London School of Economics and Political Science

Learning from the Muse: Indian Cotton Textiles and British Industrialisation

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Declaration

I declare that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of work carried out jointly by me and any other person is clearly identified on it.)

I warrant that this authorisation does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 69,591 words, excluding bibliography and indices.

In fond memory of Linda Eaton

Abstract

The thesis offers a new perspective on technological change in the British cotton industry. It explores the influence of Indian textiles on the process of cotton manufacturing, partly to match certain qualities of the products imported from India. Whereas an existing scholarship stresses this factor, the thesis analyses the nature of the influence with novel material evidence and a systematic review of documentary sources.

The thesis asks one main question: what was the impact of the imitation of Indian cotton textiles on the growth of cloth making and printing in Britain during the period 1740-1860? Using textual sources, the thesis identifies that the Indian influence was transmitted to the British cotton industry via the pursuit of quality to match that of the benchmark Indian cottons. It disentangles this impact by examining surviving British and Indian cotton textiles from this period through the lens of quality improvements related to cloth making and imprinting dye colours on to the cloth.

The research finds that cloth quality in the British cotton industry improved 99% from 1740-1820, measuring quality in terms of thread per inch count. It demonstrates a material shift towards lightweight, washable, affordable and fashionable cotton textiles. It shows that the process of imitation of Indian cottons provided solutions for two critical bottlenecks within cloth-making in Britain – first, the ability to make the all-cotton cloth, followed by the ability to make the fine all-cotton cloth. Connecting the findings from the material evidence with the mechanical evidence, the thesis identifies the making of the spinning jenny as basic mechanisation of the Indian spinning process, the waterframe as further mechanisation that enabled the overcoming of the first bottleneck and the making of the all-cotton cloth, and the mule as the key machinery that enabled the overcoming of the second bottleneck and the making of the fine all-cotton cloth. In line with historical textual evidence, it identifies a skill-gap within the British labour force related to the ability to spin adequate cotton warp that could compete with Indian cottons, and an early recognition amongst entrepreneurs to adopt mechanical spinning as a means of bridging this gap. It demonstrates that a combination of skill, technique and fibre staple determines final cloth quality, not the fibre staple in isolation.

In relation to calico printing, the thesis shows that print quality of British calicoes evolved to converge with that of Indian printed and painted cotton textiles. Textual evidence shows that

codified knowledge related to cotton printing techniques was transferred from India to Britain via Europe, and that Indian artisanal techniques of cotton printing and dyeing were adopted in Britain. The research finds that Indian textile dyeing techniques pertaining to Chay root used for imparting the colour red to cloth were adapted to develop the Turkey red process of red dyeing in Europe and Britain. It also identifies an intersection between the artisanal-empirical exploration of Indian dyeing techniques and the separately evolving science of chemistry through an overlap in the interests for understanding the properties of organic dye materials and their use in the creation of chemical dyes.

The study also points out that the historiography of dyestuffs, specifically the strand related to painting with blue on cloth, requires revision. Mainstream literature on the subject holds that the ability to paint with indigo on to cloth was first developed by the English around 1738 using the arsenic technique. This is in direct contrast to surviving material evidence in museums around the world where Indian textiles from as early as the 12th century are deemed by curators to have indigo painted on them. Scientific investigations of a handful of these Indian textiles using Raman Spectroscopy, X-Ray Fluorescence and Gas Chromatography-Mass Spectrometry have revealed that the blue deemed painted is indeed indigo but does not contain arsenic. This finding suggests that further scientific experiments are needed for the establishment of a correct and evidence-based historiography of textile dyes in human history.

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This thesis would not have been possible without the presence of two extraordinary figures in my life – my husband Arun Raman and my primary supervisor Tirthankar Roy. Arun first pushed me to pursue the life-long dream of attaining a PhD at a time when most people around me were sceptical about a shy and quiet mother-of-two embarking upon an academic career. He then pulled me out of a mental abyss and urged me to go on when, in the course of the PhD, I was close to giving it all up during our daughter's hospitalisation. Tirthankar Roy, a visionary academic, decided to respond to an email I wrote to him in the autumn of 2016 after reading one of his many books. It was a case of cold emailing a celebrated professor, that professor deciding to take your ramblings seriously and altering the trajectory of your life, culminating a few years down the road in the surreal experience of writing an acknowledgement for a doctoral thesis.

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Chapter 1: Introduction

To study the growth of cotton textile manufacturing in the 18th and 19th centuries is to study the foundations of industrialisation in Britain and those of modern economic growth in global history. The British cotton industry heralded large-scale use of machinery for the manufacture of a consumer product previously made largely by hand with the help of simple tools and rudimentary mechanical devices. In so doing, it was a pioneer, setting the trend for mechanisation and mass production of consumer goods, development and growth of machine making, and the deployment of energy resources for automation of machinery. It paved the way for the modern world as we know it, one of digital connectivity, computerisation, robotics, and artificial intelligence, through what we now know as technological change which led to an 'industrial revolution.'[1]

The history of cotton, on the other hand, is inextricably linked to the history of manufacturing in India. Recently analysed strontium isotopic evidence suggests that cotton as a plant species originated in the Indian subcontinent.[2] There exists a very long history of Indian cotton manufacture and the trade of Indian cotton goods to West Asia, South-East Asia, Eastern Europe and the Mediterranean.[3] Geographically, as well as through an artisanal tradition of manufacture, cotton is connected to India. It is no surprise that the coveted Indian blue dye is called 'indigo' and French imitations of Indian printed textiles are called 'les indiennes,' owing to the Indian origins of the techniques used to make these textiles.[4] Therefore, this thesis asks, and attempts to answer, one simple question - did the imitation of pre-industrial Indian cotton

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[1] The term was first coined by Arnold Toynbee in *Lectures on The Industrial Revolution*, Longmans Green, London, first published 1884

[2] Saskia Ryan et al, Strontium isotope evidence for a trade network between south-eastern Arabia and India during Antiquity, *Nature*, Scientific Reports, 11:303, 2021

[3] Janet Abu-Lughod, *Before European Hegemony: The World System AD 1250-1350*, Oxford University Press, 1991; John Guy, *Woven Cargoes: Indian Textiles in the East*, Thames and Hudson, 1998; Ruth Barnes, *Trade, Temple and Court: Indian Textiles from the Tapi Collection*, India Book House, 1999; John Irwin and Margaret Hall, *Indian Painted and Printed Fabrics,* Calico Museum of Textiles, Ahmedabad, 1971; John Irwin and Paul R. Schwartz, *Studies in Indo-European Textile History*, The Calico Museum of Textiles, Ahmedabad, India, 1966; Giorgio Riello, *Cotton: The Fabric That Made the Modern World*. Cambridge: Cambridge University Press, 2013; Sven Beckert, *Empire of Cotton: A New History of Global Capitalism*. UK: Penguin Random House, 2015

[4] Kim Seibenhüner, Art of making Indiennes, in Kim Seibenhüner, John Jordan, Gabi Schopf (eds.) *Cotton in Context: Manufacturing, Marketing and Consuming Textiles in the German-speaking World, 1500-1900,* Bohlau Verlag, 2019, p. 145-160

textiles have any impact on the trajectory of mechanisation and growth of the British cotton manufacture in the 18th and 19th centuries?

