Quality, Technology, and Dexterity. Female Silk-Spinning Manufacture in Barcelona at the End of the Old Regime

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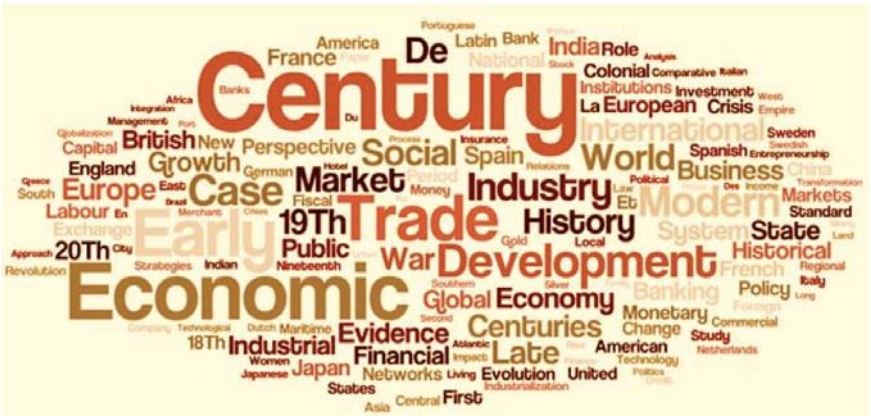

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ABSTRACT

This article analyses the Female Silk Spinning Apprenticeship School of the Barcelona Board of Trade (1784-1792) to explore the intersections between technological change, spinners' dexterity, and yarn quality. Dexterity was crucial for performing high-quality silk spinning, but the piece-rate remuneration system incentivised spinners to work as fast as possible, thereby downgrading the quality. In the prelude to the Industrial Revolution, the shift from hand spinning to mechanised spinning was a gradual process of technological innovation in which silk yarn's quality depended on technology, spinners' dexterity and the interaction with the institutional framework that either encouraged yarn quality through daily wages or discouraged it through piece-rates.

Keywords: female silk-spinning apprenticeship, spinners dexterity, silk-spinning quality, technological diffusion, Piedmontese reeling machine, Vaucanson reeling machine, Royal Barcelona Board of Trade.

JEL codes: N13 Economic History. Industrial Structure. Pre-1913 Europe; **N83** Micro-Business History. Pre-1913 Europe; **L11** Production, Pricing, and Market Structure; **L22** Firm Organisation and Market Structure; **O14** Technological Change. Industrialisation; **O33** Technological Change: Choices and Consequences.

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INTRODUCTION

This article focuses on the intersections between technology, productivity, profitability, spinners' dexterity, silk-spinning quality, and labour remuneration to expand the standard definition of technological change in the prelude to the Industrial Revolution. For this purpose, the research relies on the case of the adoption of the Piedmontese reeling machine for silk spinning in Barcelona at the end of the Old Regime through the Female Silk Spinning Apprenticeship School of the Barcelona Board of Trade (1784-1792). This case study shows that the history of technological change in the spinning phase of silk manufacture was indissolubly linked to the role of women. In this specific case, women played a crucial role both in the transfer of technological innovation itself and in the transfer of the proper functioning of said technology – meaning the correct handling and classification of cocoons, as well as the proper interaction of the spinner with the reeling machine to provide high silk-spinning quality. Women were, therefore, the active subjects of the process initiating technological change in the spinning phase of the silk textile industry. This is due to the fact that the spinning was mainly carried out by women operating in the putting-out system outside the guild organization.

This research aligns with recent studies by Hutková (2017) on the transfer of the Piedmontese reeling machine by the English East India Company to Bengal, and by Bertucci (2021) on the transfer of the Piedmontese reeling machine by the British Empire to its colony of Georgia in America. The diffusion of the new technology required spinners' "embodied expertise", a term coined by Bertucci (2021), referring to gradually acquired practical intelligence that produced high-quality spun silk through interaction with the reeling machine. Therefore, "embodied expertise" must be considered in the history of technological transfer. Recognizing the contribution of women will help deepen our understanding of the technological change that led to the Industrial Revolution.

1. THE FORMATIVE ROLE OF THE ROYAL BARCELONA BOARD OF TRADE

During the 17th and 18th centuries, most European governments established institutions to promote commercial activities abroad such as the *Bureau de commerce* in France in 1722 and the Board of Trade in England in 1696. Their implementation was closely linked to Early Modern mercantilist policies, which supported state intervention in the domestic economy to stimulate trade and encourage proto-industry to produce manufactures for export to foreign markets (Molas Ribalta 1996).

In the case of Spain, the Crown of Castile established the Royal General Board of Trade (*Real Junta General de Comercio*) in 1679, which adopted several measures to promote trade and

manufactures, namely the reduction of taxes for merchants and manufacturers, the recruitment of experts from other European centres to teach new techniques to artisans, and the establishment of trade superintendents and local boards in places such as Granada (1684) and Seville (1687) (Molas Ribalta 1978).

In the 18th century, the territories of the former Crown of Aragon also established local boards of trade to represent the interests of the merchant class, whose institutions had been abolished with the Decrees of the New Plant (*Decretos de Nueva Planta*) (1707-1716) to unify the Crown of Aragon and the Crown of Castile into the Kingdom of Spain. In 1758, Catalonia set up the Royal Barcelona Board of Trade (*Junta particular de comercio de Barcelona*) along with the Consulate and the Merchants' Registry to promote Catalan trade and industrial development. The Barcelona Board of Trade - as well as the local Boards of Trade in other territories of Spain - was a sub-delegation of the Royal General Board of Trade, which it had to notify of the most relevant issues and to whom it was accountable for revenues and investments (Carrera Pujal 1953, Ruiz i Pablo 1994).

According to the mercantilist logic of the time, the Royal Barcelona Board of Trade's aim was to intervene in the economy in order to develop manufacturing and stimulate trade.[1] For that purpose, the Barcelona Board had the authority to issue regulations and reform the guild ordinances that often opposed the guilds' interests (Ruiz i Pablo 1994, 105). However, intervention was not limited to regulation, and the Barcelona Board also promoted the adoption of new technologies as well as the training for the use of these technologies. Indeed, the Barcelona Board had a deep interest in developing formative activities: from the late 18th century to the mid-19th century, it promoted technical-professional training, scientific-technical training (chemistry applied to the arts; experimental physics; statistics, mathematics, arithmetic and practical geometry; machine engineering; technical drawing; botany and agriculture), education related to mercantile activity (commerce; shorthand; languages), and education on economic and legal-political activities (political economy and commercial law) (Carrera Pujal 1957, Monés i Pujol-Busquets 1987).

The Royal Barcelona Board of Trade established a female apprenticeship school for silk spinning in Barcelona city at the end of the 18th century (1784-1792). Scholars have briefly cited this initiative as an anecdotal example whose interest lies mainly in the fact that it was the only case of female training in the extensive formative activity of the Board of Trade (Ruiz i Pablo

[1] *"We must acknowledge that the arts will always flourish to a greater or lesser extent according to the attention and support that the government provides in protecting, promoting, and fostering their advancement by overcoming obstacles with prudent determination. It is not incomprehensibly arcane to learn the means that other governments use to achieve these important goals, because their strategies and measures are well known to everyone, and knowing also that when they observe some backwardness in any branch of industry, they try to remedy it immediately, because they look at this as a dangerous disease that leads to the ruinous necessity of relying solely on passive trade" Junta de Comerç de Barcelona* (Royal Barcelona Board of Trade 1780, 79).

[1919] 1994, La Force 1964, Monés i Pujol-Busquets 1987, Vicente i Valentín 1988, Calvo 1999, Solà 2016). However, no scholar has gone beyond citing this anecdotal example of a female apprenticeship school. This article unpacks the primary source to frame its purpose and activity within the context of the rapid technological changes in the last third of the 18th century. The female apprenticeship school primarily served as a laboratory for the Board of Trade to compare the performance of the new Vaucanson and Piedmontese foreign reeling technologies. This was a significant shift from centuries of relying on traditional reeling machines in Spain since the Middle Ages. Empirical tests were done to elucidate which one was preferable and should therefore be promoted by the Board of Trade. As highlighted by Mokyr (2005, 2012), the empirical-experimentalist approach of Enlightenment culture resulted in technological change becoming the catalyst for modern economic growth.

2. STATE REGULATIONS. SILK-SPINNING MANUFACTURE IN CATALONIA

The Catalan silk manufacturing achieved a significant development during the 18th century, both in absolute terms and in comparison to silk manufacturing in the rest of Spain.[2] The silk manufacturing sector was of great relevance in this period, not only for its size, but for its interconnections with cotton manufacture in the early stages of Catalonia's cotton textile industrialization.[3] However, at the end of the 18th century, the Barcelona Board of Trade considered that Catalan silk production was in a state of decline, which it attributed to the poor quality of the spinning yarn. Lack of competitiveness had caused a relative loss of market share in favour of France and, above all, Italy, which had become the international leader in the production of semi-finished silk products.[4]

In 1777, the Board of Trade published an Interim Ordinance on silk spinning. Denouncing the poor quality of the silk spun in Catalonia, it instituted a set of rules with the aim of securing greater quality.[5] The Ordinance had two main pillars: one concerning the qualification of the spinners, and the other regarding the quality of the spun silk.

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[2] Segura (1991, 154-157). See also Nadal (2003) for a comparison of textile manufactures across the Spanish geography.

[3] "*Silk craftsmen were authorised to use cotton, mixed with silk [...] Their technical expertise favoured the participation of masters from the silk guilds in the origins of the cotton industry*". Molas Ribalta (1970, 229, 430). See also Miguel López (1996).

[4] The Board of Trade explicitly recognizes that the art of spinning silk in Spain was behind that of other countries, adding that it was most perfected in Piedmont, whose silk was preferred to all of Europe. BC, AJC, collection LI, box 68, folder14, letter 19 July 1784.

[5] See Appendix 1 for an overview on silk spinning technology in preindustrial Spain, and Appendix 2 for the transcription translated into the English language of the Interim Ordinance of 1777.

The qualification of the spinners

The first part of the Catalan Board of Trade's Interim Ordinance of 1777 established a formal certification system for silk spinners without which the exercise of this profession was rendered illegal. Aspiring silk spinners had to pass an examination in the Art of Spinning Silk, which could be conducted in any municipality. This gave them the right to obtain a Certification from the Secretary of the Board, which qualified the worker in the practice of spinning. In addition, the position of master was established to teach silk spinning to those who wished to learn this activity from that moment onwards.

Silk spinners who wished to continue working were obligated to take the exam and obtain the certification, and their names were added to a formal registry. The registers for the years 1789 and 1790 have been preserved in the archive of the Royal Barcelona Board of Trade, and the names allow us to know each spinner's gender. Table 1 offers the data for the jurisdictions (*corregimientos*) of Barcelona, Mataró, Manresa and Villafranca.

Table 1: Spinners registered in the Board of Trade, 1789-1790

	1789					1790				
	Male		Female		TOTAL	Male		Female		TOTAL
	Number	%	Number	%	Number	Number	%	Number	%	Number
Barcelona	11	*19.30*	46	*80.70*	57	17	*26.56*	47	*73.44*	64
Mataró	3	*20.00*	12	*80.00*	15	3	*20.00*	12	*80.00*	15
Manresa	4	*80.00*	1	*20.00*	5	2	*50.00*	2	*50.00*	4
Villafranca	15	*31.91*	32	*68.09*	47	15	*34.09*	29	*65.91*	44

Source: BC, AJC, collection LI, box 68, folder 19, pp. 283-285 and 389-392. There are data for Villafranca also for the year 1788: male 14 (27%) and female 38 (73%). BC, AJC, collection LI, box 68, folder 19, pp. 149-152.

First, Table 1 reveals a very low number of silk spinners registered by the Board of Trade in comparison with the number of silk weavers registered in the Manufacturing Census of 1784 (Miguel López 1996). The main silk-weaving centres were located in Barcelona, Mataró, Manresa, Igualada and Reus. According to the census, Barcelona had 10,230 silk weavers (versus 57 to 64 spinners, see Table 1) and Manresa, 1,191 weavers (and only 4 to 5 spinners, Table 1).[6] However, the Manufacturing Census of 1784 computed only a total of 152 reeling machines for Catalonia, a figure in line with the Board of Trade's spinner registry (Miguel López 1996, 146).

