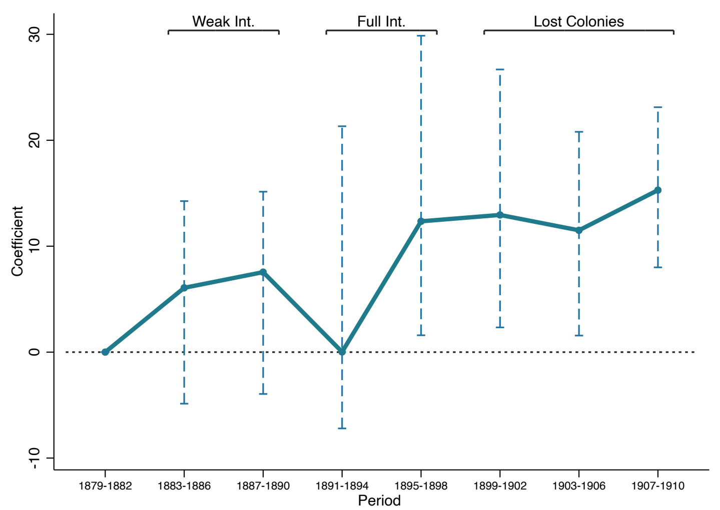
Notes: This figure displays the coefficients β_k obtained , along with their corresponding 95% confidence intervals. Yearly panel form 1878-1911 estimation of Difference-in-Difference model including differential technology group trends. 95% Confidence Intervals using Newey–West standard error with a lag length of 3, based on Greene's rule-of-thumb lag length of $T^{1/4}$ rounded upwards. Double cluster standard errors at group and year.

FIGURE B.12. **Event study: Effect market integration on cotton patents using (Only Spanish residents)**



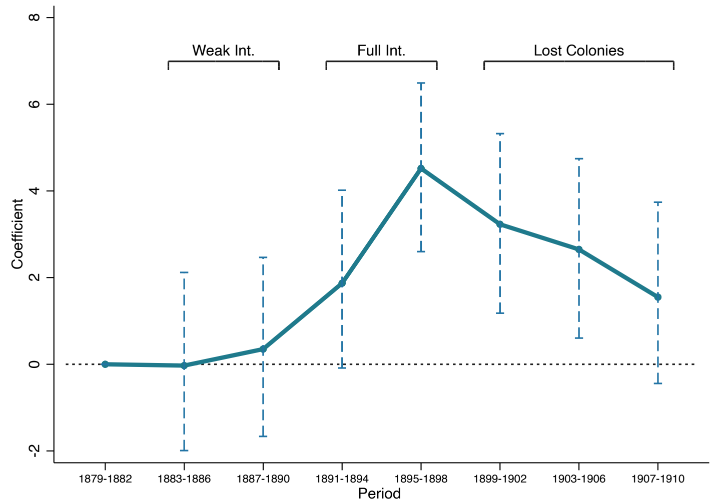
Notes: This figure displays the coefficients β_k obtained from regression 5.1, along with their corresponding 95% confidence intervals using only Spanish resident's patents. The inference is based on a randomized approach following the algorithm proposed by Garthwaite (1996) using 20,000 randomization allocations. Total number of observations 496.

FIGURE B.13. **Event study: Effect market integration on cotton patents using (Controlling by Argentinean imports)**



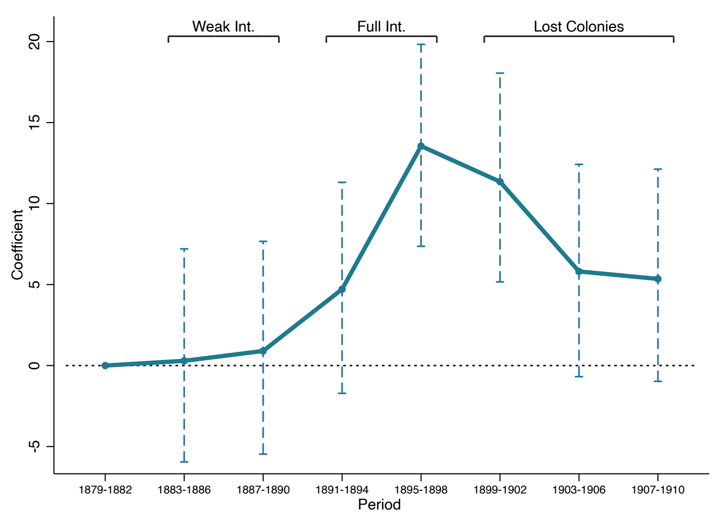
Notes: This figure displays the coefficients β_k obtained from regression 5.1, along with their corresponding 95% confidence intervals controlling by total Argentinian imports values. The inference is based on a randomized approach following the algorithm proposed by Garthwaite (1996) using 20,000 randomization allocations. Total number of observations 496.