Literature abounds on the precocious rise of the British cotton industry and the related phenomenon of industrialisation, within which resides the holy grail of technological change. The mainstream strand of literature on technological change within economic history aiming to explain the industrial revolution credits exceptional British characteristics, such as culture or geography or particular resource endowments or local factor prices, for inducing industrialisation. It offers concise and precisely measurable supply-side responses for why the industrial revolution was British, focussing on answering one key question, 'why Britain?' According to Mokyr, the 'skilled' and relatively better educated British workforce situated within a wider epistemic base of 'useful knowledge' enabled the construction and deployment of mechanised processes of production.[5] What precisely was the nature of 'skill' and 'scientific knowledge' that enabled industrialisation in the cotton industry, and how it may have been a uniquely British characteristic, is unclear and open to debate. Landes roots industrialisation and modern economic growth in the scientific culture, attitudes of rational enquiry as well as a Faustian desire for mastery over man and nature.[6] The significance of the commercial avenues as well as global encounters that stimulated and fostered this scientific culture and rational enquiry, and arguably guided their evolutionary trajectories, is overlooked in this perspective. For Allen, a combination of high wages and cheaper energy generation increased the demand for labour-saving, fossil-fuel intensive methods of production, providing incentives for technological innovations.[7] For Broadberry and Gupta, higher wages in Britain facilitated the adoption of more capital-intensive production methods and faster rates of technological improvement.[8] Both these arguments assume that prior to mechanisation, all qualities of cotton yarn could be spun in Britain, albeit at an uncompetitively high cost. Evidence presented in this thesis suggests that this assumption is incorrect. Wrigley highlights the role of energy through

[5] Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress*, Oxford University Press, Oxford, 1990, p. 239-241; Joel Mokyr, Why the Industrial Revolution was a European Phenomenon, *Supreme Court Economic Review*, Vol. 10, 2003, p. 27-63; Morgan Kelly, Joel Mokyr and Cormac O Grada, Precocious Albion: A New Interpretation of the British Industrial Revolution, *Annual Review of Economics*, Vol. 6, 2014, p. 363-389

[6] David Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the present*, Cambridge University Press, 1969, p. 15-28

[7] Robert Allen, *The British Industrial Revolution*, Cambridge University Press, Cambridge, 2009, p. 15, 33

[8] Steven Broadberry and Bishnupriya Gupta, Lancashire, India and shifting competitive advantage, *The Economic History Review*, 62, 2, 2009, p. 279-305

the exploitation of abundant coal deposits that enabled sustainability of economic growth previously constrained by the limits of human or animate power.[9] According to Pomeranz, introduction and sustained availability of New World resources was the key to successful industrialisation in Britain, though he also emphasises local British energy sources as facilitating industrialisation.[10] While inanimate sources of energy as well as access to cheap and abundant raw materials were crucial to sustained economic growth from industrialisation, these arguments do not provide a rationale for the genesis of mechanisation in the cotton industry.

A Britain and Euro-centric thread runs centrally through this strand of the literature as it gleans factors specific to Britain and Western Europe that fostered industrialisation. In the process, local variables and lines of enquiry are prioritised, often with a decided exclusion of an arguably complex and globally interconnected set of factors that contributed to industrialisation, in favour of a few quantifiably verifiable domestic variables.

One crucial perspective not adequately factored in within the mainstream induced innovation approach is that of product quality. It overlooks the fact that the innovations in the British cotton industry often targeted matching the quality of the pre-industrial Indian cotton textiles. If imitation was a route to mechanisation, then what were the qualities and characteristics of the products the imitators targeted and sought to replicate? What was the impact of the process of imitation and replication of Indian cotton goods? Mainstream induced innovation models fail to address these questions sufficiently. At best, they offer partial explanations of the complex and multi-layered phenomenon of industrialisation in the British cotton industry.

Further, this approach amplifies the search for factors that make a society technologically creative or otherwise, looking for cultural and biological attributes that predispose some societies towards technological might and leaves others to 'vegetate in the backwaters of the stream of progress.'[11] Such a search navigates perilously close to cultural and biological determinism. A corollary of this perspective, the pursuit of what makes some societies more creative, inventive and innovative than others, is the flip side of the 'why Britain' question.

[9] E.A. Wrigley, *Energy and the English Industrial Revolution*, Cambridge University Press, 2010
[10] Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy*. Princeton: Oxford: Princeton University Press, 2004
[11] Landes, *The Unbound Prometheus,* p.7

Simply put, it is a question that asks, 'Why not France or The Netherlands or India or any other country in the rest of the world'? The scale of the problem thus posed is exacerbated by the narrow British lens usually deployed to frame the question, one that is ostensibly about the first industrial revolution in Britain, but counterfactually, about everything else in global economic history that is a residual of the first industrial revolution.

The second main strand of literature on the growth of the British cotton industry addresses it through the lens of consumer preference and global connections, asking the other crucial question on the theme - 'why cotton?' This demand-side lens studying the global diffusion of cotton textiles enables a study of industrialisation from a wider perspective, including ideas of import substitution, knowledge transfer, trade-led economic and technological incentives and indeed, consumer preference for the cotton cloth. A focus on consumer preference makes us aware that buyers minded quality as well as costs, and the idea of quality owed to the features and characteristics of Indian textiles. Therefore, a broader analysis of import substitution requires the historian to take a close look at the quality of the goods that acted as benchmarks for imitation and import substitution.

One of the earliest proponents of the need to address the issue of quality and the imitation of Indian cottons in any study of the growth of the British cotton industry was P.J. Thomas, who noted that copying and adaptation of Indian printing/dyeing as well as designs was at the core of the beginnings of calico printing in Britain.[12] S.D. Chapman, also focussing on British calico printing, demonstrated that a focus on the quality of the final printed cloth remained central to the growth of the industry.[13] Prioritising the appearance and quality of Indian cotton textiles as the stimulants for the growth of the British cotton industry, Maxine Berg has argued that the imitation of Indian cottons, especially fine Indian cottons, led to technological growth in the British cotton industry.[14] Giorgio Riello has stressed that matching the quality of Indian cottons was the primary concern for European manufacturers, well above issues of productivity or

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[12] Parakunnel J. Thomas, The Beginnings of Calico Printing in England, *The English Historical Review*, Vol. 39, No. 154, April 1924, p. 206-216

[13] S.D. Chapman, Quantity versus Quality in the British Industrial Revolution: The Case of Printed Textiles, *Northern History*, Volume 21, 1985, p. 175-192

[14] Maxine Berg, Cotton, Quality and the Global Luxury Trade, in Giorgio Riello and Tirthankar Roy (eds), *How India Clothed the World*, p. 391-414; Maxine Berg, From Imitation to Invention: Creating Commodities in Eighteenth-Century Britain, *The Economic History Review*, Vol. 55, No. 1, Feb 2002, p. 1-30

competitiveness.[15] According to Beverly Lemire, the popularity of Indian cottons was a result of their cheapness, light weight, colourful prints and washability. Alongside prohibition of Indian cottons in response to complaints from the woollen manufacturers, imitation of Indian cottons led to the development of the calico printing industry in Britain through a pursuit of quality as well as variety of Indian cotton textiles.[16] Prasannan Parthasarathi has emphasised that both domestic and global demand-led competition against Indian cottons and the pursuit to match their quality led to the growth of the British cotton industry.[17] John Styles has argued that in meeting the quality challenge of the Indian cottons, the British cotton industry laid the foundations for a mass market in cottons.[18] Making a trans-Atlantic connection and highlighting the centrality of cotton textiles within the slave trade, Joseph Inikori has argued that the British cotton industry developed by imitating Indian cottons for the discerning West African market.[19]

As the above summary of the literature on quality-led innovations in the British cotton industry shows, assessing the impact of imitations of Indian cottons through the pursuit of quality is not a new idea. What these characteristics of quality meant and how they were translated into making final British textile products, however, remains uncertain and open to interpretation. A few questions arise instantaneously. What did this quality entail? What were the characteristics of 'quality' in cloth making and in calico printing? What was the extent of the impact of these quality-led imitations on the transformations in the British cotton industry in the 18th and 19th centuries? Is quality of cloth and print related to the technology deployed to make a product of a particular quality?