The different labour figures in the spinning and weaving stages have two complementary explanations. Firstly, due to the scarcity of silk cocoons in Catalonia, the local supply was

[6] Reus registered in the census 2,103 weavers. There are no employment figures for weaving in Mataró or Igualada (Miguel López 1996, appendix IV). Similarly, Molas Ribalta estimated 12,000 silk weavers in Barcelona (Molas Ribalta 1970, 362).

supplemented by imports from other regions of Spain and abroad. There was a notable prevalence of raw materials from Aragon and, particularly, from Valencia (Segura 1991, 155). It is unknown the proportion of raw material imported by Catalan silk manufacturers in the form of silk cocoons or already spun. Hence, it is possible that a considerable portion of Catalan woven silk depended on silk that had been spun outside of Catalonia. This would justify a smaller proportion of labour applied in the spinning stage compared to the weaving stage. Additionally, the different organization of the work in the two stages played a crucial role. The guild organization linked to the weaving stage coexisted with the free labour of the spinning stage. Spinning was subcontracted and carried out in the domestic sphere of the putting-put system (Miguel López 1996).[7] As a result, a significant number of spinners were likely not subjected to examinations for inclusion in the official registry. Consequently, they remained beyond the control of the Board of Trade, despite the institution's efforts to regulate spinning in order to promote quality improvements.[8]

Secondly, Table 1 shows a predominantly female silk spinning workforce, as in the rest of Europe. According to Table 1, female spinners were between 65% and 80% of total registered spinners (except for Manresa, which can be considered an outlier because of the especially low number of registered spinners). This proportion is similar to the case of Piedmont, where females employed in silk spinning were around three quarters of workforce in 1788 (Chicco 1995, 213).

The dominance of women in the spinning sector made sense in the social and cultural milieu of the time. Positioned within the domestic sphere, it was considered a part-time activity compatible with other domestic tasks. In economic terms, the remuneration acted as a complement to the family income (Vicente i Valentin 1988). This system of production was therefore compatible with the social influence of the Enlightenment as understood through the Catholic lens. Catholic morality imposed virtuous seclusion in accordance with public customs, and the Spanish Enlightenment's perspective of working from home did not, therefore, violate such morality:

> *"[…] the two Royal Decrees of 1779 and 1784 does not specifically indicate to women in which specific manufactures they can work. Desirous of restoring them to the freedom to work that nature had given them, the Government enabled them, in the one of January 12, 1779, for all the work proper to their sex, but without specifying any, and thus cut off the chains that guild legislation had placed in their hands so abruptly. The one of September 2, 1784, issued upon consultation of this Board, appears to conspire to*

[7] On the putting-out system, see Berg (1986).

[8] Manresa had 150 silk throwing machines in 1789, according to the contemporary observer Francisco de Zamora (Solà 2016, 114), but the Board of Trade registered only 5 silk spinners, which reinforces the hypothesis that many spinners were not examined to be included in the official registry. Similarly, the Manufacturing Census of 1784 had registered only 152 reeling machines for the whole of Catalonia. Official registries, both the Manufacturing Census and the Board of Trade Registry, underestimated the size of silk spinning activity as they did not possess reliable data for the silk spinning labour force of the putting-out system.

establish the generality under which the previous Decree was conceived, and it explains that women should be understood as allowed to undertake all those jobs which, not being repugnant neither to heir delicacy nor their decorum, should be considered suitable for their sex.[9]

The quality of the spun silk

The second part of the Interim Ordinance of 1777 briefly details some practical rules on the classification of cocoons, reeling practices, and machinery changes to improve the quality of the spun silk. From this set of rules, it is worth mentioning those relating to the types of reeling machines to be used for spinning. The traditional reeling machine had a large reel, which made it possible to speed up the process, with a consequent loss of product quality. The Board of Trade imposed the use of smaller reels that would increase the quality by slowing down the spinning process, which entailed a longer working time for the spinner per unit of spun silk.

The increase in the time employed in spinning did not necessarily mean an increase in the remuneration of the spinners, since payment was made in piece rates (per Catalan pound of weight) and not in daily wages (for the time of work employed in spinning).[10] As a result, the Board's decision met with strong resistance on the part of the spinners that delayed the implementation of the regulations. In fact, ten years after the publication of the Interim Ordinance, in May 1788, the controversy was still open. Documents from this period reveal that the reduction of the circumference of the reel to 14 Catalan palms meant that it would not be possible to spin as much silk per day as with the current larger reels, which would lead the spinners to ask for higher remuneration, "*for which reason difficulties will arise between harvesters and spinners, and with recourse to justice days will go by and this year's spinning will be over*".[11]

The Board of Trade archive contains some scattered information on the retribution of silk spinning (see Table 2). Payments differed in each town. According to the Interim Ordinance of 1777, these differentiated payments were due to the differences in the fineness of the silk spun, which depended on where the cocoons had been cultivated, but also the spinners dexterity. Indeed, the Board "*determined not to set at this time the price that the spinner must charge for each pound of spun silk, this being more or less thin, according to the places where it is harvested and the hands that work it, prices must be convened upon by the harvester and the spinner with the corresponding fairness*" (see section IV of the Ordinance of 1777 in Appendix 2). However, in practice, payment was the same for all

[9] Jovellanos (1785, 434). The Royal Decree of 1779 stated: *"Royal Decree of His Majesty and Lords of the Council: by which it is ordered that under no pretext whatsoever, by the Guilds of these Kingdoms or other persons, the teaching to women and girls of all those works and artifacts that are proper to their sex, notwithstanding the privative ones that in their respective Ordinances the Masters of the mentioned Guilds have, with the rest that is expressed".* The Royal Decree of 1784 stated: "R*oyal Decree of His Majesty and Lords of the Council, by which it is declared in favour of all the women of the Kingdom the faculty to work in the spinning manufacture as in all the other arts in which they wish to occupy themselves and which are compatible with the decorum and strength of their sex, with the rest that is expressed".* See also Sarasúa (1997, 2008).

[10] On spinners' remuneration, see section IV of the Interim Ordinance of 1777 in Appendix 2.

[11] BC, AJC, collection LI, box 68, folder 19, pages 113-114, 4 May 1788.

registered spinners in the same town, which meant that the dexterity of the spinner and, therefore, the quality of the spun silk, had nothing to do with the payment per piece. There were also no differences in payment based on gender: both men and women received the same payment in each town. The payment was also the same irrespective of the type of silk spun (*aldúcar* silk or fine silk).[12] When there were differences in the payments (lower piece rate), these reflected a business arrangement by which the harvester also paid for the wood in kind to produce the spun silk, or the spinner's upkeep. The quantity of cocoons allocated to each spinner was small enough for the spinners to spin themselves. That is, it was unlikely that registered spinners subcontracted unregistered spinners to work on their behalf. The system of assigning the cocoons was by concurrence: one or more spinners from the town or towns in the area would concur to take the batch of cocoons for spinning.

The most remarkable feature about the piece-rate system is that quality did not count in the payment. The Board of Trade's 1777 regulations sought to certify the qualification of the spinners by examination, but once the minimum required qualification had been demonstrated, the law did not stipulate a higher payment for higher spinning quality. Therefore, what incentives would spinners have to seek higher yarn quality if this did not increase their retribution?

Table 2: Piece rate - price per Catalan pound (of weight) of silk spun, 1789 (*in Catalan* sueldos)

	Barcelona *corregimiento* 1789	Villafranca *corregimiento* 1788
Number of observations	15	21
Minimum (plus firewood in kind)	6	6
Minimum (without payments in kind)	14	12
Maximum	18	16
Unweighted average	15.42	14.40
Weighted average	15.23	14.05
Statistical mode	15	14
Total quantity of silk spun (in Catalan pounds of weight)	1,750	1,085

Source: Barcelona BC, AJC, collection LI, box 68, folder 19, p. 243; Villafranca BC, AJC, collection LI, box 68, folder 19, pp. 225-226: "*The towns that pay less than a* peseta *and a half for each pound (=11.24* sueldos*) usually provide the firewood needed to spin the silk*". Similar payments are given in the jurisdiction (*corregimiento*) of Girona in 1788 (BC, AJC, collection LI, box 68, folder 19, p. 231).

This payment system differed from the one that existed in Piedmont, where payment was made per day of work and not per quantity of spun silk. According to Ruiz i Pablo (1994: 81), the Catalan regulations were based on those from Turin (published in 1724). However, there were great differences, notably in relation to the way in which the spinning activity was remunerated, as the Turin Ordinance explicitly stated that: "*The payment of the spinners shall be arranged by the day's wages and not by the pounds of silk they spin, and in case of contravention the owner of the spinning mill shall*

[12] *Aldúcar* in Spanis language is a cocoon formed by two or more silkworms together (see Appendix 2).

incur the loss of all the silk already spun, and the spinner the loss of 20 pounds in addition to the loss of the wages due to them"[13]. Notice the difference is not only related to the system of payment per piece instead of per hour of work, but also the structure of the labour system. While in the early 18th century spinning work in Piedmont was organized in mills where workers sold the time they spent labouring in exchange for wages, Catalonia at the end of the 18th century was still organized according to the putting-out system in which the spinners owned the means of production (i.e., the traditional spinning machines) and sold the product of their work (payment as piece rates), and not their working time (Marglin 1974).

This form of labour organization was, however, starting to shift towards the adoption of modern technology in the prelude of the Industrial Revolution, and the Board of Trade aimed to explore the intersections between technology, productivity, profitability, spinners' dexterity, silk-spinning quality, and labour remuneration. But the spinning activity was a black box for the Board of Trade as it was a domestic activity not controlled by the guilds. To that end, the female silk-spinning apprenticeship school was a means to empirically test the relationship between the improvement of spinners' dexterity and the improvement of silk-spinning quality through apprenticeship (see section 3). The school was also meant to rationalize the relationship between technology, productivity, profitability, silk-spinning quality, and labour remuneration through empirical testing of high-quality spinning, comparing the Piedmontese and Vaucanson reel machines for the same level of spinners' skill (see section 4). That is, the Board of Trade sought to unpack the black box of silk-spinning at the end of the Old Regime by means of the female apprenticeship school.

3. SILK-SPINNING APPRENTICESHIP SCHOOL. DEXTERITY AND QUALITY

The creation of a silk spinning school for girls and young women was not a project sought by the Board of Trade. Nor was the adoption of the Piedmonts' technology. On 22 January 1784, María Margarita Bertot presented herself to the Board of Trade as an expert silk spinner in the style of her homeland, Piedmont, with the aim of spreading her knowledge in the province of Barcelona.[14] In May of the same year, before approving María Margarita's proposal to

[13] (Art. 13) «Manifesto del Consolato di S. M. concernente l'osservanza delle refiole per la Filature, Filaroj e Fabriche delle Stoffe da Seta, e loro tinture, che S. M. commanda venglino in avenire osservate, e a tal' effetto a Regio Suo nome pubblicate per manifesto del Consolato di Torino, nel Distretto della Sua Giuridizzione. — In data delli 8 Aprile 1724. — In Torino MDCCXXIV. Per Gio. Battista Valetta, Stampatore» (BC, AJC, collection LI, box 19, pages 6-15). See also Chicco (1995).

[14] María Margarita arrived in Spain accompanying her husband, who was a corporal in the Swiss Regiment of Pedrohart in Madrid. The geographical mobility of army forces was an important cause of female emigration in the 18th and 19th centuries, as the army mobilised not only men, but also the women who accompanied them. Bertot migrated from Madrid to Barcelona in search of greater opportunities, believing that she would be able to earn a higher income as a master in Barcelona.

set up a silk spinning school, the Board of Trade decided to hold a series of tests to assess the ability of the future master. Once the perfection of María Margarita's spinning had been demonstrated, the Barcelona Board of Trade requested the approval of the school from the General Board of Trade. The latter agreed to open it on the condition that one of the members of the Barcelona Board of Trade would supervise the school, stipulating that the school's activities would be overseen monthly and that a half-yearly report would be given to the General Board of Trade on the progress made in the school. Finally, on 8 July 1784, the *Escuela de Enseñanza de Hilatura de Seda según el método de Piamonte* (Piedmont Method Silk Spinning School) was opened in Barcelona.[15]

The Barcelona Board of Trade looked for pupils at the Barcelona poorhouse (*Casa de la Misericordia*), from where it received three girls who were enrolled in the first year and twice as many in the second year.[16] The members of the Barcelona Board of Trade were in charge of supervising the progress made by the pupils in their apprenticeship, drawing up an annual report on the time spent by each pupil in their apprenticeship, which they sent to the General Board together with samples of spun silk.[17]

María Margarita's employment contract was established for a period of 4 years, and it stipulated a salary of 3,000 *reales* per year, to be paid every four months. However, in August 1785, the master claimed that this wage did not allow her to make a decent living, and she tried to obtain remuneration from the Board of Trade by providing them with a proposal of instructions for perfect silk spinning. However, the Board considered that Bertot's instructions were not new compared to the established Interim Providence of 1777 (Appendix 2), and therefore did not pay her for them. [18]

Bertot's instructions provide a valuable written record detailing the Piedmontese way of spinning silk in the late 18th century (see the instructions reproduced in Appendix 3). Bertot's instructions detailed, first, how to cook the cocoons to avoid wasting half of them, which is what

[15] BC, AJC, collection LI, box 68, folder 14, letter 8 July 1784.