FIGURE B.14. **Event study: Effect market integration on cotton patents using (High quality patents)**



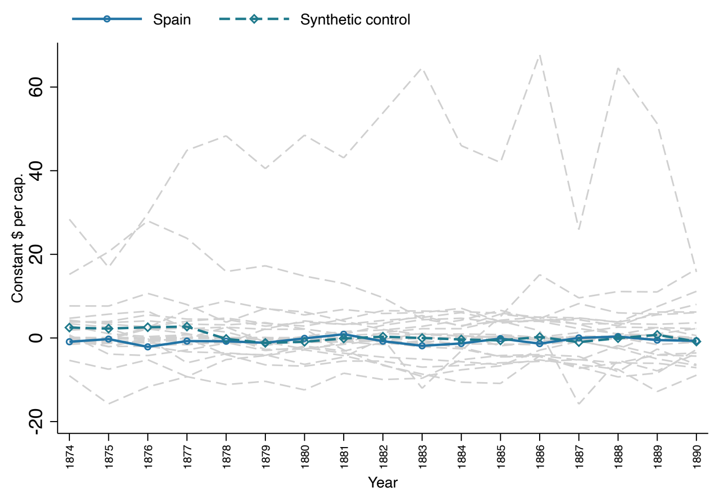
Notes: This figure displays the coefficients β_k obtained from regression 5.1, along with their corresponding 95% confidence intervals using only patents which have confirmation of being used during the first 2 years after the application. . The inference is based on a randomized approach following the algorithm proposed by Garthwaite (1996) using 20,000 randomization allocations. Total number of observations 496.

FIGURE B.15. **Event study: Effect market integration on cotton patents using (Innovation patents)**



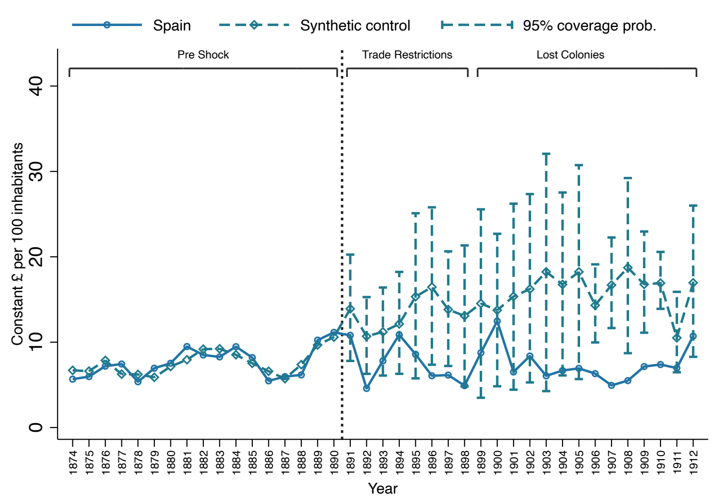
Notes: This figure displays the coefficients β_k obtained from regression 5.1, along with their corresponding 95% confidence intervals using only innovation patents. The inference is based on a randomized approach following the algorithm proposed by Garthwaite (1996) using 20,000 randomization allocations. Total number of observations 496.

FIGURE B.16. **Synthetic control analysis - Trade balance**



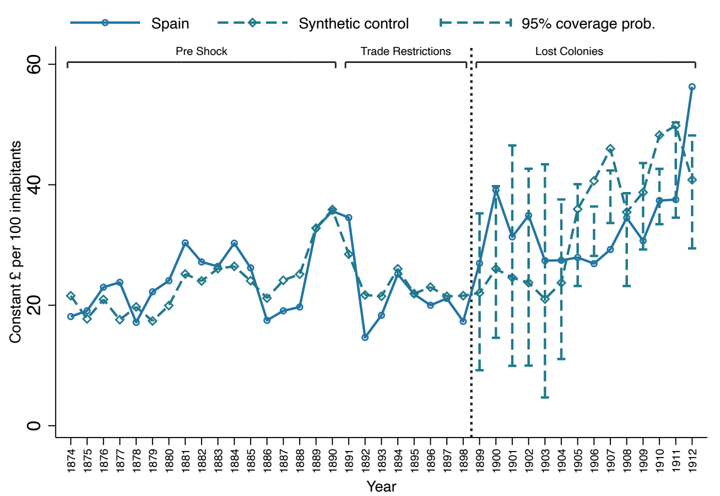
Notes: Data from Federico and Tena Junguito (2018b). This graph displays the pre-1891 time series of Spain's trade balance, estimated contrafactual Spain's trade balance, and the trade balances of the 27 countries included in the donor pool. The dashed lines represent the trade balances of the individual donor countries.