Another theme common to both strands of the literature, though more so to the first, is the emphasis given to productivity gains through technological change. David has argued that experiential learning through 'learning by doing' leads to greater productivity and quality-

[15] Riello, *Cotton*, p. 224-227
[16] Beverly Lemire, *Fashion's Favourite: The Cotton Trade and the Consumer in Britain, 1660-1800*, Oxford University Press, 1991, p. 30-34
[17] Prasannan Parthasarathi, *Why Europe Grew Rich and Asia did not: Global Economic Divergence, 1600-1850*, Cambridge University Press, 2011, p. 89-114
[18] John Styles, Fashion, Textiles and the Origins of Industrial Revolution, *East Asian Journal of British History*, Vol. 5, 2016, p. 161-189
[19] Joseph Inikori, Slavery and the Revolution in Cotton Textile Production in England, *Social Science History*, Vol. 13, No. 4, Winter 1989, p. 343-379

related gains than protectionist policy interventions.[20] Recently, Peter Maw, Peter Solar, Aiden Kane and John Lyons have shown that productivity gains associated with the initial transition from hand to machine spinning have been overstated and that larger gains were made in the post-invention improvement phase of technological change.[21] This is an important finding which suggests that 'macro inventions' were motivated by a stimulus other than that of increase in productivity. This finding is expected from mechanical improvements to new machinery and begs one straightforward question – what was the need for the new machinery? In other words, what was the need for the mule if incremental technological improvements in the waterframe and jenny were sufficient for cotton manufacturing in Britain? While increased productivity is an integral component of any successful technological innovation, the early British cotton industry exhibits the onset of new machinery in quick succession. The raison d'être of the 'macro invention' of the mule cannot be explained through productivity gains alone and must necessarily factor in the issue of product quality. The issue of quality, in turn, is fundamentally connected with that of the benchmark, pre-industrial Indian cotton textiles as they set the market approved standards for the parameters of quality.

Existing literature touches upon, and even refers to, an innovative impulse coming from India and the replication of Indian cottons. But what this process precisely entailed and what was the form of the impact as well as its scale is unclear and subsumed under the expansive term of import-substitution.[22] While import-substitution as a theoretical concept aptly denotes the imitation of Indian cottons in Britain, it fails to delineate the different phases that marked this transitory period, the sources of impulses for technological advancements and the processes involved therein. Import-substitution also emphasises tariff and legislative protection for the growth of an emerging industry in its early phase at the expense of side-lining an organic and spontaneous imitation of foreign goods by domestic manufacturers once introduced into a new economic setting. While policy-based tariff-oriented protectionist measure have been well

[20] Paul A. David, Learning by Doing and Tariff Protection: A Reconsideration of the case of the Antebellum United States Cotton Textile Industry, *The Journal of Economic History*, Vol. 30, No. 3, 1970, p. 521-601

[21] Peter Maw, Peter Solar, Aiden Kane, John S. Lyons, After the great inventions: technological change in UK cotton spinning, 1780-1835, *Economic History Review*, forthcoming 2021

[22] Robert Allen, *The British Industrial Revolution in Global Perspective: How commerce created the Industrial Revolution and Modern Economic Growth*, Nuffield College, University of Oxford, 2006, p. 9; Joseph Inikori, *Africans and the Industrial Revolution in England*, Cambridge University Press, 2002, p. 405, 409

documented and studied by economic historians, the impact of imitations of foreign goods on the development of industry has been explored less extensively.

O'Brien has emphasised that 'As pioneer movers into unexplored realms and spaces for the exploitation of novel industrial products and technologies, British investors and entrepreneurs lacked examples of anything like a prior range experiments and experience from elsewhere.'[23] This research argues that British manufacturers had Indian benchmark cottons as examples of market and consumer-approved commodities that combined centuries of experiments and experience of Indian artisans. In imitating Indian cottons, British manufacturers benefited from these 'prior experiments and experience' and learning from them.

On the other hand, Rosenberg has observed that technological change is shaped by technological knowledge inherited from the past. He notes, 'Existing technologies commonly throw off signals and focussing devices indicating specific directions in which technological efforts may be usefully exercised.'[24] Further, referring to a 'soft determinism,' Rosenberg observes that historical events and technologies, without rigidly prescribing the path of future technological growth, often guide the sequence of technological changes.[25] In line with Rosenberg's reasoning, this research attempts to identify the 'soft determinism' of pre-existing Indian cottons on the machine-made British cotton goods, as well as on the trajectory of mechanisation during the critical phase of industrialisation, 1740-1860. The research identifies and analyses the influences that pre-industrial Indian cottons - the benchmark cotton products of the time - had upon early British cotton manufacturers, their products and production processes. It assesses their impact on British cotton manufacturing through the perspective of cloth and print quality. It aims to distil the effect that imitation of these benchmark products had on the trajectory of technological change in the infant British cotton industry.

While many variables have been proposed for technological change pertaining to the British industrial revolution, the influences of pre-existing products and their imitations – in this case the Indian cotton goods and their imitations in Britain – remain under-explored. This thesis

[23] Patrick O'Brien, A Representation of the First Industrial Revolution as a conjuncture for the Global Economic History of Transitions to Industrial Economies, *The East Asian Journal of British History* (2016) Vol. 5, p. 20
[24] Nathan Rosenberg, *Exploring the Black Box: Technology, Economics and History*, Cambridge University Press, Cambridge, 1994, p.14
[25] Ibid. p.15

fills this key gap in the literature. It contends that in the absence of written accounts aiding the knowledge transfer pertaining to their manufacture, new materials themselves act as the repositories of knowledge required for their making, as well as for demand stimulation in their new environments.[26] In this instance, the varieties of fabrics imported from India embodied the material knowledge required for their imitation, acting as prototypes for the nascent British cotton industry to gear its imitative efforts towards. The cloth, effectively, contained the knowledge required for its imitation. The thesis analyses the source at the heart of cotton manufacturing, but which has not played a significant role in shaping the industrialisation debate so far – the cotton cloth itself. This is a key contribution of the research, as it builds on information extracted from material sources, the textiles themselves, defining 'benchmark' as imitable characteristics of cloth and print quality for the purpose of recreating a cotton textile that contained the imitated characteristics.

The approach of this thesis rests on the view that industrialisation in the British cotton industry is an outcome of the historical intersection of Indian product and British production processes. According to Berg and de Vries, the introduction of new products into the early modern European societies contributed to knowledge transfer related to their manufacturing techniques. New products brought with them the knowledge required for their making, while simultaneously stimulating the demand for their manufacture in the new economies they were introduced into.[27] Following on from Berg's illustration of 'useful knowledge' of porcelain from China and other Asian goods accessed by the Europeans,[28] it may be argued that to understand the technological developments that marked the industrial revolution, it is first critical to understand how this shift began to take place and what the early means through which this shift manifested itself entailed. The pivotal phase then is the early period of import substitution when British textile manufacturers attempted to imitate the cottons from India. The

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[26] Ibid.; Alfred P. Wadsworth and Julia de Lacy Mann, *The Cotton Trade and Industrial Lancashire 1600-1780*, Manchester University Press, Manchester, 1931, p. 131-138; Beverly Lemire, *Fashion's Favourite: The Cotton Trade and the Consumer in Britain, 1660-1800*, Oxford University Press, New York, 1991, p. 31-35

[27] Maxine Berg, Useful knowledge, industrial enlightenment, and the place of India, *Journal of Global History*, 2013, p. 8; Maxine Berg, In pursuit of Luxury: Global History and British Consumer Goods in the Eighteenth Century, in *Past and Present*, 2004, p. 182; Jan de Vries, Understanding Eurasian Trade in the Era of the Trading Companies, in Maxine Berg et al (eds) *Goods from the East, 1600-1800, Trading Eurasia*, Palgrave Macmillan, 2015, p. 22; Prasannan Parthasarathi and Giorgio Riello (eds), Introduction, *The Spinning World: A Global History of Cotton Textiles, 1200-1850*, Oxford University Press, Oxford, 2009, p. 5

[28] Berg, Useful knowledge, p. 182

varieties of fabrics imported from India embodied the material knowledge required for their imitation, acting as prototypes for the nascent British cotton industry to gear its efforts towards. In addition to providing the competitive stimulus, Indian textiles also offered the benchmarks for yarn thickness, print, weave, and finish, acting as imitable examples of the market-approved final cotton products.