[16] BC, AJC, collection LI, box 68, folder 14, letter 15 September 1784. Poorhouses proliferated throughout Spain at this time as the state sought to integrate the poorer classes into the social order (Callahan 1972, 61). The Barcelona Board of Trade's policy of instructing the girls of the Barcelona poorhouse in silk spinning aligns with this objective, as women were excluded from the regulated training offered by the guilds. Regarding the Barcelona poorhouse, see Carbonell-Esteller and Marfany (2017).

[17] BC, AJC, collection LI, box 68, folder 14, letter 14 January 1786.

[18] The master's initial claim was to charge 6,000 *reales* per year. BC, AJC, collection LI, box 68, folder 14, letter 28 July 1784. Teaching was a seasonal activity, which could only be carried out from July to early November due to the impossibility of preserving the silk cocoon for longer without causing it to deteriorate. The salary received for the actually working days was approximately 25 *reales* per day (2.5 Catalan pounds per day), higher than the salary she received in Madrid working as a spinner, which was 20 *reales* per day (2 Catalan pounds per day). However, in order to make ends meet, the master had to supplement this salary with other activities during the rest of the year. Bertot therefore requested a perpetual salary for her husband and herself, higher than that established in the contract, arguing that the fact that she had unveiled the method of spinning silk in Piedmont deprived her of returning to her homeland. However, the Board decided that she would only be remunerated after the expiry of her contract if she continued to receive pupils to learn the method of spinning. BC, AJC, collection LI, box 68, folder 14, letter 5 September 1785.

was happening at the time in Barcelona (articles 1-5, Appendix 3). This was of great importance considering the high cost of the raw material, whose correct handling had a very strong impact on the profitability of the silk spinning. Second, the instructions explained the selection and classification of cocoons, which was also extremally important to procure the highest silk quality (article 9, Appendix 3). Bertot proposed several thread qualities, some of them taken from the Piedmont classification, others new proposals based on the specific features of local silkworms. Thirdly, her instructions detailed the concrete procedures that spinners should follow to store and handling the cocoons to allow for high-quality silk spinning (articles 6-26, Appendix 3). Bertot's instructions also identified the main mistakes that spinners usually made, so that awareness led to their avoidance (article 27, Appendix 3). Finally, they described the Piedmont reeling machine in order to facilitate its manufacture (article 29, Appendix 3).

From the instructions drafted by María Margarita Bertot, it is clear that technological adoption was a multidimensional process combining technology (machines) and know-how (the correct handling of raw materials in the machines by the workers). Know-how required a high degree of workers' dexterity and was a crucial element for the proper adaptation of the technology. Similar conclusions were recently obtained by Hutková (2017) for the case of the transfer of the Piedmontese reeling machine by the English East India Company to Bengal, and by Bertucci (2021) for the transfer of the Piedmontese reeling machine by the British Empire to its colony of Georgia in America. Hutková (2017) highlights the interest of the East India Company in defining procedures to store the cocoons and classifying quality standards for spun silk according to the cocoons' typology, in much the same way as the cocoon classification proposed in Bertot's instructions (Appendix 3). Bertucci (2021) proposes considering spinners' "embodied expertise" in the history of technology transfer, which implied a gradually acquired practical intelligence that, in interaction with the reeling machine, produced high-quality raw silk that did not break during the subsequent process of twisting multiple threads together to make the final yarn, thus reducing waste and saving labour time (see Appendix 1 for a description of the silk spinning processes). The interaction of the spinner with the machine consisted first in selecting and sorting cocoons, and then in adapting the motions of their bodies to the reeling machine to maintain a constant movement to form a homogeneous thread from the silk filaments, modifying the speed according to the thickness of the thread and stopping the machine to tie two ends together if the thread broke. María Margarita Bertot's instructions were entirely oriented towards providing apprentices with the needed "embodied expertise" as defined by Bertucci (2021) to produce high-quality spun silk (Appendix 3).

Master Bertot undertook to instruct girls and young women in silk spinning within two years. Training took place over a period of approximately 4 months per year. The apprenticeship

required full-time dedication, the working day being 15 hours long, consisting of 13 hours of worktime plus two short breaks of 1 hour each (article 16, Appendix 3), similar to the Piedmont 14-hour workday (Bertucci 2021, 1014). The first-year pupils did not complete the training claiming that they had no means of subsistence during the apprenticeship, which was unpaid.[19] To solve the problem, the Board of Trade approved giving them a subsistence payment of two Catalan *sueldos* a day for the first year of training, three for the second year and four for the third year. In this way, the Board expected the pupils to work as masters from the third year onwards, with the aim of spreading the silk-spinning training throughout Catalonia.[20]

The Board of Trade wanted to establish a self-financing school, and indeed, the school made a profit in the first year. However, it made a loss the following two years. The school's annual revenue and expenditure data details the revenues from the sale of spun silk and the ordinary and extraordinary expenditures of purchasing cocoons, the cost of purchasing and repairing machinery, the running costs of utensils, coal, and firewood, the salary payments of the teacher and pupils. The volatility of the gross margin -that is, the margin between the cost of the cocoons and the selling price of the spun silk- was the main cause of the school's losses, which led to its closure (see Table 3). On the one hand, silk manufacture started suffering falling prices due to oversupply in the colonial markets in times of crisis, which had an important impact in Spanish silks and calicoes (Solà Parera *et al.* 2020). On the other hand, cocoons were scarce and expensive, having changing prices depending on harvests.[21]

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[19] The Board of Trade decided to pay the trainees as a result of the appeals presented by several pupils, i.e.: "*Barbara Marceli maiden, aged fourteen years, with the most attentive veneration to you exposes: that from the 23rd of September until the 12th of November of the current year she worked in the School of silk spinning, established in Madame Maria's Casa Lonja, and being a poor person who lives by the work of her hands, she has been deprived of three daily Catalan* sueldos *by attending the School, which she earned by making lace or stitches for Narcisa Cerdá Casanovas widow, who lives in the Tapineria. She therefore earnestly begs you to remunerate the petitioner with that reward that your charitable zeal dictates to you, which she will gracefully receive*". BC, AJC, collection LI, box 68, folder 14, letter 15 December 1785. However, the Board's decision to remunerate the apprenticeship was limited to only 6 pupils. Other girls could attend the school if they wished but would receive no remuneration.

[20] BC, AJC, collection LI, box 68, folder 14, letter 9 January 1786.

[21] Provisioning enough silk cocoons was one of the main problems of the Catalan silk industry. BC, AJC, collection LI, box 68, folder 14, letter 6 July 1784; BC, AJC, collection LI, box 68, folder 14, letter 13 July 1784. Therefore, the Board of Trade promoted their production (Molas Ribalta 1970, 429). María Margarita Bertot offered to plant mulberry trees and breed silkworms in the style of her country. On 15 December 1785, the Board of Trade approved this proposition, agreeing to grant the master a proportion of the profit obtained therein. In August 1786, the members of the Board informed the Secretary of the results obtained from the Piedmont-style silkworm breeding experiment. According to them, the only novelty was the use of grass instead of the twigs used by the Catalan harvesters, which, according to the master, made it easier for the worms to spin better. However, it was not possible to verify the validity of the experiment, as Bertot admitted to not having taken care of watching over the silk cocoons, because in her country the worm took three weeks to breaking out of the cocoon and in Barcelona only eight days. In view of the exorbitant cost of the experiment, the master did not receive any reward for carrying out this experiment. BC, AJC, collection LI, box 68, folder 14, letter 14 August 1786.

Table 3: Main expenditures and revenues of the silk-spinning apprenticeship school: cost of cocoons vs. price of spun silk, 1784-1786 (*in Catalan pounds*)

Year	Cost of silk cocoons	Price of spun silk	Gross Margin (%)
1784	199.63	359.58	80.12%
1785	441.60	310.57	- 29.67 %
1786	538.58	488.10	-9.37 %

Source: BC, AJC, collection LI, box 68, folder 14, letters 19 July 1784, 20 December 1784 and 29 August 1785 (year 1784). BC, AJC, collection LI, box 68, folder 14, letters 29 August 1785, 26 January 1786 and 13 February 1786 (year 1785). BC, AJC, collection LI, box 68, folder 14, letter 14 August 1786; BC, AJC, collection LI, box 69, folder 30, letter 8 January 1787; BC, AJC, collection LI, box 68, folder 16, letter 4 December 1786 (year 1786). Gross margin = (price of spun silk- cost of silk cocoons)/cost of silk cocoons.

The lack of cocoons was a recurrent problem at the school, and training could not be extended beyond 4 or 5 months a year. This, according to the master, made it impossible to train the pupils within the 2 years initially estimated in the contract, stating that they needed at least 5 or 6 years.[22] However, the members of the Barcelona Board of Trade did not believe that the seasonality of the activity caused this problem at all, and instead accused the master of behaving opportunistically. That is, they considered that she did not want the pupils to advance in order to extend the term of her employment contract.[23] However, this statement is contradicted by the evaluation made by the experts Isidro Catalá and Joseph Juliá of the samples spun by the pupils, which spoke of the "*perfection of the spun and twisted silks*" at María Margarita Bertot's school.[24]

In July of 1787, the Barcelona Board of Trade decided to review María Margarita Bertot's file, considering that the school had not produced the expected progress in three years. The review of the school's reports was to be used to decide its future, as the master's contract expired on 8 July 1788. In this file, the members of the Barcelona Board of Trade stated that *"Bertot had been somewhat negligent in the teaching of her pupils, and in complying with a pact in her contract, which states that within two years she should present to the Board masters who were taught and able to practise all that she had acquired and would acquire during this time*".[25] This assessment was in contradiction with that of the General Board of Trade, which stated that it was "*satisfied with her zeal and the application of the aforementioned master, to whom you will make her understand this, in order to encourage her to bring the silk-spinning school to their ultimate perfection*" in September of the same year.[26]

[22] In addition to the problem of the shortage of silk cocoons, there were also disagreements between the teacher and the school managers which, according to Bertot, hindered the smooth running of the school. The master exposed the lack of interest of the Board members in the school, which manifested itself in poor working conditions, such as the existence of mice in the cocoon storage room, which spoiled the cocoons, broken machines and utensils, and internal disputes. BC, AJC, collection LI, box 68, folder 14, letter 18 August 1786.
[23] BC, AJC, collection LI, box 68, folder 14, letter 18 August 1786.
[24] BC, AJC, collection LI, box 68, folder 14, letter 6 May 1785. BC, AJC, collection LI, box 68, folder 14, letter 22 March 1786.
[25] BC, AJC, collection LI, box 69, folder 30, letter 23 July 1787.
[26] BC, AJC, collection LI, box 69, folder 30, letter 26 September 1787.

The future of the school was put on hold when master Bertot's contract expired without any pronouncement from the General Board of Trade. Finally, in 1791, the Barcelona Board, which had been in favour of closing the school since 1787, decided to dismiss her definitely in the absence of a resolution by the General Board.[27] It is worth noting that the interest of the members of the Barcelona Board in the closure of the school happened after the completion of the experiments to compare the quality of the silk produced with the Piedmontese and Vaucanson reeling machines. Bertot was in charge of carrying out the experiments, so that the silk-spinning apprenticeship school seems to have been regarded by the Board more as a means to explore the intersections between technology, productivity, dexterity, quality, profit and labour remuneration, than as an institution with a genuine formative purpose. Section 4 illustrates these intersections through the experiments conducted by the Board of Trade in collaboration with master María Margarita Bertot at the silk-spinning apprenticeship school.

4. SILK-SPINNING APPRENTICESHIP SCHOOL. TECHNOLOGY AND QUALITY

The General Board of Trade promoted several initiatives to adopt new technologies in 18th-century silk manufacturing in Spain. In 1748, the General Board appointed a French technician, John Rulière, to establish the first factory to concentrate silk spinning, weaving and dyeing under one roof (The Royal Factory for Silks at Talavera de la Reina). For the spinning stage, 44 reeling machines, 12 throwing machines and 6 doubling machines were placed in the factory, all of them powered by 4 oxen (see Appendix 1 for a description of the silk-spinning processes). John Rulière was contracted with an exorbitant salary of 45,000 *reales* per year, nobility status, naturalisation and a lifetime pension for his wife and daughter in the event of his death (La Force 1964, Peñalver 2000). In 1769, the General Board conceded to the Frenchman Santiago Reobull, the exclusive right to use the Vaucanson reeling machine in Vilanesa (Valencia). Having partnered with Joseph Lapayese, they failed to establish the Vaucanson technology in Valencia, but Lapayese then hired another Frenchman with whom he worked for two years to improve

[27] The members of the Barcelona Board of Trade explained to the General Board of Trade that it had not been possible for the pupils to achieve the progress that master Bertot had promised because the lack of a constant supply of cocoons limited the time that spinning could be undertaken throughout the year. Therefore, they considered that the whole notion of silk spinning schools was unfeasible. They also argued that the school should finance itself with the sale of spun silk; otherwise, it would expend a great amount of resources in vain. To eliminate the school's dependence on cocoons, the master requested to conduct a new silkworm breeding experiment in 1787, but the Board rejected this proposal because it presupposed its failure in view of the negative results obtained the previous year. Since no decision was made, in August 1788 the master's contract was renewed for six months as a temporary measure until a definitive resolution was passed. In March 1789, Bertot requested a decision on the continuation of her contract. Since the General Board had not resolved anything yet and no meeting could be convened, the Barcelona Board decided to continue honouring her salary until a final decision was reached. In July 1791, the General Board had still not pronounced itself, and the Barcelona Board decided to terminate the assignment. BC, AJC, collection LI, box 68, folder 30, letter 24 October 1791.