FIGURE B.17. **Synthetic control analysis - UK textile machinery exports to Spain**



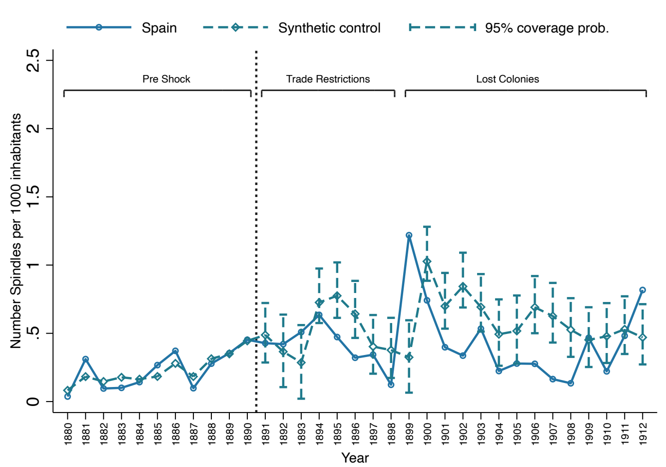
Notes: The graph illustrates the behavior of textile machinery exports from the United Kingdom to Spain, along with the estimated synthetic control unit constructed using a pool of 27 donor countries before 1891. The estimation of the synthetic control unit includes a 95% coverage probability that follows the methodology outlined by Cattaneo, Feng, and Titiunik (2021). Positive weights for the construction of synthetic Spain are France (34%), Egypt (18.8%), Argentina (18.7%), the United States (15%), Germany (9.5%), and Turkey (3.7%)

FIGURE B.18. **Synthetic control analysis - UK machinery exports to Spain placebo**



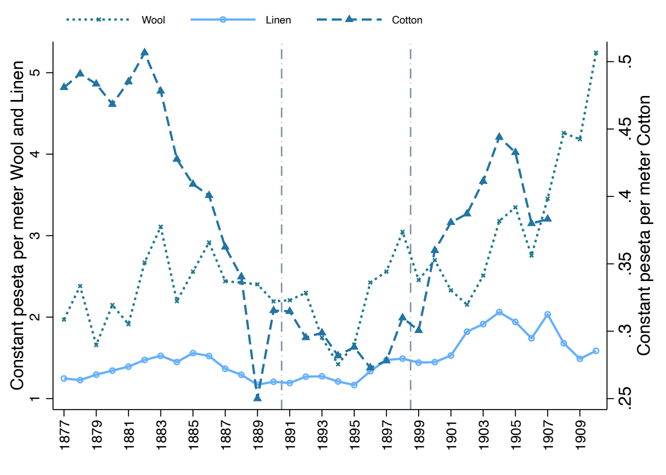
Notes: The graph illustrates the behavior of machinery exports from the United Kingdom to Spain, along with the estimated synthetic control unit constructed using a pool of 27 donor countries before 1898. The estimation of the synthetic control unit includes a 95% coverage probability that follows the methodology outlined by Cattaneo, Feng, and Titiunik (2021). Positive weights for the construction of synthetic Spain are China (61.72%), France (33%), Uruguay (3.9%) and Egypt (1.3%).

FIGURE B.19. **Synthetic control analysis - UK spinning machinery orders from Spain**



Notes: Data from Wright (2011). The graph illustrates the behavior of spinning machinery ordered from the United Kingdom to Spain, along with the estimated synthetic control unit constructed using a pool of 27 donor countries before 1891. The estimation of the synthetic control unit includes a 95% coverage probability that follows the methodology outlined by Cattaneo, Feng, and Titiunik (2021). Positive weights for the construction of synthetic Spain are France (56.1%), the United States (25.7%), Italy (13.3%), and Holland (4.8%).