Linen-cotton production, part of the fustian manufacture in England, provided the domestic base upon which an import-substitution based cotton cloth-making and printing industry took roots. Linen-cotton manufacturers in England, as elsewhere in Europe, first attempted imitations of Indian cottons.[29] According to Lemire, prohibition of cotton goods in favour of woollens ensured that the emerging British cotton manufacture, which was experimenting with ways of making the all-cotton cloth, was effectively shut down.[30] This re-directed the focus of textile manufacturers towards fustians and allowed British manufacturers time and a protected domestic market to improve their wares. I argue in this thesis that this re-channelling of focus ensured that mechanisation took a specific path, geared as it was towards overcoming the limitations of fustian manufacture as entrepreneurs pursued the all-cotton cloth.

This thesis identifies learning from the benchmark product and competition against it as two simultaneous stimuli shaping the growth of the British cotton industry. It builds upon a longstanding literature on the global roots of industrialisation motivated by a demand and consumer preference-led approach, as adopted by Maxine Berg, Beverly Lemire, Prasannan Parthasarathi, Giorgio Riello and John Styles.[31] Its interface with material and textile analysis follows the works of Rosemary Crill, Ruth Barnes and Philip Sykas, who have all used historic textiles as evidence.[32] Its engagement with the history of science through chemical analysis follows in the footsteps of the works of Pamela Smith, Vibe Martens and Dominique Cardon.[33]

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[29] Lemire, *Fashion's Favourite*, p. 30, Berg, Useful knowledge, p. 117-141
[30] Lemire, *Fashion's Favourite*, p. 77
[31] Berg, Useful knowledge; In pursuit of Lux*ury*; Lemire, *Fashion's Favourite*; Parthasarathi, *Why Europe Grew Rich*; Riello, *Cotton*; John Styles, *Threads of Feeling: The London Foundling Hospital's Textile Tokens,* The Foundling Museum, London, 2010
[32] Rosemary Crill, *Chintz: Indian Textiles for the West*, V&A Publishing, 2008; Ruth Barnes, Rosemary Crill and Stephen Cohen, *Trade, Temple and Court: Indian Textiles from the Tapi Collection,* India Book House, Mumbai, 1999; Philip Sykas, *The Secret Life of Textiles: Six Pattern Book Archives in Northwest England*, Bolton Museum, Art Gallery and Aquarium, Bolton, 2005
[33] Pamela Smith, *Entangled Itineraries: Materials, Practices and Knowledges across Eurasia*, University of Pittsburgh Press, Pittsburgh, 2019; Vibe Martens, The Colourful Qualities of Desire, in Marie-Louise Nosch, Zhao Feng and Lotika Varadarajan (eds.) *Global Textile Encounter*s, Oxbow

I build on this densely packed body of existing scholarship by applying systematic scientific and statistical analysis to show the connections between pre-industrial Indian cottons and the growth of the British cotton industry.

1.2 Sources and Methodology

As the cotton industry - Indian or British - is fundamentally about the printed and/or plain cotton cloth, this research adopts a multidisciplinary methodology based upon empirical, scientific and digital analysis of surviving historical materials as well as textual evidence pertaining to the cotton industry.

The thesis brings to light the writings of manufacturers, traders and historians/observers of the period to assess how they viewed the cotton products from India, imitations of these products and the impact that they had on the infant British cotton industry. The study re-assesses the archival records of Richard Arkwright, the inventor of the waterframe, Samuel Crompton, the inventor of the mule or the muslin wheel, Samuel Oldknow, one of the first and most prominent English muslin makers, and Samuel and William Salte, Oldknow's London agents. It uses the writings and historical accounts of contemporaries and later commentators such as Edward Baines, Robert Guest, Andrew Ure and Thomas Ellison, who were some of the first observers and historians of the British cotton industry, to piece together contemporary accounts regarding the influence of Indian cottons on the growth of the infant British cotton industry.

The thesis adopts a novel methodology of relying primarily on material sources in the form of historic textiles to test the hypothesis of Indian influence on the growth of the British cotton industry. It tracks the evolution of both cloth and print quality in the British cotton industry to show convergence with Indian cotton cloth and print quality. It uses the textile samples in the Barbara Johnson Album at the Victoria and Albert Museum to determine the evolution of cloth quality in the British cotton industry from 1740-1820. It uses the John Holker Album at the Museé des Arts Décoratifs in Paris to check and corroborate the data from the Barbara Johnson Album. It compares this cloth quality data against Indian cotton samples of this period contained in the Textile Manufactures of India compilation by John Forbes Watson, currently residing at the Harris Museum in Preston. Using the vast cotton textiles collection at the

books, Oxford, 2014; Dominique Cardon, *Natural Dyes: Sources, Tradition, Technology and Science,* Archetype Publications Limited, London, 2007

Winterthur Museum, the thesis charts the evolution of colours in the British calico printing industry from 1700-1860. It then compares this finding against Indian cottons in the collection from the same time period.

Any material museum collection suffers from collection as well as survival bias. Pieces that are found in museums are carefully selected and curated, often reflecting curatorial and/or collector bias. The English and Indian textiles that primarily form part of this study have all been selected for specific purposes as additions to the museums' collections. Several others that have not survived the centuries are lost to us and our analyses. It is also likely that the use of textile materials collected by museums over time exhibits some other inherent selection biases not immediately discernible or even currently known. However, it is not possible to predict the nature and scale of these biases. Despite these limitations, the surviving textiles impart information and knowledge embedded in them, allowing them to be 'read' as texts. These historic material sources are used to construct data of cloth and print quality.

The thesis also uses three French manuscripts translated into English by John Irwin and P.R. Schwartz to determine codified transfer of printing and dyeing knowledge from India. These are the Roques manuscript compiled by Georges Roques between 1678-1680, the Beaulieu manuscript compiled by Antoine Georges Nicolas de Beaulieu sometime between 1726-1739, and the Coeurdoux manuscript, a series of letters by Père Coeurdoux, a Jesuit living in India between 1742-1747. It assesses their impact on the popular work by Edward Bancroft titled *Experimental Research concerning the Philosophy of Permanent Colours* first published in 1795. It uses these findings to reassess material evidence related to the technology of spinning and dyeing to distil the impact of Indian technology and techniques of cotton printing and dyeing. It uses descriptive accounts of the working mechanisms of the key machinery related to cotton spinning – spinning jenny, waterframe and the mule – to determine technological path dependence upon Indian cotton spinning techniques. These include accounts by R.L. Hills, Julia de Lacy Mann, Charles Singer, Morton and Wray to re-create the techniques of the spinning machines. For assessing the impact of Indian cotton printing techniques on the growth of British calico printing, a comparative assessment of the Turkey Red method of dyeing red is conducted alongside the Chay root method of dyeing red using Dominique Cardon's *Natural Dyes: Sources, Traditions, Technology and Science* (2017), Stena Nenadic and Sally Tuckett's *Colouring the Nation: The Turkey Red Printed Cotton Industry in Scotland* (2013), and the French manuscript by Beaulieu. Published dye manuals from 1700-1860 at the Winterthur

Library Collections are used to track the evolution of the demand for calico printing techniques. Using Voyant digital text analysis to get insights into Berthollet's famous dye manual *The Elements of the Art of Dyeing and Bleaching*, translated from French by Andrew Ure in 1841, the research tests for a shift away from art-based techniques of printing towards more scientific techniques and assesses if a continued emphasis upon cotton may be discerned despite the shift to chemical dyeing techniques.