Vaucanson's system. Vaucanson's method of spinning silk was applied for the first time in Spain in the Lapayese factory in Vilanesa (Santos Isern 1981, 188-189).[28] Later, in 1783, King Charles III of Spain obtained 1,500 Vaucanson machines from a captured convoy and offered 108 of them at a discount to harvesters in Catalonia to promote the use of new technologies (La Force 1964).

Along with the promotion of the Vaucanson machine, the adoption of the Piedmontese machine was also encouraged by the General Board of Trade. In 1770, Fernando Gasparro obtained the rights to establish a silk-spinning factory in Murcia. He hired the master Juan Octavio Quadropani from Turin to adopt the Piedmontese reeling technology and Margarita Rosa to teach spinners. His company had the authorisation to set up spinning factories in other places in Spain, except in Valencia where Reobull already had the exclusive rights with the Vaucanson machine. The company went bankrupt in 1774 and came under the direct control of public administrators until it was ceded in 1786 to the *Cinco Gremios Mayores de Madrid* (the corporation that aggregated the five main guilds of Madrid). Then, a new Italian female master – Teresa- was recruited to teach 60 girls and young women to spin silk (Solà 2016, 115).

In Catalonia, according to the Manufacturing Census of 1784, most reeling machines were still the traditional Spanish ones (see Appendix 1), but there were already a few Piedmontese reeling machines listed in Villafranca, San Feliu de Llobregat, San Juan Despi y Quadra de Palou, and a few Vaucanson machines in Lleida, Oliana, Reus and Esparraguera (Miguel López 1996, 146). According to Calvo (1999, 118), the Piedmontese reeling machine was introduced in Barcelona in 1784 by Juan Berta, a soldier from Flanders, who had spun for 22 years with the reeling machine in Piedmont. The carpenter B. Ardit would improve it thanks to his contact with J. Cornalia, a foreigner briefly associated with María Margarita Bertot. The story told in the primary source -i.e., the archives of the Barcelona Board of Trade- is somewhat different: María Margarita Bertot introduced the Piedmontese reeling machine in Barcelona. In 1784, the Barcelona Board of Trade did not know how to make the Piedmontese reeling machine and commissioned Bertot to instruct a carpenter to make it.[29] Therefore she was the one who introduced the Piedmontese technology in Barcelona to be used by the pupils in the silk-spinning apprenticeship school.

In addition, she not only introduced the technology and taught silk spinning in the apprenticeship school, but also made some experiments under the direction of the Board of

[28] Treatises were published to disseminate Vaucanson silk technology in Spain, such as Reboul (1776, published for public benefit and distributed by the Valencia Board of Trade), Valcárcel (handwritten, 1779), Lapayese (1779), and Ortells y Gombau (1783, printed by order of the Valencia Board of Trade).

[29] BC, AJC, collection LI, box 68, folder 14, letter 22 January 1784. One reeling machine was made for the school in the first year and two additional ones were made in the second year as the number of students doubled. BC, AJC, collection LI, box 68, folder 14, letter 7 March 1785. Force (1964: 339) also recognised María Margarita Bertot as the person who introduced the Piedmontese reeling technology in Barcelona.

Trade to compare the Vaucanson and Piedmontese reeling machines.[30] These experiments are an example of the empirical-experimentalist approach of the Spanish Enlightenment culture adopted by the Board of Trade to promote technological adoption in the prelude to the Industrial Revolution (see Mokyr 2005, 2012).

These experiments were carried out under the supervision of experts in silk manufacturing (veil weavers and hosiery manufacturers, the main branches of silk manufacturing in Catalonia). Results reported to the Barcelona Board of Trade can be organised according to the following main variables: (1) spinning quality (2) amount of waste (3) working time per unit of spun silk (4) remuneration per working hour. A summary of these was reported to the General Board of Trade.[31]

First, regarding spinning quality, experts tested both Vaucanson and Piedmontese reeling machines with María Margarita Bertot (master in Piedmontese technology) and the best spinner on the Vaucanson method they could find in the surrounding areas (who lived in San Feliu village near Barcelona). Experts agreed that María Margarita Bertot was better than the spinner from San Feliu with both machines, and that María Margarita spun to the identical standard with the Piedmontese and Vaucanson reeling machines. The first conclusion was that the quality of the spun silk depended on the dexterity of the spinner rather than on the reeling machine. Moreover, the few data available in the experiments (Appendix 4) -summarised in Table 4- shows the crucial relevance of the proper classification of cocoons, i.e., the highest quality of silk was priced more than twice as much as silk of the lowest quality. Mixing qualities would reduce the sale price drastically. As we have seen in the previous section, instructions made by master María Margarita Bertot (see Appendix 3) stressed that dexterity consisted not only of the correct handling of the reeling machine, but also on the correct selection of cocoons that had a strong impact on profitability.

[30] The first experiments were approved to be conducted in May 1784. BC, AJC, collection LI, box 68, folder 14, letter 17 May 1784. Further experiments were ordered in Dec 1785. BC, AJC, collection LI, box 68, folder 14, letter 5 December 1785.

[31] BC, AJC, collection LI, box 68, folder 14, letter 19 July 1784 (from Jyan Vidal i Mir to Melchor de Guardi, Jayme Canet and Matheo Civil; and from Jayme Canet i Ferrussola to Matheo Civil). BC, AJC, collection LI, box 68, folder 14, letter 12 January 1785. BC, AJC, collection LI, box 68, folder 14, letter 22 March 1786. BC, AJC, collection LI, box 68, folder 14, letter 8 January 1787. The transcription of the most relevant experiments is available in Appendix 4.

Table 4: Unitary Prices and Labour Time of silk spinning with Piedmontese and Vaucanson reeling machines

	PIEDMONTESE REELING MACHINE		**VAUCANSON REELING MACHINE**	
	Unitary Price (*reales*/*libra*)	Labour Time (hours/*libra* of weight)	Unitary Price (*reales*/*libra*)	Labour ime (hours/*libra* of weight)
Fine white silk	95	8.05	n.a.	n.a.
Fine silk	90	n.a.	86 81 81 Average: 82.66	10.47 12.66 8.47 Average: 10.53
White silk	82.5	n.a.	88 ½	n.a.
Fine yellow silk	87 ½	n.a.	n.a.	n.a.
Yellow silk		n.a.	75	n.a.
Silk	90 82.5 80 71.25 Average: 80.93	n.a.	78 ½ 70 Average: 74.25	7.96 7.04 Average: 7.5
Corrupted Cocoon	56.5	n.a.	n.a.	n.a.
Aldúcar	37 ½ 40 Average: 38.75	n.a.	38 ½	6.34

Source: BC, AJC, collection LI, box 68, folder 14, letter 19 July 1784 (see appendix 4).

Second, because the experts wanted to minimise processing losses and thefts, each experiment recorded the weight of the cocoons both at the time of purchase (raw material) and after the silkworm had been killed (before spinning), as well as the final weight of the spun silk. The weight of cocoons delivered for spinning was known, but there was uncertainty about the weight of spun silk that the harvester would receive after spinning. Theft was a common occurrence in the of silk spinning activity in the Old Regime, but it was difficult to control by the harvester who delivered the cocoons for spinning since the spinning process was carried out in the domestic sphere.[32] Therefore, notional equivalences between the weight of cocoons and the weight of spun silk were of interest to the Board of Trade to try to limit thefts during the spinning process. Additionally, the process of spinning generated a loss of weight when killing the silkworm, a necessary step before spinning to prevent the worm from breaking the cocoon if alive, which would have spoiled the silk filaments. Experts measured that the spinner from San Feliu wasted two more Catalan ounces of cocoon per Catalan pound than master María Margarita Bertot did (this translates into one-sixth extra weight loss per Catalan pound of weight). Experts

[32] On thefts in silk manufacturing at the end of the Old Regimen, see Avellino (2023)

were unable to determine whether the additional weight loss was due to prolonged immersion of the cocoons in water, or the distinct technique employed in Piedmont, specifically, killing the silkworms in the oven instead of the traditional method of boiling used in Spain. Here again, experiments quantitatively illustrated the relevance of best practice in handling the cocoons for proper spinning as detailed in the instructions written by Bertot (see previous section and Appendix 3).

Third, time worked per unit of spun silk was a crucial variable in measuring labour productivity. Experiments showed that Bertot was faster than the spinner from San Feliu in addition to producing a higher quality of spun silk. Comparing Bertot's performance on both the Piedmontese and Vaucanson reeling machines, while the quality of the output was identical, the master was one-fifth faster with the former, a difference that the experts attributed to Bertot's familiarity with it. This result echoes the concept of "embodied expertise" defined by Bertucci (2021) by which the spinners mastered the interactions with the reeling machine to produce high-quality spun silk while saving labour time (see previous section, and Bertot's instructions in Appendix 3). Moreover, the breakdown of the estimated sale price and spinning time for the Vaucanson experiment provides a proxy of the relationship between spinning quality and profitability (Table 4). The lowest quality silk (*aldúcar*) had a price of 38.5 *reales*/*libra* (i.e., Catalan pound of weight) and required a working time of 6.34 hours per Catalan pound of weight. Moving from low (*aldúcar*) to medium-high quality (silk), the price increased by 92.8% (74.25 *reales*/*libra*), while working time increased by only 18.3% (7.5 hours/*libra*). And transitioning from low (*aldúcar*) to high quality (fine silk) resulted in a price increase of 114.7% (82.66 *reales*/*libra*) and a working time increase of 66.1% (10.53 hours/*libra*). This indicates that the rise in the sale price was significantly greater than the rise in working time from low to medium-high and high qualities. Consequently, it was much more profitable for the silk owner (harvester) if the spinner classified the cocoons before spinning. However, simultaneously, it was logical for the spinner not to classify the cocoons and instead spin all of them as quickly as possible because their remuneration was based on the quantity of spun silk, regardless of quality.

Fourth, the experiments were designed to calculate payments per working hour while controlling quality (see experiments 1 and 2 in Appendix 4). The first experiment proposed that the spinner would earn 21 *sueldos* for a 13-hour working day while producing the highest quality spinning, i.e., without attempting to save working time but dedicating the necessary time to achieve the best quality thread. This represented the maximum labour remuneration without considering any return on capital in the putting-out system, *given* the purchase price of cocoons (as the harvester realised a profit from the sale price of cocoons minus their cultivation cost), and *given* the sale price of spun silk (as the weaver gained from the sale price of the woven silk minus

the cost of the spun silk). However, a second experiment already divided the gross profit between labour remuneration at 15 *reales* (equivalent to 30 *sueldos*) (50% of gross profit) and the remaining 15.79 *reales* as the net profit after compensating labour (that is, the other 50% of gross profit allocated to meet the return on capital). This was applicable in the case of spinning the highest quality raw material (fine white silk) that yielded the highest profitability. The primary interest of the Board of Trade was not to reduce spinners' remuneration but rather to enhance quality and generate a larger margin to be shared between labour and capital in the transition from the traditional putting-out system to the emerging factory system. Under this system, workers would be compensated for their worktime rather than the product of their work, and capital would be rewarded with the net profit after paying workers. Such a system had already been effectively implemented in Piedmont, achieving remarkable success in getting the highest quality standards, thus enabling the region to secure the largest share in the international market.

Finally, from the experiments described above, the question arises as to whether the wage in Catalonia was a "high wage", allowing the profit derived from quality improvement to be allocated to capital return, or if it was instead a "low wage", suggesting that the proposal of sharing profits between capital and labour should be interpreted more in terms of a proposal of capital domination over labour. For this purpose, it is necessary to convert contemporary piece-rates to equivalent daily wages in order to determine the estimated daily wages as per the Board's calculations compared to the existing remuneration, a task that poses a considerable challenge (see Humphries and Schneider 2019 for the British case). Taking into account that the piece rate in Barcelona was approximately 15 Catalan *sueldos* per Catalan pound (of weight) regardless of quality (Table 2), and that the working time required for the lowest quality silk by a master spinner was 6.3 hours/Catalan pound of weight (*aldúcar*, as shown in Table 4), the piece-rate effectively equated to 30.95 Catalan *sueldos* per working day. For medium-high quality silk, the working time was 7.5 hours/Catalan pound of weight (Table 4), corresponding to 26 Catalan *sueldos* per working day. And the working time for high-quality silk (fine silk) was 10.53 hours per Catalan pound of weight (Table 4), which translated to 18.51 Catalan *sueldos* per working day. Consequently, the piece-rate remuneration system was very regressive in relation to quality.