Figure B.20. **Cotton, wool and linen prices**



Notes: This graph shows prices series for cotton, linen and wool finished fabric. Cotton price correspond to *Percalina superior lisa* found on inventory ledgers of *La España Industrial.* Wool and linen prices correspond to English export prices to Spain gathered by Nadal Ferreras (1978) in pounds and converted to pesetas using historical series provided by Federico and Tena Junguito (2018a). All prices measured in constant pesetas per meter.

Appendix C. Tables

Table C.1. textile patent technology classification: 1879-1911

Category	No Cotton	Cotton
Preparation and Spinning		
Mechanical treatment of natural fibrous or filamentous material to obtain fibres or filaments	110	87
Chemical or biological treatment of natural filamentous or fibrous material to obtain filaments or fibres for spinning	46	28
Mechanical methods or apparatus in the manufacture of man-made filaments, threads, fibres, bristles or ribbons	20	21
Chemical features in the manufacture of man-made filaments, threads, fibres, bristles, or ribbons	12	11
Preliminary treatment of fibres	25	96
Spinning or twisting	38	146
Crimping or durling fibres, filaments, yarns or threads, yarns or threads	14	28
Warping, beaming or leasing	6	28
Finishing or dressing of filaments, yarns, threads, cords, ropes or the like	8	40
Weave		
Shedding mechanism; patterns cards or chains; punching of cards; designing patterns	21	98
Woven fabrics; methods of weaving; looms	184	836
Auxiliary weaving apparatus; wavers tools; shittles	5	106
Knitting	11	82
Textile and Finishing		
Braiding or manufacture of lace, including bobbon-net or carbonised lace; breading machine; braid; lace	35	64
Trimming; ribbons, tapes or bands	13	34
Making nets by knotting of filamentous material; making knotted carpets or tapestries	15	10
Making textile fabrics from filamentous material; non-woven fabrics; wadding	53	172
Sewing	16	147
Embroidering	8	58
Treating textile materials using liquids, gases or vapours	16	76
Finishing, dressing, tendering or stretching textile fabrics	17	66
Laundering, drying, ironing, pressing or folding textile articles	14	127
Mechanical or pressuring cleaning of carpets, rugs, sacks, hides or other skin or textile articles or fabrics	6	10
Marking, inspecting, seaming or severing textile materials	6	34
Pleating, kilting or goffering textile fabrics or wearing apparel	2	12
Dry-cleaning, washing or bleaching fibres, filaments, threads, yarns, fabrics. Bleaching leather or furs	18	60
Treatment, not provided for elsewhere in class	26	71
Wall, floor or like covering materials	28	3
Dying of printing textiles; dyeing leather, furs or solid macromolecular substances	39	219
Decorating textiles	12	53
Ropes or cables in general	16	26

Notes: List of all patent categories with at least one patent between 1878-1911.

TABLE C.2. Sample cotton textile patents

Year	Description	Category	Type	Loc.
1880	A tracing machine applicable to mechanical looms to give movement to several wraps	Woven fabrics; methods of weaving; looms	In	S
1882	A mechanical ironing procedure by means of the devices described	Laundering, drying, ironing, pressing or folding textile articles	In	S
1890	A procedure for machine combing cotton blankets.	Preliminary treatment of fibres	In	S
1891	A mechanical procedure to cut corduroy fabrics of any gender	Marking, inspecting, seaming or severing textile materials	In	S
1892	Improvements introduced in the mechanism to move the whole apparatus of the shuttles	Auxiliary weaving apparatus; wavers tools; shuttles	In	S
1892	A loom for weaving with continuous weft feeding by automatic placement of the shuttle.	Woven fabrics; methods of weaving; looms	It	O
1896	An improved procedure for sizing and conditioning of fabrics	Finishing, dressing, tendering or stretching textile fabrics	It	S
1897	Modifications introduced in the *Jacquard* looms devices	Woven fabrics; methods of weaving; looms	It	S
1900	Improvements or refinements introduced in the machines that serve to mercerise, degrease, bleach, dye, wash, glue or paste or treat in a similar way textile materials in the form of skeins.	Dry-cleaning, washing or bleaching fibers, filaments, threads, yarns, fabrics. Bleaching leather or furs	In	O
1902	The mechanical operation of embroidering *toquillas* knitted cotton wrap and other knitted items	Sewing	In	S
1903	A loom for weaving with continuous weft feeding by automatic placement of the shuttle.	Woven fabrics; methods of weaving; looms	It	O
1904	Improvements in the rings and other equivalents of ring spinning and twisting machines and the similar ones	Spinning or twisting	It	O
1905	A mechanical procedure for the production of hollow patterns on knitted fabrics	Knitting	In	S
1910	Improvements introduced in chambers for the methodical drying of yarns, fabrics or raw textile fibres, by flowing air	Treating textile materials using liquids, gases or vapours	In	S

Notes: Sample of textile patents in different years and for different category technologies between 1878-1911. It = Introduction, In = Innovation, Sp = Spain, O = Outside Spain.