The thesis also conducts scientific analysis using Raman Spectrometry, X-Ray Fluorescence and Gas Chromatography-Mass Spectroscopy on select Indian printed/painted cottons to determine Indian re-oxidation reducing agents for enabling direct painting with indigo on to cotton cloth.

1.3 Contribution and Thesis Structure

This thesis asks two inter-related questions: Did the imitation of Indian cotton textiles impact the growth of British cotton manufacturing; and is the technological change in the British cotton industry – the foundation of industrialisation – technologically connected to Indian techniques of cotton spinning, printing and dyeing? The thesis demonstrates that cloth and print quality in the British cotton industry evolved to match that of the Indian cottons – the benchmark cotton textiles of the period. It shows that first the all-cotton cloth, and then the fine all-cotton cloth, were made in Britain in imitation of Indian calicoes and muslins. Evidence demonstrates that codified knowledge transfer from India contributed to the development of printing and dyeing in the British calico industry. It clarifies that technological change related to the spinning of cotton yarn was a process of mechanisation of the Indian spinning techniques to compensate for an existing skill-gap in the British labour force. The analysis displays that in British calico printing, Indian dyeing techniques were adopted and adapted to the British printing and dyeing processes, and that there exists an overlap between the empirical knowledge from Indian dyeing techniques and the growth of the chemical science of dyestuffs. Further, the research challenges the current historiography of dyestuffs which claims that direct painting with indigo on to cloth became possible with the English discovery of the arsenic technique in the second half of 1730s. It points to the existence of material evidence since as early as the 12th century where curators deem parts of the blue on cloth to have been painted on rather than resist dyed. Scientific investigations, including destructive analysis of the material evidence, have demonstrated that the blue deemed painted on pre-1738 Indian cottons is indeed indigo, and it does not contain arsenic as per the English technique, highlighting the need for further investigations to determine pre-industrial Indian techniques of direct textile painting with indigo.

The thesis begins with Chapter 2 offering a historiography of pre-industrial textile manufacture in Britain, the introduction of Indian cottons and the early stirrings of imitation of these Indian goods in Britain. Chapter 3 provides the textual evidence related to imitations of Indian cottons as well as the rationale for the isolation of quality as the pathway for the imitative impulse. Chapter 4 presents the material evidence of the evolution of cloth quality in the British cotton industry and a comparative assessment with Indian cloth quality. Chapter 5 assesses the material evidence from the previous chapter against the mechanical evidence to show that the spinning machinery evolved to overcome the twin sequential bottlenecks of making the all-cotton cloth and making the fine all-cotton cloth, in order to match the quality and variety of cotton textiles from India. Chapter 6 sets out the evolution of colours on British printed calicoes from 1720-1860 to show that the colour count increased over the period to converge with the Indian printed and painted cottons. It shows that codified transfer of knowledge related to Indian printing and dyeing techniques came to Britain via Europe. It also points out problems with the current historiography of dyes pertaining to painting with indigo on cloth and conducts scientific experiments related to it. Chapter 7 shows that Indian artisanal printing and dyeing techniques were adopted and adapted to develop calico printing in Britain. It also shows an overlap in the interests of artisanal-empirical investigators of Indian printing-dyeing techniques with those of chemists – the two separate cohorts intersected in the pursuit to understand the elemental composition of natural dye substances with a view to creating synthetic dyes. Chapter 8 concludes the thesis.

As this thesis relies upon material evidence, the different sources of the materials are abbreviated as follows for the purpose of image/figure identification:

Barbara Johnson Album: BJ
John Holker Manuscript: JH
Textile Manufactures of India: TMOI
Winterthur Textiles Collections: W

Chapter 2: The Early Cotton Manufacture of Britain: A Historiography

Abstract

This chapter sets out the historiography of the early British cotton industry and the pre-industrial linen-cotton manufacture that it developed upon. It illustrates the historical background within which Indian cottons were introduced in Britain and discusses their reception in Britain. It shows that Indian cottons shaped the nature of domestic and overseas demand for textiles in favour of cheap, lightweight, and colourful printed and painted cottons, already in demand both domestically and overseas, stimulating early imitations of the Indian cotton goods in Britain.

2.1 Pre-industrial Textile Manufacturing in Britain

Before the advent of complex machinery and the factory system for the production of cotton fabrics, cloth-making was a domestic occupation in Britain focussed on wool and linen. Carding, spinning and weaving fibres into fabrics were activities carried out within the family unit, alongside other agricultural endeavours.[34] According to Wadsworth and Mann, the cloth thus produced was mainly for domestic consumption; its coarseness and the slow production process suggest a 'backwardness of organisation.'[35] The operational structure of the industry comprised small independent households involved in spinning and weaving, connected to the sources of raw materials and markets for their products by middlemen.[36] This system developed into the putting-out system by the 17th century where the role of the middlemen was solidified. The middlemen provided credit to the producers for buying the raw materials such as cotton and yarn as well as bought the finished goods, like spun yarn and woven cloth, from them.[37] Despite describing English woollen industry of the period as 'one of the more technologically stagnant and conservative industries in European economic history,'[38] Coleman also observes

[34] Mary B. Rose, *The Lancashire Cotton Industry: A History since 1700*, The Alden Press, Oxford, 1996, p. 3; Wadsworth and Mann, *The Cotton Trade and Industrial Lancashire, 1600-1780*, Manchester University Press, Manchester, 1961, p. 6

[35] Wadsworth and Mann, *The Cotton Trade*, p. 6

[36] Ibid. $

[37] Ibid. p. 36; Daniels, *Early English Cotton Industry*, p. 56; John Styles, The Rise and Fall of the Spinning Jenny: Domestic Mechanisation in Eighteenth-Century Cotton Spinning, *Textile History*, 51:2, p. 195-236

[38] D.C. Coleman, Textile Growth, in N.B Harte and K.G. Ponting (eds), *Textile History and Economic History: Essays in Honour of Miss Julia de Lacy Mann*, Manchester University Press, 1973, p. 5

extensive division of labour within the rural household alongside ‘commercially organised production for distant markets.’[39]

The literature notes a change within the 16th century, when ‘light, cheap and bright’ coarse woollens from Lancashire joined those from Kendal and Wales in securing foreign demand for the lightweight wool-based British textile manufactures in Spain, Portugal and France.[40] In the beginning of the 17th century textile manufacture in Britain benefitted from the advent of Flemish immigrants who introduced bays - one of the new lighter woollen fabrics to be popularly known as the ‘new draperies.’[41] According to Coleman, the onset of the ‘new draperies’ represented two simultaneous streams of change – commercialisation of peasant techniques and the copying and adaptation of Italian textile techniques.[42] Around the same time, ‘cotton’ manufacture was introduced in England, in Norwich by Walloon and Dutch immigrants.[43] This was mainly in the form of the manufacture of a mixed linen-cotton fabric, comprising flax warp and cotton weft.[44] Within Lancashire, Wordsworth and Mann demonstrate a shift in manufacture first from woollens to linens and fustians and then from linens and fustians to cottons from the 16th to the 18th century.[45]