In summary, the remuneration for spinning at a piece rate of 15 *sueldos* per pound of weight (Table 2), translated to a gross daily wage ranging between 18.51 (for the highest quality of silk) and 30.95 *sueldos* (for the lowest quality of silk) from which a daily coal (or firewood) cost needed to be deducted (see Appendix 4). This resulted in net daily wages of 9.51 (for the highest quality of silk) to 21.95 *sueldos* (for the lowest quality of silk). In comparison, Martínez-Galarraga and Prat (2016) estimate the wage of cotton spinning in Barcelona during that period to be around 8 or 9 Catalan *dineros* per working hour based on Okuno (1999). Assuming the same 13-

hours working day for comparison, this wage ranged between 8.66 and 9.75 *sueldos* per day. According to Martínez-Galarraga and Prat (2016), this wage level in cotton spinning was sufficiently high to incentivize the adoption of labour-saving spinning technologies, in line with Allen's "high wage economy" view, which states that high labour cost relative to capital drove innovation and the adoption of new technologies (Allen 2009). Comparing cotton and silk, the wage for cotton spinning was close to the lowest silk-spinning wage (for the highest quality silk-spinning), implying an integrated labour market in Barcelona characterised by a high wage in an international context (8.66 to 9.75 *sueldos* per day for cotton versus 9.51 *sueldos* per day for silk). However, the cotton spinning wage was less than half of the wage for the lowest quality silk-spinning (8.66 to 9.75 *sueldos* per day for cotton versus 21.95 *sueldos* per day for silk). In simple terms, the spinners were spinning at a very low level of quality, driven by a remuneration system based on the number of pieces spun, regardless of quality. This system encouraged them to spin rapidly in order to more than duplicate their wage in relation to the market wage for spinning activity, a strategy potentially influenced by the seasonal nature of silk spinning in contrast to cotton spinning.

CONCLUSIONS

At the end of the Old Regime, Catalan silk manufacturing was not competitive in the international markets because of the poor quality of silk spinning. This article has analysed the female silk-spinning apprenticeship school of the Barcelona Board of Trade in the prelude to the Industrial Revolution to explore the intersections between technological change, productivity, profitability, spinners' dexterity and silk-spinning quality and profitability of the silk-spinning activity.

The Barcelona Board of Trade was a sub-delegation of the General Board of Trade, which had to be notified of the most relevant issues and to whom it was accountable for revenues and investments. As a consequence of this institutional structure, the archives of the Barcelona Board of Trade contain abundant quantitative and qualitative information about the school's performance in its historical context. The main conclusions can be summarised as follows:

First, focusing on the relationship between silk-spinning quality and spinners' dexterity: dexterity was crucial for achieving high quality standards. Dexterity impacted quality at two levels. One was concerning the interaction with the machine to maintain a constant movement to form a homogeneous thread from the silk filaments to produce high-quality spun silk that did not break during the subsequent process of twisting together several threads to make the final yarn.

Dexterity had a significant impact on the reduction of waste and labour time. The other was related to the handling and classification of cocoons to avoid wasting expensive raw material by mixing different qualities of silk, which would drastically reduce the selling price of high-quality silk. However, the piece-rate system of spinning retribution discouraged spinners from aiming for quality, as producing higher quality was more time-consuming.

Second, focusing on the relationship between quality and technology: when comparing the two main silk-reeling technological innovations introduced at the end of the Old Regime, both Vaucanson and Piedmontese machines were better than the traditional Spanish machine in terms of improving quality and saving labour time, but neither was inherently superior to the other since the quality of the spun silk did not depend so much on the technology of the respective machines as on the dexterity of the spinner. In the prelude to the Industrial Revolution, the shift from hand spinning to mechanised spinning was a gradual process of technological innovation in which the silk yarn's quality depended on technology, spinners' dexterity, and the interaction with the institutional framework that either encouraged yarn quality through daily wages or discouraged it through piece-rates.

PRIMARY SOURCES

Fons de la Junta de Comerç de Barcelona. **Archive of the Royal Barcelona Board of Trade (*Biblioteca de Catalunya, Barcelona*)**

- BC, AJC, collection LI, box 68, folder 14 (206 pages): "*Expediente de María Margarita Bertot, natural de Piamonte, que ha de enseñar el método de hilar la seda como en su país (1784-1786)*" [File of María Margarita Bertot, a native of Piedmont, who is to teach the method of spinning silk as in her country (1784-1786)]

- BC, AJC, collection LI, box 68, folder 16 (72 pages): "(1785) Informe de la *Companya de Filats de Cotó* sobre el desorden y los abusos que se cometen en los tejidos y pintados de las fábricas de indianas de Cataluña" [(1785) Report of the *Cotton Spinning Company* on the disorder and abuses committed in the fabrics and painted fabrics of the factories of calicos of Catalonia].

- BC, AJC, collection LI, box 68, folder 19 (449 pages): "*Expedientes sobre la hilatura de seda. Reglamento interino de la Junta de Comercio*" [Silk spinning records. Interim regulations of the Board of Trade]

- BC, AJC, collection LI, box 69, folder 30 (88 pages): "*Expediente de la hiladora María Margarita Bertot, maestra de hilar la seda*" [File of the spinner María Margarita Bertot, master of spinning silk]

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APPENDIX 1. SILK SPINNING TECHNOLOGY IN PREINDUSTRIAL SPAIN

Silk manufacturing was introduced to Spain by Arabs in the 10th century. According to Solà (2016), we know little about the spinning machines used in Spain in the preindustrial period, despite the long tradition of silk manufacturing.

Silk spinning consisted of three main processes: reeling, throwing and doubling. **Reeling** was the first step in the preparation of the silk yarn in which filaments from cocoons were wound together on a reel to form a single thread. The documentary "*Silk. This is how the silk thread is obtained and elaborated from the breeding of the worms*" (2020) shows the preindustrial Spanish reeling machine still in use in the Museum *Las Hilanderas El Paso*.[33]

The description of the reeling machines offered in this Appendix is mainly based on the explanations given by the Interim Ordinance of the Royal Barcelona Board of Trade (1777) (see Appendix 2). The preindustrial Spanish reeling machine looks like the Chinese one described by Kuhn (1981) (see Image A1.1), similar to the traditional Calabrian (south-west Italy) large reel reeling machine (*ad aspo grande*) (Fusco 2011, Figure 2)[34]. The cocoons were put into hot water and rotated with a brush to soften their gummy substance (sericin). The outer part of the cocoon that was not going to be reeled was removed (*cadarzo* in the Spanish language). The thread formed with the cocoon filaments passed through the guiding-eye, then went up to the roller to dry it out, from where it passed through a hook that crossed the filaments within the thread due to the movement of the ramping-board, and finally, the thread was wound onto the reel.

The second step in the process was **throwing,** wherein the silk thread that had been reeled into skeins was first degummed and then stretched onto a wooden frame from which the thread was spooled by a throwing motion and wound onto bobbins. Finally, **doubling** consisted of twisting together several threads to make the final yarn strong enough to be used in the loom.

Diderot's *Encyclopédie* illustrates the Spanish throwing and doubling machines in 1770s (see Image A1.3).[35] Again, the Spanish throwing machine imitated the Chinese described by Kuhn (1981, 60-61). The doubling machine was hand-operated and resembles the ordinary spinning wheel used in Europe since the Middle Ages (see Crippa 1990 and Patterson 1956).

Spanish throwing was described by Diderot and d'Alembert (1772, 5) as: "A female worker unwinds a skein of silk that is stretched by means of two vertical pieces of wood fixed on wooden blocks; we call these pieces of wood, which must be rounded and polished on the outside, poles [wooden frame]; it is on these two pieces that the skein is stretched. Near one of

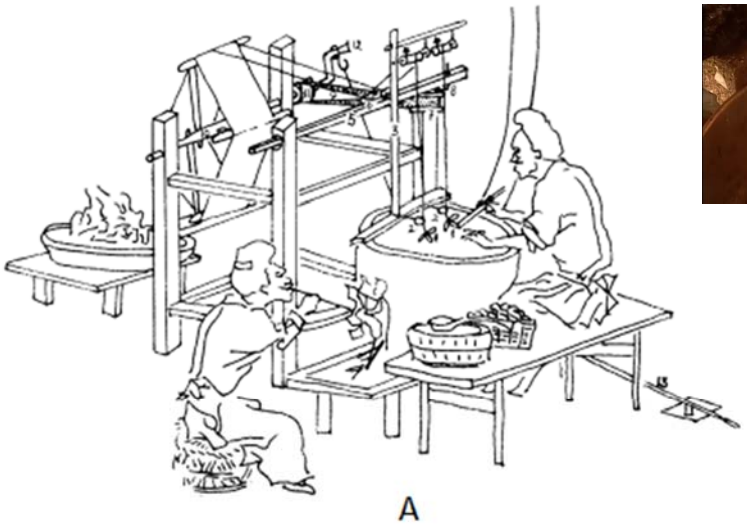
[33] Museum Las Hilanderas El Paso (founded in 2002) http://lashilanderaselpaso.com/en/ (Documentary on preindustrial silk spinning available in youtube: https://youtu.be/vpRIABctmrY)

[34] N.B. the French reeling machine was similar, but it did not have the roller, see Image A1.2

[35] Diderot's description of Spanish machines is consistent with that given by the contemporary Ramón Buxeau, who described in this travel book *Diario de los Viajes hechos en Cataluña* that all the silk-throwing machines in Manresa (Catalonia) were powered by men in 1789, except only one that operated by hydraulic power for a few years (in Solà 2016, 114)

the poles, and in the same block, there is a stanchion at the top of which is hinged a wooden ruler. This ruler, loaded at one end with enough weight to hold it up high, is topped at the other end by a glass hook over which the silk thread passes and descends again to the bobbin onto which it is wound, and upon which the worker's left hand leads back-and-forth, while with her right hand she rotates the wheel. The ruler - to which the glass hook is attached - is tied with a rope by which the worker lowers it to be able to place the end of the silk on the hook".

Image A1.1. Chinese and Spanish silk-reeling



A. The Structural and Functional Parts.
B. The Functional Parts.
C. The Pulley and the Eccentric Lug.
1 Cocoon-assemblies 2 Guiding-eyes 3 Rollerframe 4 Rollers 5 Ramping-board 6 Hooks 7 Pulley 8 Eccentric Lug 9 Driving-belt 10 Axle of the Silk-reel 11 Crank-case 12 Crank 13 Treadle