TABLE C.3. World count: most frequent terms

Word (Spanish)	Word (English)	Freq
procedimiento	procedure	1634
tejido	weave	1001
fabricación	manufacturing	741
máquina	machine	728
industria(l)	industry (industrial)	519
algodón	cotton	488
telar	loom	463
hilo	thread	435
mejora	improvement	368
producto	product	347
aparato	apparatus	343
mecánico	mechanical	299
fibra	fibre	294
nuevo	new	286
lana	wool	281
textil	textile	273
punto	knitting	264
seda	silk	263
materia(l)	material	256
clase	class	255
perfeccionamiento	perfecting	252
toda	whole	227
tela	fabric	205
color	color	187
fabricar	manufacture	169
dibujo	draw	163
medio	means	156
pana	corduroy	151
género	gender	150
sistema	system	146
lanzadera	shuttle	132
coser	sew	132
trama	weft	124
mecanismo	mechanism	121
urdimbr	warp	112
hilar	to spin	109
dos	two	107
hacer	to do	105
teñir	to dye	104
mezcla	mix	102

Notes: The table shows the first 40 most frequent words in the textile patents from 1878 to 1911.

Table C.4. Word Correlations with current machines improvements

Procedimiento *Procedure*		Mejora *Improvement*		Perfeccionamiento *Perfecting*	
Word	Corr	Word	Corr	Word	Corr
fabricación *manufacturing*	0.35	introducida *introduced*	0.22	introducido *introduced*	0.60
tejido *weave*	0.17	máquina *machine*	0.19	telar *loom*	0.16
fabricar *manufacture*	0.15	coser *to sew*	0.17	cajon *drawer*	0.12
químico *chemical*	0.14	maquinaria *machinery*	0.12	espada *sword*	0.12
mecánico *mechanical*	0.14	extend(er) *extended*	0.12	mover *to move*	0.11
algodón *cotton*	0.13	material *material*	0.10	llevado *carried*	0.11
medio *means*	0.11	fino *fine*	0.10	realizado *performed*	0.11
seda *silk*	0.10	hilar *to spin*	0.09	máquina *machine*	0.10
estampación *printing*	0.10	telar *loom*	0.09	encolar *to paste*	0.09
blaqueo *bleaching*	0.10	tejer *to weave*	0.09	tundidora *shearing mach.*	0.09

Notes: This table presents the mean and standard errors of provinces without (column 1) and with (column 2) cotton machines in 1879. Column 3 reports the differences between these two groups, and the corresponding p-value is shown in square brackets.

Table C.5. Descriptive statistics province by cotton industry presence

	No cotton presence (1)	Cotton presence (2)	Difference (3)
Log population	12.638	12.768	0.129
	(0.419)	(0.392)	[0.298]
Share of men	0.493	0.488	-0.005
	(0.014)	(0.021)	[0.349]
Share of regular residents	0.963	0.965	0.002
	(0.039)	(0.044)	[0.883]
Share of single	0.535	0.541	0.006
	(0.029)	(0.025)	[0.490]
Share of married	0.400	0.390	-0.010
	(0.031)	(0.029)	[0.253]
Share of literate	0.272	0.195	-0.077
	(0.113)	(0.095)	[0.019]
Share of catholics	0.999	0.998	-0.002
	(0.001)	(0.006)	[0.203]
Share born in the same province	0.933	0.925	-0.008
	(0.088)	(0.056)	[0.716]
Share of regular residents in the same municipality	0.970	0.956	-0.014
	(0.017)	(0.085)	[0.475]

Notes: Column 1 reports mean and standard errors for province without cotton machines in 1879. Column 2 reports mean and standard errors for province with cotton machines in 1879. Column 3 reports differences between province with and without presence of cotton machines. p-value in square brakets.