It is widely acknowledged in the historiography that cotton manufacture in Britain grew within an established linen-cotton manufacture, often abridged as fustian manufacture.[46] However, Emery notes that fustians have always been referred to as ‘heavy workday fabric’ with either a linen or woollen warp alongside a cotton weft.[47] Fustians, which arrived into Britain via the Continent, refer to cloth made with cotton weft and linen warp. References to the manufacture of ‘barchent’ in Germany since the 15th century inform of the production of a cloth comprising cotton weft and linen warp.[48] For Daniels, the decline of German barchent manufacture with the outbreak of the Thirty Years War is directly linked to the rise in prominence of the English

[39] Ibid. p. 3
[40] Wadsworth and Mann, *The Cotton Trade*, p. 4-5
[41] Ibid p. 5, 13
[42] D. C. Coleman, An Innovation and its Diffusion: The “New Draperies,” *The Economic History Review*, Vol. 22, No. 3, Dec 1969, p. 417-429
[43] S.D. Chapman, *The Cotton industry and the Industrial Revolution*, Macmillan Education Limited, London, 1972, p. 11; Wadsworth and Mann, *The Cotton Trade*, p. 19
[44] Ibid.
[45] Wadsworth and Mann, *The Cotton Trade*, p. 23-25
[46] Daniels, *The Early British Cotton Industry: with some unpublished letters of Samuel Crompton*, University of Manchester Press, Manchester, 1920, p. 15; Wordsworth and Mann, p. 15, 19
[47] Irene Emery, *The Primary Structures of Fabrics*, Thames and Hudson, London, 1994, p. 176
[48] Daniels, *The Early English Cotton Industry*, p. 14

fustian manufacture in the first half of the 17th century.[49] Coleman notes that the introduction of new textile goods stimulated demand for a 'series of substitutes,' that is, textile goods that differ not necessarily only in price but also in how they look and appear, through new colours, designs and finishes.[50] While the Continental influences brought variety to British textile manufacture, for Coleman, these paved the way for the 'extraordinarily powerful and much more exotic stimulus to textile change - cottons from India.'[51]

The earliest references to 'cottons' produced in Britain, are misleading in their nomenclature in terms of their composition, though not in their source of inspiration. These early 'cottons' were called 'cotton' despite being entirely, or partially, made of linen or wool.[52] One of the earliest references to what may be described as the Manchester cotton industry is found in Lewes Robert's '*The Treasure of Traffike*' published in 1641. Roberts, describing the manufacturing of cotton textiles in Manchester notes, 'They buy cotten wooll in *London*, that comes first from *Cyprus*, and *Smyrna*, and at home worke the same, and perfit it into Fustians, Vermilions, Dymities, and other such Stuffes; and then returne it to *London*, where the same is vented and sold, and not seldom sent into forraigne parts…'[53]

These cottons, referred to by Roberts, were mixed cotton-linen fabrics, a segment of the 16-17th century fustian manufacture. Edward Baines, one of the first contemporary observers to write about the evolution of the British cotton industry notes, 'As linen yarn was used for the warps of cotton goods, the progress of the cotton manufacture increased the demand for linen yarn to such an extent as to inconvenience the linen weavers of Scotland and Ireland…"[54] Baines observes, 'There is undoubted evidence that the "cottons" of Manchester, like the Kendal and Welsh "cottons" of the present day, were a coarse kind of woollens.'[55]

As is evident from these records, the term 'Manchester cottons' existed long before the machine-made 'Manchester cottons' finally arrived on the scene, the earliest evidence for the term referenced by Baines from a statute for the period of Henry VIII and another from the

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[49] Ibid
[50] Coleman, *Textile Growth*, p. 10
[51] Ibid. p.11
[52] Baines, *The History of Cotton Manufacture*, p. 93; Wadsworth and Mann, *The Cotton Trade*, p. 16
[53] Lewes Roberts, *The Treasure of Traffike, or a Discourse of Forraigne Trade*, London, 1641
[54] Baines, *The History of Cotton Manufacture*, p. 108
[55] Ibid. p. 93

time of Edward VI in 1552. The techniques of 'dressing and frising' detailed in these statutes are applicable to woollens and not cottons.[56] Baines is convinced that, 'The name was adopted from the foreign cottons, which, being fustians and other heavy goods, were imitated in woollen by our manufacturers.'[57] According to Baines, it was the norm to adopt the name of a fabric to a different material when manufacturers were in the process of imitating it. He provides the example of 'cambric,' which is a cotton cloth made in Scotland, but named thus after being imitated from a linen fabric originally bearing the same name.[58] A similar trend becomes visible in later imitations of Indian cottons.[59]

Further evidence that linen was used as the warp yarn in fabrics termed 'cottons' in England in the early 18th century is provided by Baines' following observation - 'As linen yarn was used for the warps of cotton goods, the progress of the cotton manufacture increased the demand for linen yarn.'[60] With the availability of raw cotton from overseas, heavier varieties of fustians and hollands, which lent to the deployment of linen as warp, were perfected early.[61] The all-cotton cloth, however, remained elusive for longer. Did the pursuit of the ability to manufacture this elusive cloth underpin the technological advancements, which fundamentally constitute industrialisation in the British cotton industry?

Woollens, linens and silks dominated textile manufacturing in pre-industrial Britain. Silks remained largely luxury fabrics, woven with exquisite patterns and decorated with embroidered threads, but unaffordable for the bulk of the population. Woollen fabrics of all qualities and several varieties were made extensively in Britain and consumed by the masses, alongside linens, which were prized for their washability and lightness of weight in comparison to woollens. Linens also served as fabrics preferred for use against the skin, for making undergarments and to line woollen clothes.[62]

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[56] Ibid. p. 94
[57] Ibid.
[58] Ibid. 95
[59] TNA, T70/1516, Letter from James Johnson to Captain Bassett, 28 December 1750, describes English imitations of Indian cottons by their Indian names.
[60] Baines, *The History of Cotton Manufacture*, p. 108
[61] Baines also attributes this development to the arrival of Protestant artisans from Flanders as migrants into England, and the pragmatic policy of the rulers to allow the immigrants to settle without grief or incidence. Baines, Ibid. p. 99
[62] Lemire, *Fashion's Favourite*, p. 38

Yet all of these three fibres - woollens, silks and linens - have some common limitations. Linens do not take to printing/dyeing in the way fabrics made of all-cotton yarns do and their colour fastness is limited in comparison to mordant-dyed cottons. They are generally heavier fabrics than cotton. Wool and silk take to colourants well and are the easiest fibres to dye. Being of animal origin and hence made of protein, their molecular structures contain both alkaline and acidic groups enabling the fibres to attach with relative ease to the dye molecules.[63] However, the usability of woollens is limited, they are largely unsuitable for wearing against the body in warmer climates, although they are used as blankets and cloaks for covering over in some seasons. A key limitation is that they are heavier in weight than both cotton and silk. Silks are lightweight, usable and take on colour easily and strongly. Despite the presence of some cheap varieties of silk, including silks mixed with other fibres, and cheaper silk goods like ribbons, silk on the whole is an expensive fibre, and a garment made of silk would be much dearer than an equivalent garment made of cotton, linen or wool. The cost of the fibre, therefore, did not lend itself to the development of a mass production industry.