2. Guiding-eye

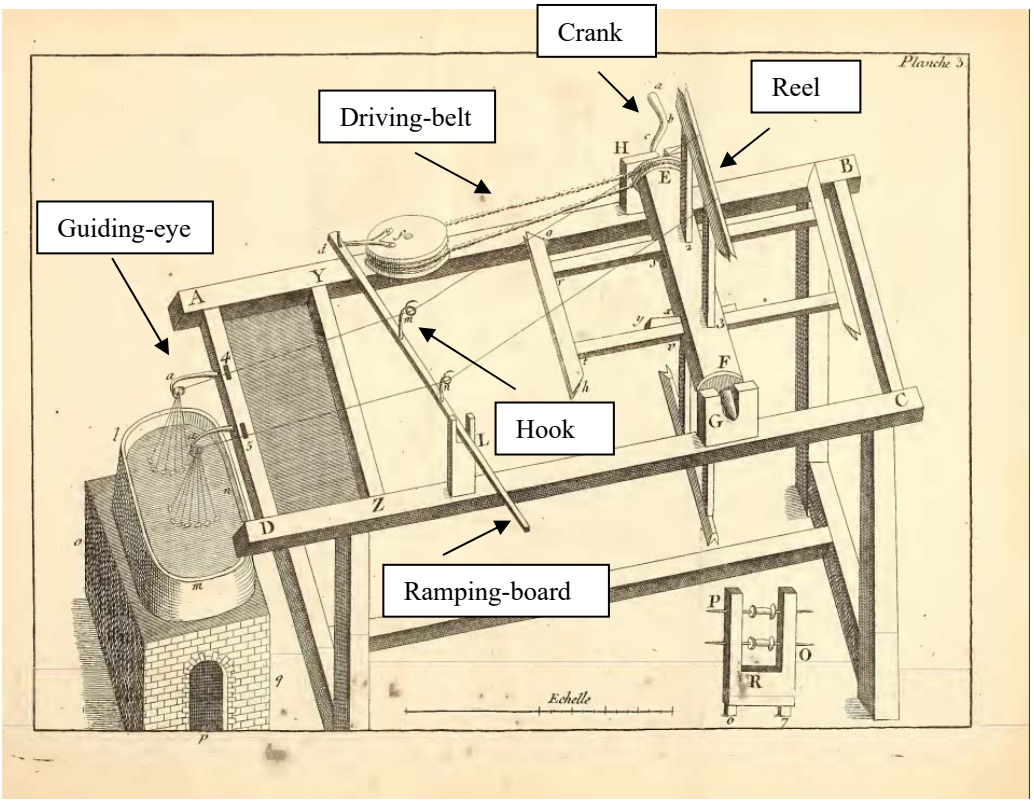
5. Roller

6. Hook

5. Ramping-board, and
9. Driving-belt

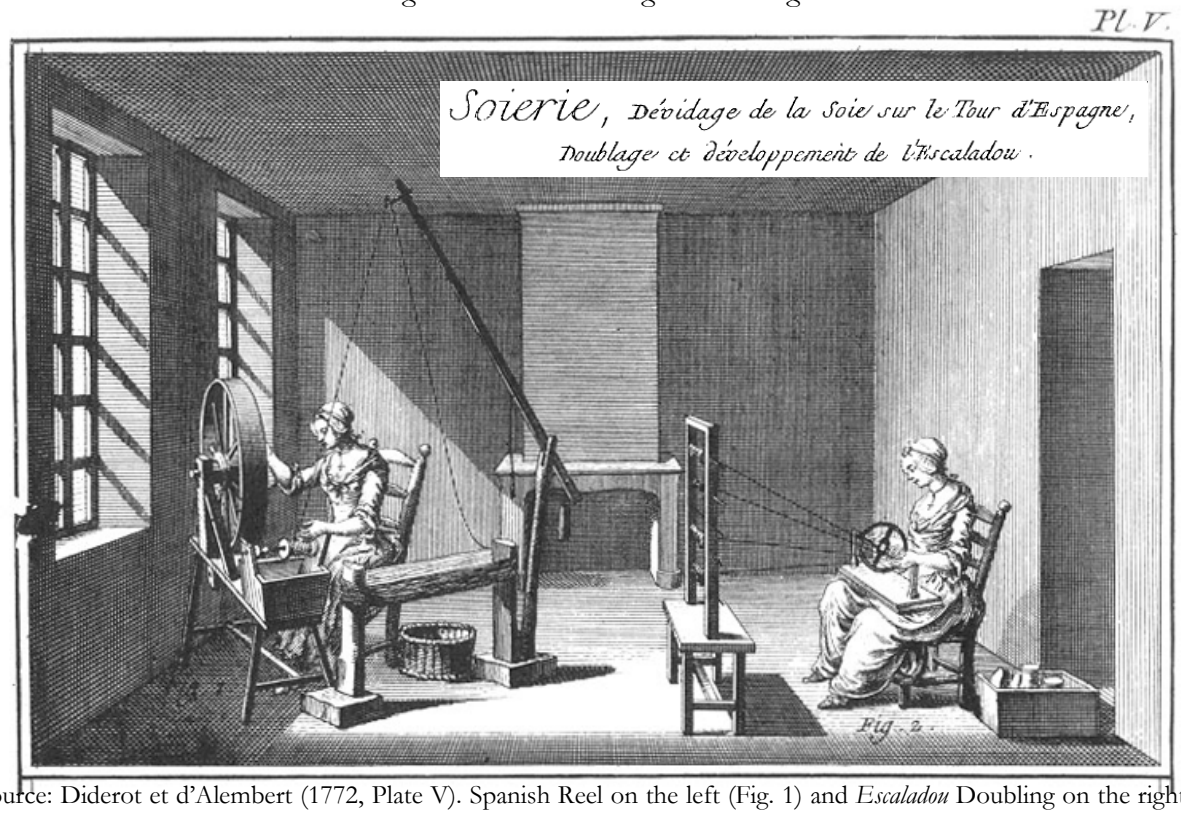
Source: drawing of 13th century Chinese silk-reeling machine in Khun (1981, Fig. 5,6). Images of the relevant parts of the Spanish silk-reeling machine are taken from the documentary *Silk. This is how the silk thread is obtained and elaborated from the breeding of the worms*" (Museo Las Hilanderas El Paso).
On small reels, the same person who controlled the cocoons rotated the crank with her/his foot by means of a treadle at the same time. On large reels, a second person moved the crank directly.

Image A1.2. French silk reeling (before Vaucanson)



Source: Pomier (1754, planche 3)

Image A1.3. Silk throwing and doubling



Source: Diderot et d'Alembert (1772, Plate V). Spanish Reel on the left (Fig. 1) and *Escaladou* Doubling on the right (Fig. 2).

APPENDIX 2. INTERIM ORDINANCE OF THE ROYAL BARCELONA BOARD OF TRADE REGARDING SILK SPINNING (18 May 1777)[36]

The notorious damage caused to silk artifacts by the inadequate or null expertise of the male and female spinners of this Principality, who enter upon the execution of this delicate practice without any knowledge other than that which their own intelligence provides them, complemented by a brief instruction, and a poor observance and exercise, and no rules besides those dictated by their discretion and the malicious objective of hoarding enough wealth in a short period of work to spend the rest of the year at leisure, has led to several appeals being directed to the Royal Governing Board of Trade of this Principality (*Real Junta de Gobierno de Comercio del Principado de Cataluña*), asking for the establishment of an Interim Ordinance that will dictate what is needful for the silks that are gathered in this Principality to be properly spun, and, with certain inalterable rules, in conformity with those that are established in the Kingdom of Valencia.[37] And aware of the abovementioned damages and of the means with which they can be prevented in the future, the Royal Board has determined the requisites that must be fulfilled by those who dedicate themselves to the practice of silk spinning and the way in which they must spin it, in the following:

INTERIM ORDINANCE

I.

All individuals, of both sexes, who wish to engage in the art of silk spinning henceforth, must first present themselves before the Royal Barcelona Governing Board of Trade. The Board will arrange for their examination by specified individuals whom the Board itself will designate for this purpose within the jurisdiction (*corregimiento*) of Barcelona. Those who are from other jurisdictions must present themselves, or send representatives, before this same Board, so that it may determine the most appropriate procedure for their examination under the same rules as those applicable in the present city and jurisdiction. Those who, without having taken the aforementioned exams, practice the art of silk spinning in any town in Catalonia will be subject to a penalty of twenty-five [Catalan] pounds.

II.

All male and female spinners who pass the exams will be included in a list or roll that will be formed with them, which will contain, for each, their name, surname, and place of origin, the day of their examination, and the names of the examiners who examined and approved them, and this list or roll will be in the hands of the Royal Barcelona Board of Trade for its information.

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[36] BC, AJC, collection LI, box 68, folder 19, pages 2-5. Printed document, no publisher.

[37] The Regulation of Silk Spinning in Valencia (12 March 1772) is reproduced in BC, AJC, collection LI, box 19, pages 89-93. Valencia had the first position in the Spanish silk manufacture (Segura 1991, 154).

III.

After being examined and included in said roll, male and female spinners will each be given a certificate by the secretary of the same Royal Board, with which they must present themselves before the Justices of the towns where they want to spin silk, so that, having shown it, they will not be prevented from exercising their profession.

IV.

Since it has been determined not to set at this time the price that the spinner must charge for each pound of spun silk, this being more or less thin, according to the places where it is harvested and the hands that work it, prices must be convened upon by the harvester and the spinner with the corresponding fairness. If the two parts cannot amicably reach an agreement, they will go to the town Justice, who, after regarding all circumstances of the case, will assess the price according to what he thinks is fair.

V.

Once the aforementioned roll or list is formed, anyone who henceforth wants to enrol as a spinner must first practice the art of spinning for a time under an enrolled male or female master, who shall then grant them the corresponding certification that attests to this practice period, and, having been authorized by the Justices of the respective town and with this certification and another that certifies his/her name, surnames, and place of origin, the aspirant must go to the Royal Barcelona Board of Trade, which will dispose to have him/her examined, according to what is established in Chapter I. After verifying his/her suitability, he/she will be included in the book of enrolment of silk spinners and will receive the corresponding certificate. Master spinners are warned to behave faithfully in the granting of the mentioned certifications. If any one of them is discovered to have committed fraud in this regard, he/she will be rigorously punished.

HOW THE SILK MUST BE SPUN

VI.

Spinners shall separate the cocoons into three classes, that is, *espuma pura* for fine silk[38], the *paches* or soft cocoons for the silk that is vulgarly referred to as *retriado*[39], and the *aldúcar* for the silk of the same name[40], all of it drowned silk[41], and spinners shall not mix them, under penalty of ten *reales*, Catalan coin, for every pound that is spun contravening this Chapter.

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[38] *Espuma (*or *escuma) pura* is the silk from the cocoons containing only a single worm (Navarro Espinach 2004, 16).
[39] *Paches* (or *parches*) refer to cocoons glued together (Mármol Avila 2020, 62).
[40] *Aldúcar*, also known as *adúcar* or *capullo ocal*, is a cocoon formed by two or more silkworms together, which produces a filament that does not unwind smoothly and tangles easily (Navarro Espinach 2004, 16, and Mármol Avila 2020, 62).
[41] Drowned silk is the silk that is spun after drowning the worm by introducing the cocoon in hot water or in a hot oven.

VII.

Spinners shall ensure that cocoons are clean and the *cadarzo* has been removed before putting them in the pot[42], and that the water has the appropriate temperature, depending on what each class needs for the silk to be well cooked, and for no reason are they to mix outside or inside the pot, oil, honey, soap, alum, or any other ingredient that can adulterate the silks in the least, under penalty of ten Catalan pounds for each time that what this Chapter orders is contravened.

VIII.

Male and female spinners shall not (for now, and until another Ordinance allows it) use reels that exceed the measurement of fourteen Catalan palms of circumference, having to reduce the reeling machines that until now they have been making use of to these measurements. If they were larger, they shall also be especially attentive that their activity does not produce neither raw silk, nor the wrong cross, paying great care that the hooks have the proper movement, so that the skein is perfectly reeled, and clean of impurities, with the reel at least five palms distant from the pot, under penalty of confiscation and burning of the reeling machines that exceed the cited measurement, and five Catalan pounds for each time that that which is ordered is in this Chapter is contravened (see Image A1.1 on the silk-reeling machine).

IX.

No male or female spinner shall have more than five guiding-eyes for spinning nor give any of them together more than ten to twelve cocoons, to keep the thread running with the adequate evenness, under penalty of three Catalan pounds for every guiding-eye and cocoon that is exceeded, making sure that the guiding-eyes that are closest to the water have narrow and proportionate eyes to keep the worms' gummy substance [sericin], vulgarly referred to as mucus, from going through them.

X.

Being abusive and tremendously damaging to the skein the custom that female spinners have of covering the reel with a cloth, they are forbidden henceforth from this operation, so that they must conform their way of spinning to that of the male spinners, under penalty of three pounds for each time they contravene this.

XI.

Every spinner shall always have at least three current reels, so that they can obtain the silk well dry, with no need to shoot the first reel for at least twenty-four hours, under penalty of three Catalan pounds (see Image A2.1)

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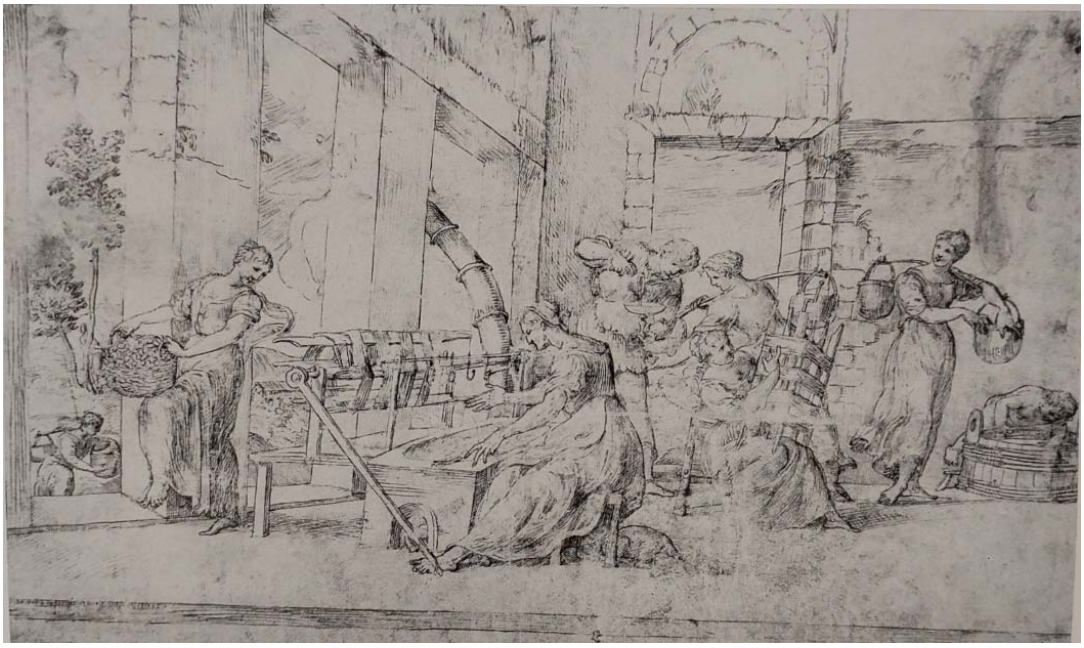
[42] *Cadarzo* refers to the coarse silk from the outer part of the cocoon that will not be spun (Mármol Avila 2020, 56) (see also https://skosmos.silknow.org/thesaurus/en/).