TABLE C.6. Cross sectional dependence and serial correlation tests Difference-and-difference Model

	Yearly Model (1)		*4 Years Model* (2)	
	Panel A: Cross sectional dependance			
Pesaran CD-test	7.881		14.419	
	[0.000]		[0.000]	
	Panel B: Serial Correlation			
	AR(1)	AR(2)	AR(1)	AR(2)
Q-stat	5.469	5.488	1.610	4.238
	[0.019]	[0.064]	[0.204]	[0.120]
LM-stat			15.915	26.387
			[0.026]	[0.015]

Notes: This table presents the test for cross sectional dependence (Panel A) and serial correlation (Panel B) for difference-and-difference models errors. Panel A null hypothesis is cross section independence against alternative hypothesis of correlation among panel groups. Panel B null hypothesis is not serial correlation against the alternative hypothesis of serial correlation up to order 1 or 2. Q-stat is Born and Breitung (2016) biased corrected test. LM is portmanteau test for serial correlation developed by Inoue and Solon (2006). This test is designed for panels with small number of period observations (T), as in the case of 4 year panel. With moderate number of periods the test is not adequate since its dimension increases with the number of periods. Therefore the test is not suitable in the yearly panel. P-values in double brackets.

TABLE C.7. Response of cotton industry to colonial markets capture

Cotton x ...	Dependent Variable: Variable per 10.000 Inhabitants					
	Mechanical Spindles		Mechanical Loom		Mechanical Raising	Mechanical Shearing
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Machines						
... x Trade Restrictions	−0.21	2.03	2.81	−12.29*	−0.02	0.03
	(1.86)	(2.96)	(7.34)	(7.08)	(0.05)	(0.02)
	[0.670]	[0.650]	[0.110]	[0.100]	[0.400]	[0.010]
	[[0.347]]	[[0.212]]	[[0.006]]	[[0.612]]	[[0.511]]	[[0.542]]
... x Early colonies lost	−0.30	1.92	3.21	−11.41	0.00	0.04
	(1.97)	(3.23)	(7.31)	(7.05)	(0.02)	(0.02)
	[0.670]	[0.790]	[0.050]	[0.070]	[0.980]	[0.000]
	[[0.277]]	[[0.164]]	[[0.001]]	[[0.147]]	[[0.176]]	[[0.923]]
... x Late colonies lost	0.93	4.39	3.35	−11.10	0.02	0.04*
	(1.80)	(2.80)	(7.31)	(7.05)	(0.02)	(0.02)
	[0.390]	[0.460]	[0.050]	[0.070]	[0.330]	[0.000]
	[[0.184]]	[[0.076]]	[[0.001]]	[[0.170]]	[[0.108]]	[[0.276]]
Panel B: Firms						
... x Trade Restrictions	0.07	0.05	0.08	0.04	0.02	0.03
	(0.08)	(0.09)	(0.05)	(0.03)	(0.05)	(0.07)
	[0.060]	[0.130]	[0.090]	[0.100]	[0.280]	[0.160]
	[[0.347]]	[[0.587]]	[[0.093]]	[[0.170]]	[[0.650]]	[[0.682]]
... x Early colonies lost	0.08*	0.06	0.14**	0.10**	0.01	0.06
	(0.04)	(0.07)	(0.06)	(0.04)	(0.05)	(0.07)
	[0.030]	[0.070]	[0.000]	[0.000]	[0.550]	[0.020]
	[[0.151]]	[[0.371]]	[[0.006]]	[[0.032]]	[[0.366]]	[[0.867]]
... x Late colonies lost	0.07*	0.06	0.14**	0.09*	0.02	0.05
	(0.04)	(0.07)	(0.06)	(0.05)	(0.05)	(0.07)
	[0.060]	[0.140]	[0.000]	[0.000]	[0.200]	[0.040]
	[[0.164]]	[[0.358]]	[[0.011]]	[[0.082]]	[[0.429]]	[[0.698]]
Observations	1716	1144	1716	1144	1144	1144
Material fixed effects	✓	✓	✓	✓	✓	✓
Time x Province fixed effects	✓	✓	✓	✓	✓	✓
Comparison Cotton vs.	W and L	W	W and L	W	W	W

Notes: W stands for wool and L for linen and hemp. Columns 1 and 3 compare the cotton industry with wool and linen (hemp) industry and columns 2, 4, 5 and 6 compare the cotton industry only with the wool industry. Comparison period 1979. P-values from a randomized test using 1000 allocation in squared brackets. P-values from a test based on HC2 standard errors tested against a t-distribution are in double squared brackets. I follow the correction proposed by Imbens and Kolesár (2016). Standard errors in parentheses are clustered on province-year level. * is significant at the 10% level, ** is significant at the 5% level, *** is significant at the 1% level.