Table 1: *Basic characteristics of fabrics based on natural fibres*

Characteristics	*Woollens*	*Silks*	*Linens*	*Cotton*
Affordability	✔	X	✔	✔
Washability	X	X	✔	✔
Ease of wear	X	✔	✔	✔
Light fabric	X	✔	X	✔
Ease of printing/dyeing	✔	✔	X	✔
Colourfastness	✔	✔	X	✔

Source: Author's own

An assessment of the general characteristics, feasibility and usefulness of fabrics made of different fibres is presented in Table 1. Textile consumption in Britain consisted mainly of practical and sturdy woollens and linens, with the occasional and limited luxury of silk, often mixed with other fibres like wool or in small quantities/items like ribbons. The advent of light, breathable cotton fabrics from India - printed and painted in vivid colours - was an exotic novelty desired both for luxury and common consumption. These fabrics were unlike anything

[63] Joy Boutrup and Catherine Ellis, *The Art and Science of Natural Dyes: Principles, Experiments and Results*, Schiffer Publishing, Atglen Pennsylvania, 2018, p. 15

the British population was accustomed to and the excitement of the consumers was matched by the 'frenzy' of the manufacturers to meet the demands of the population for lighter fabrics.[64]

Was cotton warp spun in Britain before the development of Arkwright's waterframe? It is very much likely, indeed, to be expected that British spinners would have spun some cotton warp. Without attempting to spin the warp it would not be possible to determine whether the vast majority of spinners could indeed spin adequate warp to supply the needs of a growing cotton industry, or not. Wadsworth and Mann show that there is some evidence to suggest that short lengths of low-quality cotton warp had been made in Britain in the 17th century. This warp was likely made for the manufacture of small cotton goods like handkerchiefs.[65] It also alludes to the early attempts at making cotton warp in Britain. It cannot be reasonably said that no British spinner could spin adequate cotton yarn since exceptionally talented spinners may be expected to have been able to obtain reasonable and even exceptional success. However, the vast majority could not, and therefore a successful cotton manufacture could not be built upon the output of a few exceptionally talented spinners. The yarns produced by the vast majority of British spinners were such that the tensile strength needed for a robust cotton warp could be obtained only by doubling the locally sourced British cotton yarns or using Indian warp yarn.[66] Doubling the warp would not only double the price of raw material but also increase the weight of the fabric, making it uncompetitive against Indian cottons.

Linen-warp cotton-weft fabrics, on the other hand, were readily made in Britain. Why did their imitations of Indian cottons not suffice to compete satisfactorily with the original Indian cottons? Linen-warp cotton-weft fabrics were not all-cottons – and herein lay the fundamental problem for the infant English cotton industry. The linen warp of these mixed-fibre textiles resulted in a cloth that was heavier and coarser than the all-cotton cloths imported from India.[67] In addition, this mixed-fibre combination of warp and weft led to a print quality that was dissimilar to that evident in the all-cotton Indian printed textiles. This is because the linen warp

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[64] S.D. Chapman in C. Aspin, *James Hargreaves and the Spinning Jenny*, The Guardian Press, Preston, 1964, p. 34

[65] Wordsworth and Mann, *The Cotton Trade*, p. 112-113

[66] Lemire, *Fashion's Favourite*, p. 80; John Holker's Livre d'Échantillons, compiled in 1752 includes some samples of all cottons from India printed in Britain. Discussed later in more detail on pages 79-80

[67] Letters of Samuel Crompton in George Daniels, *Early English Cotton Industry*, Manchester University Press, Manchester, 1920, 167; Andrew Ure, *The Cotton Manufacture of Great Britain*, Volume I, Charles Knight, London, 1836, p. 190

of a fustian fabric takes to dyes differently from cotton, resulting in a more speckled, diffused imprint.[68]

In a study undertaken to analyse the fibre identity of yarns in prints, checks and stripes found in London's Foundling Hospital billet books for July 1759 and January 1760, Styles found that 48 out of the total 105 samples studied were made of linen warp and cotton weft. Only seven out of the 105 samples were all-cottons.[69] While it is not possible to be able to authoritatively attribute the provenance of the textiles or indeed the fibres that constitute the yarns without deploying some method of destructive testing on the textiles, in line with the historical accounts above, evidence suggests that these seven samples were most likely either of Indian origin entirely or woven in Britain using Indian hand spun imported cotton yarn. This evidence lends empirical support to the view that the first 'cottons' produced in Britain were linen warp and cotton weft.

The inability of British spinners first to spin cotton warp yarn, and subsequently the fine cotton warp yarn, constitutes key obstacles in the making of all-cotton cloth and fine all cotton cloth. These two sequential obstacles offered sequential pathways for mechanised solutions, paving the trajectory of technological change in the British cotton industry.

2.2 Introduction of Indian Cottons and their Imitations in Britain

The growth of linen-cotton manufacture in Britain is rooted in the move towards lighter, wearable fabrics during the first half of the 18th century, with the emergence of 'new draperies' and linen-cottons, both embodying this trend. This shift is itself a product of the sustained exposure to mixed cotton fabrics from the Continent.[70] Alongside the existing market for fustians, the English East India Company first introduced Indian cottons in England in 1602.[71] The following decades marked the development of a distinct preference for Indian cotton goods in Britain and almost immediately thereafter, we find historical evidence of the beginnings of imitations of Indian cottons by English fustian manufacturers, though actual samples of cloth

[68] John Styles, Fashion, Textiles and the origins of the industrial revolution, *East Asian Journal of British History*, Vol. 5 (2016) 180.
[69] Ibid. 173
[70] Wadsworth and Mann, *The Cotton Trade*, p. 13
[71] P.J. Thomas, *Mercantilism and the East India Trade*, p. 36

from this period have not survived.[72] The introduction of Indian cottons into the British markets stimulated this trend while simultaneously giving a fresh impetus to the domestic manufacturers to venture towards new textile products and processes. Technological evolution, however, had not reached a stage where viable imitations of all-cotton Indian goods could be successfully achieved. One of the major hurdles, as discussed earlier, was the inability to spin viable cotton warp. The first major machinery, the spinning jenny, was able to make cotton weft but even that was not of an even, desirable quality.

Entrepreneurs and manufacturers realised early on that replication of Indian cottons by English linen-cottons was not equal to imitating the quality of Indian cottons, despite the jenny's technological strides. Daniels provides examples from 1692 of attempts at obtaining patents for 'cotton wool … to be spun so extraordinarily fine, as to be fit to make cloths commonly called callicoes … as well as in the East Indies.'[73] The patentee further applied for another patent for securing an invention for 'making callicoes, muslins, and other fine cloths … to as great perfection as those which are brought over and imported hither from Calicut and other places in the East Indies.'[74] While these patents amounted to nothing, they underscore the early recognition of the value of machinery for making fine cotton goods in the absence of local labour skill to produce fine cotton yarns.

Daniels' account offers us some insights into early cloth-making in the British Isles. Artisans and manufacturers in Britain, as elsewhere in the world, readily imitated goods from other regions that they came in contact with, despite the lack of codified knowledge transfer through books or manuals. This is primarily because of artisans' ability to deconstruct a product into its essential components and rebuild a similar newer version, or to assemble a fusion of different elements, often leading to the creation of new products – a case in point being the velveret cloth, a cotton pile fabric typically raised like corduroy,[75] which, according to Inikori, was a result of trial and error in experimenting with new products and methods of production.[76] 'Learning by doing' comprised, in this instance, of a process of imitation of goods from the

[72] Wadsworth and Mann, *The Cotton Trade,* p. 118-119, 134; Thomas, *Mercantilism*, p. 37-38, 41-47
[73] Daniels, *The Early English Cotton Industry*, p. 17
[74] Ibid.
[75] Florence Montgomery, *Textiles in America, 1650-1820*, Winterthur Books, 1983, p. 370; John Aikin, *A Description of the Country from Thirty to Forty Miles Around Manchester*, John Stockdale, London, 1795, p. 161-163
[76] Joseph Inikori, Slavery and the Revolution in Cotton Textile Production in England, *Social Science History*, Vol. 13, No. 4 (Winter 1989) 343-379

East, which also clarified aspects of the manufacturing process that were unsuitable for the ways in which production was aligned in Britain. Cotton yarn was hand spun into fine long length warp yarns in India, but in Britain the production of this longer warp yarn presented a major challenge, ultimately resolved by a mechanical innovation.