Image A2.1. Workshop of reeling silk (16th-century Florence)



Source: Patterson (1956, plate 8). Drawing of a silk reeling workshop. The reels were disassembled from the reeling machine, as shown by the woman to the right of the reeling machine.

XII.

If the circumference of the reeling machine were short, it shall be a four-sided reel only, for this will prevent the need for two of the supports that are commonly called *Udéts*, vulgarly *Boléts*, and the penalty for those who are found using reeling machines that being more than four-sided reels are liable to having them burned and paying a fine of three Catalan pounds.[43]

XIII.

Individuals in the guilds dedicated to the art of silk will have a special authority to vigilantly monitor if silks have been spun according to the present Interim Ordinance, and they are to inform the Barcelona Board of Trade of any violation that they learn about, so that it may carry out the actions that it sees fit.

[43] Older reeling machines were eight-sided reels instead of four. *Bolét* is a Catalan word defined in the Alcover-Moll dictionary of dialectal varieties of Catalan as: "Crust that is produced in the skeins of *grège* silk (natural colour raw silk reeled, but not twisted or degummed) due to the gummy substance that the silkworm secretes and that dries at the points of contact with the reel where the silk is placed during its winding operation, making the torsion afterwards difficult, for which reason these crusts are usually moistened by leaving them for a few hours in a water bath with vaseline or soap".

XIV.

All of the fines imposed in the chapters of this Interim Ordinance will be destined thus: a third for the expenses of the Chamber of the Royal General Board of Trade of the kingdom, another third for the Barcelona Board of Trade, and the other third part will be divided equally between the inspectors that said Barcelona Board of Trade will have appointed, and the informer; and in the case of there not been an informer, that corresponding half will be distributed among the said inspectors.

XV.

The Justices of the Principality will watch for the strict compliance of this Interim Ordinance and send to the Barcelona Board of Trade the names and surnames of the spinners in the respective districts under their jurisdiction, at the same time letting them know that during the following year inspectors (who will be named by said Board of Trade) will be sent to examine if it is being followed [and] teach them the method of spinning with perfection if they do not know it; and in case that some are contravening what is set out in this Interim Ordinance, the inspectors are granted with the authority to suspend them temporarily from their work, informing the cited Board of Trade so that it determines what is more convenient to guarantee the Ordinance's strict compliance.

CHAPTER ADDED

To the preceding Interim Ordinance, that must be equally observed.

White cocoons must be spun separately from the rest, so that the fabrics that need this kind of fine silk, and especially gauzes and blonde lace, can reach the appropriate degree of perfection.

APPENDIX 3. INSTRUCTIONS ON THE PERFECT SPINNING OF SILK BY MASTER SPINNER MARIA MARGARITA BERTOT[44]

"Rules that mut be observed in a silk spinning workshop, working under these General Rules, and other particular ones that Mrs. Maria Bertot promises to teach with the assistance of her husband Don Jayme Bertot, who has the plans for the entire process, from the ovens for steaming the cocoons to the spinning workshop, the mulberry plantation, and the arrangement of the seeds and worms. If the silk of Spain were spun according to the following Rules, it would be undoubtedly more perfect and more useful than that of Piedmont.

1st

Having observed the proponent that this is a very perfect climate, both for the planting of the trees and other practices poorly executed in this Province, whether it be regarding the arrangement of the worms or the creation of the seed, perfumes, as well as the handling of cocoons without distinction, which is very bad indeed, for the good one needs warmer water than the medium one, and the medium one a bit warmer than the bad one. Not observing this that is said, I see that in this country more than half are wasted, regarding which I want to make an advantageous experience.

2nd

Given that this climate is very favourable to this purpose, master spinner Maria was very surprised that spinners place the cocoon to bake in the sun, which causes it great harm. The worm does not die later, and at night, it pees and corrupts the rest, which leads half to be wasted.

3rd

Since master spinner Maria Bertot also promises for the next year of 1786 to conduct an experiment to have the worm be reborn, that is, to have two harvests, for the entire process should be concluded within a period of forty days.

4th

To make the separation of the seed [silkworm eggs], it will be necessary to distinguish between male and female cocoons, thus the seed will be good, and the cocoon will be perfect.

5th

When the purchase of cocoons is made, the Master must be obligated to verify them to be sure they are good. Then they should be chosen according to the seven qualities [listed] below, that is, separating the flower from those that are corrupted or stained. When this is not executed, when they are placed in the oven, the heat transmits this corruption to the good ones and weakens their gummy substance [sericin], which will not rise up with the other good ones. The spinner must be careful to take this bad cocoon, divide it, and place it with the waste silk, and if this is not carried out, the owner of the silk will suffer significant damage.

[44] BC, AJC, collection LI, box 68, folder 14, letter 16 December 1785.

6th

The Master will supervise how the spinners work the cocoon, for it happens that when little care is used, they cause significant harm to the owner, for which the master or director must held accountable.

7th

The day before, the work for the spinners must be prepared. They must examine those who choose the cocoons as follows: they will place the cocoons on a large table in the middle of which there will be two large baskets. In one of them, they will put the 2nd *Ducad*, and in the other, the 1st not cooked yet. Each of the women will have another basket under the table, where they will put the flower, and one of them will be emptying the baskets and placing others. Then, they will be placed in a room where they can be properly conserved.

8th

When this selection has been carried out, they will placed in the sun for three quarters of an hour and no more. Then, they will be placed in baskets, in such a way that they are not too full, for it is necessary to place a thin cardboard over them with bricks on top so that they do not move with the heat, and the heat can be communicated to the bottom of the basket. They will be thus placed in the oven in this way: when they are cooked, the baskets will be placed one on top of the other, well covered, for a period of three hours in a tidy room, and the next morning, they will be taken and placed in reed beds in a well-aired room, and they will be well stirred to prevent them from being tormented by any woodworm. If what is stated is properly observed, the cocoon will last eight months and more.

9th

In order to ensure that the silk is perfect and useful, it will be necessary to make the following quality distinctions when selecting the cocoon:

Cochetti	1st -Flower Cocoon	Flower
Mazzo Capuglio	2nd -Half Cocoon	Half Flower
Taloppe	3rd -Somewhat Corrupted	Open
Cocaloni	4th -First *Ducad*	Similar to *Ducad*, and has no than a worm
Punti	5th -Pointy	Pointy, unknown
Sordi	6th – The one that does not sound.	Deaf. Corrupt.
Ducat	7th -*Ducad*	*Ducad*

And these different types of cocoons must be worked one by one without using with one the water of another kind of silk.

Puntiagudo and *Sordo* are proposals made by Don Jayme Bertot and approved by Master Spinner Maria.

10th

Care must be taken that the silk does not get smoked, because the smoke fattens it and it loses its lustre, and for this reason the spinning workshop must be built like those in Piedmont, the designs for which are held by Master Maria or her husband.

11th

The master will oversee that the spinners soak well in the hot water all those cocoons that must be worked for a period of the four hours of work, and [make sure that] at the same time they have a bucket with water to temper those of the tub, according to what the cocoons require; and [make sure that] the spinners have few cocoons in the tub, and if all that is said here is observed, Spain's cocoon will give more than that of Piedmont.

A warning: if the cocoon is fresh, it shall not be soaked before, but if it is dry or baked, it must be soaked before work.

12th

They should also observe that spinners have their brush low when they work, so that the cocoon is purged and, at the same time, they do not purge more than five or six at once, and from this more production will than from those who, having one or two filaments left, purge five or six, and doing this makes the silk uneven. [They should also observe that] they keep the tub full of water and with few cocoons inside, which will be very advantageous.

13th

For the silk to acquire a proper lustre, it is necessary for the reeling machine to turn strongly and evenly.

14th

It will be observed that, if the spinners have many cocoons in the tub, and the water is made hotter than it should be, more than half will be spoiled.

15th

The master will verify that the fire in the stoves is below the filament that is rising to observe the work well, and that they are separated in equal parts. If the fire is extended below the entire tub, the cocoon will take it all and the work of the spinners will not be visible.

16th

The workday: at four in the morning, the spinners shall have their baskets ready, and filled with weighed cocoons to start their work, which will last until nine. From nine to ten, they will have freedom, and at ten, they shall return to work until two, when they will have another free hour. Then, they will return to work until nightfall.

17th

Every night at seven, spinners will hand over their work to the master spinner, who will put on each skein the name of its respective spinner.

18th

A good spinner should not have the silk thread too high on the finger to shape it, for, having the finger thus high, the reeling machine will never be used properly.

19th

The boy or woman operating the reeling machine and selecting the cocoons must fill the tubs and buckets with water, light the stoves, and ensure that everything is prepared and clean to start work at four in the morning. The director or master is responsible for this. The director or master must also inspect the reeling machines every night to check for missing items, and to provide all necessary instruments, and arrange for a carpenter to perform any necessary task.

20th

When the fire of the stoves is lit, it will be necessary to be careful that the water does not boil before placing the cocoon inside, because if it boils, the water breaks, and the work will turn out poorly.

21st

The oven to bake the cocoon shall be built in the Piedmont style, of which Don Jayme Bertot has the design, which is as follows: the heigh of the floor nine or ten ounces, oval shaped; height in the middle must be nineteen or twenty ounces, with a rounded width that is four manly steps in length all around. The oven's mouth must be wide enough to allow the basket's easy entry, and behind, a small hole must be left that can easily accommodate a finger, and this will be used to check if the cocoon is baked.

22nd

It is necessary to warm the oven with vine shoots, for they produce the most violent fire, and when it is very warm, all of the fire and the ashes must be taken out.

23rd

No mice or any other animal must enter the room where the cocoons are placed.

24th

The kinds of silks produced in Piedmont are nine, and the master must carefully watch the spinners to make sure that the silk is worked according to those rules, so that there is beautiful and strong silk in the kingdoms of S.M.C. [His Catholic Majesty] profitable for trade and for the rights of S.M. [His Majesty].

The first will be called...*Fii*..... which will be of 3 to 4 filaments
The 2nd .....*Fin* (End)..... of 4 to 5
The 3rd .....*Media* (Middle)..... of 5 to 6
The 4th .....*Putativa* (Putative)..... of 7 to 8
The 5th .....*Ordinaria* (Ordinary)..... of 9 to 10
The 6th .....*Segunda Suerte* (Second Sort)..... of 12 to 12
The 7th .....*Mala* (Bad)..... of 20 to discretion
The 8th .....*Primer Ducad* (First *Ducad*); unknown
The 9th .....*Segundo* Ducad (Second *Ducad*)

There is another kind of silk called *Dubina* that is used for velvet, which the Noble Board has not seen made, and Master Spinner Maria Bertot makes it as exquisitely as she does the rest.

25th

Anybody will be allowed to spin the silk, and with six stoves in the workshop, it is necessary to have a master spinner to make sure that *Fii* silk is worked following the said rules, under penalty of one hundred gold *escudos*.

26th

All those who have silk workshops must take the silk to the royal weighting machine every week under penalty of having it seized and being punished by the Intendent as he sees fit. The silk must not leave the Kingdom without paying its custom duties, and removing it without payment will be considered contraband, leading to the confiscation of horses and carriages.

27th

The main damage caused by spinners to silk owners are eight:

1st - not purging the cocoon enough,

2nd - purging it too much,

3rd - those that want to appear as if they are always working, when they stop stepping on the reeling machine, allow the filaments to run over, which produces uneven silk,

4th - those who want to earn a higher wage, allow more filaments than are needful,

5th - those who do not observe the said Rules,

6th - those who let the filaments run over,

7th - those who do not regard the work as their own, and do not complete the task of spinning the cocoon, but instead break it and toss it with the waste silk,

8th - the little product rendered by the beginners; it is enough that the little that they make is good and does not injure the owner.

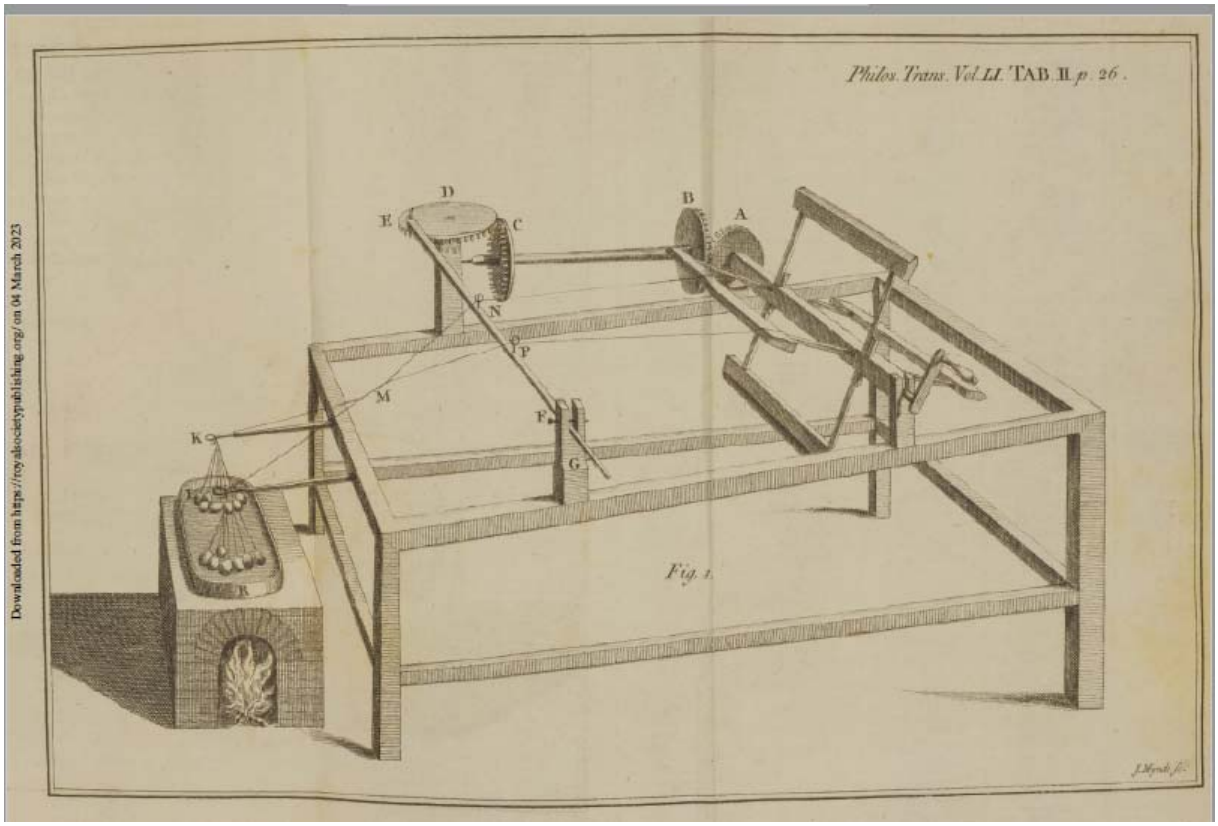
28th

If when the gentlemen consuls or government representatives visit said workshop, they do not find the silk adequate, they shall cut the threads, close the workshop, and have [the owner] pay one hundred gold *escudos*.

29th

The Piedmont style machine must be all of walnut wood, the wheels and other parts [of the machine] of apple wood in this way: the machine must be nine palms and a half tall and four palms wide; of the two front feet, the first must have two palms, two quarters and a half, and the other between three and three quarters; the feet of the back bench [must be] four palms and three quarters; the base of the wheel, two palms three quarters and a half; the reel on which the silk is wound must be eleven palms three quarters and a half; the tree of the wheel, two palms and half; the ramping-board that comes and goes, five palms; the tin to spin all sorts of cocoons must be two palms and three quarters latitude, and two palms and a half deep. Whosoever does not observe this shall be fined one hundred gold *escudos* (see Image A3.1).[45]

Image A3.1. Piedmontese reeling machine



Source: Pullein (1959, Tab. II). Pullein (1959) offers a very detailed description of the Piedmontese reeling machine.

[45] A documentary showing the Piedmontese reeling machine is available in https://vimeo.com/180895996

APPENDIX 4. RESULTS OF EXPERIMENTS ON PIEDMONTESE AND VAUCANSON REELING MACHINES [46]

CALCULATIONS OF THE SILK SPINNING EXPERIMENT WITH THE PIEDMONTESE REELING MACHINE

1) Test, 10 June 1784:

Purchase of 17 lib. 2 onz. cocoons at 12 s./lib. ..... 10 l. 6 s. 0

The above mentioned 17 lib. 2 onz. produced 16 lib. 1 onz. of drowned coccons.

[Although said operation was practiced in two different days, we calculated, adding the time it took up each day, a full 13-hour workday]

The above-mentioned drowned 16 lib. 1 onz. produced:

13 ¾ onz. 3 arg. fine silk of 5 cocoons at 90 *reales*/lib. ..... 10 l. 9 s. 0

3 onz. 3 arg. *aldúcar* [47] at 37 1/2 *reales*/lib. ..... 1 l. 0 s. 0

7 onz. cocoon (left for spinning later) at 12 s./lib. *[purchase price]*..... 0 l. 7 s. 0

..... 11 l. 16 s. 0

They are reduced by 1 ½ arrob. coal at 9 s./1 ½ arrob. ..... 0 l. 9 s. 0

..... 11 l. 7 s. 0

[Market value is estimated by experts]

"According to the above demonstration, the profit obtained from the value and expenses of the spun cocoon -without taking into account the spinner's wages-, considering the value given by experts to the spun silk and *aldúcar* is 1 l. 1 s. 0 *[that is, the final amount of 11 l. 7 s. minus the cost of 10 l. 6 s. for the purchase of the cocoon]*, so that applying this profit for the work of the spinner does not result in the slightest detriment form this experiment, and it produces the benefit of a perfect silk that is not commonly spun."

Nota bene: notice the experiment shows that the maximum daily wage that the spinner could earn at the highest level of quality is 21 *sueldos* (1 l. 1 s. 0) if the spinner works for herself, that is, without considering an entrepreneurial profit if the spinner works for a third party.

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[46] BC, AJC, collection LI, box 68, folder 14, letter 19 July 1784. The abbreviations for mass units are: lib.=*libra* (Catalan pound), onz.=*onza* (Catalan ounce), arg=*argenzo*, arrob.=*arroba*. The equivalences between mass units are: 1 lib. = 12 onz., 1 onz. = 16 arg. The abbreviations of the currency units are: l .= *libra*, s. = *sueldo*; the amounts that are not accompanied by any abbreviation are *dineros*. The equivalences between currency units are: 1 l. = 20 s., 1 s. = 12 *dineros*. Additionally, the equivalence with *reales* is: 1 l. = 10 *reales*. Alsina i Català (1996).

[47] *Aldúcar* is a cocoon formed by two or more silkworms together (see Appendix 2).

2) Test, 11 June 1784:

Purchase of 17 lib. 11 onz. white cocoons at 14s./lib. .....12 l. 10 s. 10

The above mentioned 17 lib. 11 onz. produced 16 lib. 1 onz. of drowned coccons.

The above-mentioned drowned 16 lib. 1 onz. produced:

1 lib. 7 ¼ onz. 2 arg. fine white silk of 6 cocoons at 95 *reales*/lib..... 15 l. 2 s. 9

1 lib. 4 onz. cocoon (left for spinning later) at 14 s./lib. *[purchase price]*.....18 s. 8

.....16 l. 1 s. 5

[The above was operated on a single working day the aforementioned day]

They are reduced by 1 ½ arrob. coal at 9 s./1 ½ arrob. ..... 0 l. 9 s. 0

..... 15 l. 12 s. 5

Minus the cost of the cocoon .....12 l. 10 s. 10

Profit..... 3 l. 1 s. 7

[Market value is estimated by experts]

"According to the above demonstration, it follows that the value and expenses of the spun white cocoon -without taking into account the spinner's wage- would generate a profit of 3 l. 1 s. 7 *[3.08 pounds]*, considering the value given by the experts to the spun silk. Thus, applying 15 *reales [1.5 pounds=30 sueldos]* to pay the spinner's work would result in a profit of 1 l. 11 s. 7 with the great benefit of the perfect silk which is not commonly spun."

Nota bene: notice that by spinning white silk, which is a higher quality silk than in the previous experiment, a gross profit (before remunerating labour and capital) is obtained that allows paying the spinner a slightly higher salary than the market rate (15 *reales*; that is, 1.5 pounds, which is the 50% of the gross profit) with the other 50% of the gross profit constituting the net entrepreneurial profit (within a context of labour organization in workshops where spinners are remunerated for their working time and capital takes the surplus profit).

3) Test, 12 June 1784:

Purchase of 32 lib. 3 onz. yellow cocoons at 14s./lib. ..... 22 l. 11 s. 6

The above mentioned 32 lib. 3 onz. produced 31 lib. 3½ onz. of drowned cocoons.

The above-mentioned drowned 31 lib. 3½ onz. produced:

1 lib. 10 onz. fine yellow silk of 7 cocoons at 87½ *reales*/lib. ..... 16 l. 0 s. 10

13 lib. 9½ onz. cocoon (left for spinning later) at 14 s./lib. *[purchase price]* ..... 9 l. 13 s. 1

..... 25 l. 13 s. 11

They are reduced by 1 ½ arrob. coal at 9 s./1 ½ arrob. ..... 0 l. 9 s. 0

..... 25 l. 4 s. 11

Minus the cost of the cocoon ..... 22 l. 11 s. 6

Profit ..... 2 l. 13 s. 5

[Market value is estimated by experts]

4) Test, 14, 15, 16 and 17 June 1784:

Purchase of 64 lib. cocoons at (13s.10)/lib. ..... 44 l . 0 s. 0

The above mentioned 64 lib. were reduced to 58 lib. of drowned cocoons.

They were increased with those that remained from the 12th of the drowned cocoons[48]

13 lib. 9½ onz. at (13s. 10)/lib. ..... 9 l. 10 s. 9

The drowned 71 lib. 9½ onz. produced:

14 June: 1lib. 10 onz. spun silk of 8 cocoons at (8 l. 5 s.)/lib. ..... 15 l. 2 s. 6

15 June: 1lib. 1¼ onz. 3 arg spun silk of 4 cocoons at 9 l./lib. ..... 10 l. 1 s. 6

16 June: 11¼ onz. 2 arg spun white silk of 7 cocoons at (8 l. 5 s.)/lib. ..... 7 l. 2 s. 7

1 lib. 3½ onz. spun silk of 10 cocoons at 8 l./lib. ..... 10 l. 6 s. 8

17 June: 6¾ onz. spun silk of 12 cocoons at (7 l. 2 s.6)/lib. ..... 4 l. 0 s. 2

4¼ onz. 1 arg spun silk of worm cocoon at (5 l. 12 s. 6)/lib. ..... 2 l. 0 s. 5

1 lib. 3¾ onz. 1 arg of *aldúcar* at 40 *reales*/lib. ..... 5 l. 5 s. 5

..... 53 l. 19 s. 3

[In this latter experiment, profit, which can easily be obtained by subtracting the purchase price of the cocoon and a value of 9 sueldos *daily from the cost of coal, was not calculated directly.]*

[48] Keep in mind that this operation does not entail transformation but refers to the inventory valuation method, which is the current price (and not the purchase price). That is, it refers to cocoons that had been valued at 14s./lib. the previous day (at the purchase price of that day), and they are revalued the next day at the current price of (13s.10)/lib.

CALCULATIONS OF THE SILK SPINNING EXPERIMENT WITH THE VAUCANSON REELING MACHINE

Test, 16 June to 30 June 1784:

Purchase of 69 lib. 3 onz. cocoons at (13s.10)/lib. ..... 47 l. 18 s. 0
The above mentioned 69 lib. 3 onz. were reduced to 67 lib. of drowned cocoons.
The above-mentioned drowned 67 lib. produced:
6 ¾ onz. 2 arg fine silk of 5 cocoons which were spun on the 18th and 19th
in the course of 6 hours (estimated by experts) at 86 *reales*/lib. ..... 4 l. 18 s. 7
9 onz. fine silk of 7 cocoons which were spun on June 21st in the course of
9 ½ hours at 81 *reales* /lib. .....6 l. 1 s. 6
10 ½ onz. 2 arg. fine silk of 8 cocoons which were spun on June 22nd in the
course of 7 ½ hours at 81 *reales* /lib. .....7 l. 3 s. 5
4 ½ onz. white silk at 6 cocoons and 4 ½ onz. 2 arg yellow silk of 9 cocoons
that were spun on June 23rd in the course of 8h ¾ at 88 ½ *reales* /lib the white one
and 75 *reales* /lib. the yellow, with a joint value of (3 l. 6 s. 4 and 2 l. 17 s. 10) .....6 l. 4 s. 2
11 ½ onz. 3 arg silk at 10 cocoons which were spun on June 25th in the course of
7 ¾ hours at 78 ½ *reales* /lib. ..... 7 l. 13 s. 0
18 ¾ onz. silk of 12 cocoons that were spun on June 26th in the course of
11 hours at 70 *reales* /lib. ..... 10 l. 18 s. 9
13 ¼ onz. *aldúcar* that were spun on June 30th in the course of 7 hours
at 38 ½ *reales* /lib. .....4 l. 5 s. 0
3 lib. cocoons left for spinning at (13s.10)/lib. .....2 l. 1 s. 6
.....49 l. 5 s. 11
Reduced by 7 arrob. 13 lib. coal.....4 l. 11 s. 3
.....44 l. 14 s. 8
Minus the cost of the cocoon .....47 l. 18 s. 0

Profit.....-3 l. 3 s. 4 [LOST]