2.3 Market Demand and Consumption of Indian Cotton Goods

Cotton goods were demanded both in the domestic British market as well as overseas and British manufacturing catered to both sets of demands. Within Britain, Lemire argues that cotton textiles arrived suddenly and acquired 'phenomenal popularity almost overnight,' heralding a 'calico craze.'[77] Immediate attempts to imitate the Indian printed and painted cottons led to the establishment of commercial dye-works and manufactories focussed on the domestic imitation of the Indian goods initially on the linen-cottons, woollens as well as plain linens.[78] The well-known Calico Acts, aimed at protecting the British wool and silk industries, soon followed in 1700 and 1721.[79] However, the chief characteristics of the cotton textiles – their light weight, colourful prints and washability – ensured sustained popular demand and the continued efforts of British craftsmen to perfect the techniques of calico printing for the export trade.[80]

According to Edwards, domestic British demand for cottons offered a secure foundation for the cotton industry and was potentially more important than the overseas market until the 1790s. It provided a 'stable influence' on the cotton trade by being 'less volatile, subject to fewer crises, and was considerably easier to serve.'[81] Until the 1770s about two-thirds of the total value of cotton goods were consumed domestically; this figure changed to one-thirds by the second half of the 1790s.[82] Edwards notes that all classes of the population consumed British calicoes and muslins, though the wealthy preferred traditional silks, handmade linens or the original 'brilliant East Indian fabrics' and not the expensive varieties of British cottons.[83] In the segment of the market where quality and fashion ruled over price, preference remained

[77] Lemire, *Fashion's Favourite*, p. 4, 12
[78] Ibid. p. 31
[79] Ibid. p. 31-35
[80] Ibid. p. 38-42
[81] Edwards, *The Growth of the British Cotton Trade*, p. 27
[82] Ibid.
[83] Ibid. p. 30

steady for the Indian muslins which carried 'social weight.'[84] This did not deter British manufacturers from attempting to mechanise the fine cloth-making process and competing with Indian fine cotton goods, as muslins had become synonymous with high fashion.[85] In the large proportion of the domestic market, which comprised plain and printed calicoes and cheap muslins, the cheaper British cloths fared much better than their Indian competition.[86] Lemire has shown how this demand was based upon potent desires for textiles, china as well as domestic accessories, not only through the market for new goods but also through the hidden demand from the second-hand trade.[87]

P.J. Thomas writes of the excitement that Indian cottons created in Britain once they were introduced by the English East India Company. Increase in imports of calicoes and muslins was a result of changing consumption patterns influenced by these new, exotic commodities. He refers to public debates, pamphlets espousing diverse views on the use of imported textiles, politicization of the society along types of fabrics, and the surfacing of 'enthusiastic schemes' to make/imitate calicoes.[88]

Ellison, writing in 1886, believed that the popularity of Indian cottons made economic sense to pursue their imitation, yet the inability to spin adequate yarn propelled mechanisation in the industry, in pursuit of suitable yarn. He wrote, 'The popularity of these [Indian] goods suggested the obvious desirability of making a still further approach to the Indian article by producing a fabric composed entirely of cotton; but in the absence of a machine capable of turning out a yarn hard and strong enough to be used as warp (hitherto supplied by linen), this was found to be impossible; and it was to the production of such a machine that the efforts of the mechanics of the time were directed.'[89] Ellison's assessment offers a direct link between Indian cottons, early British attempts to imitate them, frustrations at the inability to reproduce key elements of the product, and subsequent efforts aimed at finding alternative ways of producing viable copies of the benchmark products.

[84] Ibid. p. 39
[85] Bishnupriya Gupta, Competition and Control in the market for textiles: Indian weavers and the English East India Company in the eighteenth century, in Giorgio Riello an Tirthankar Roy, *How India Clothed the World: The World of South Asian Textiles*, Brill, Leiden, 2013, p. 281
[86] Ibid. p. 47
[87] Lemire, *Fashion's Favourite*, p. 56, 61-76
[88] P.J. Thomas, *Mercantilism*, p. 40-47, 130-131, 159
[89] Ellison, *The Cotton Trade,* p. 13

That there existed widespread imitation of Indian goods soon after their introduction into Britain is plainly evident from the sources. That the early imitations were unpromising and posed little threat to the India trade is also corroborated by EEIC correspondence. In contrast to the views of Irwin and Schwartz regarding European influence on Indian designs and patterns, Thomas observed that Indian patterns were preferred over European or European imitations of Indian work.[90] He quotes a 1683 correspondence from the Directors of the EEIC to their officials in Bombay saying, 'Let your weavers take out such flowers most convenient and agreeable to their own fancies which will take better here than any strict imitation which is made in Europe.'[91] Another 1731 EEIC correspondence from London to Bombay notes, 'Let the Indians work their fancies, which is always preferable before any patterns we can send you from Europe.' [92]

By the 1790s, the export market had become more significant for the cotton industry and overseas demand for cotton goods had a lasting impact on cotton manufacturing in Britain. According to Inikori, the cotton industry in Britain grew as an import substitution and re-export industry served by protective barriers. The export trade with West Africa afforded the industry significant opportunities by providing a larger market where competition with Indian goods encouraged 'cost-reducing and quality-raising innovation.'[93] Early imitations of the Indian printed goods in Britain were attempted on woollen, woollen-silk, cotton-linen as well as linen fabrics, especially for textiles for the West African trade.[94] Initial attempts were unsuccessful not only in the making of adequate cotton warp that would result in satisfactory all-cotton textiles able to compete with Indian cottons in the West African market, but also in the print quality on the various non-cotton fabrics as they were not colourfast.[95]

Records of contemporary traders show the significance of cottons to the African trade. Imitations of Indian checked and striped cloth were especially produced for the West African consumers.[96] In the second half of the 17th century, linen warp and cotton weft fabrics were made in England and sent to West Africa, in imitation of Indian cottons. According to Inikori,

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[90] John Irwin and P.R. Schwartz, *Studies in Indo-European Textile History*, Calico Museum of Textile, Ahmedabad, 1966, p. 17
[91] P.J. Thomas, *Mercantilism and the East India trade*, F.Cass, London, 1963, p. 40
[92] Ibid. 40
[93] Inikori, *Africans and the Industrial Revolution*, p. 428
[94] Wadsworth and Mann, *The Cotton Trade*, p. 118-119
[95] Ibid
[96] Ibid

between 1750-1774, this cotton-linen cloth constituted between 48-86% of English cloth sent to West Africa.[97] For him, the 'initial development of the export sector was a function of demand by Africans.'[98] This was the pre-existing demand for Indian textile products which fuelled the British attempts to replicate the Indian goods for the West African market. According to Styles, 'New products do not automatically find a market… This is fundamentally a matter of product definition. The new product must take a form that can be sold successfully.'[99] British textile goods were described in the language of the West African market-approved Indian cottons - they took their names from, and compared their characteristics with, the Indian products which had sold successfully in the African markets.

According to Berg, not only did British manufacturers target their manufactures for specific markets, they organised technological improvements related to the production processes with the wider global trade in luxury goods in mind.[100] In the free market setting of West African trade where British traders faced stiff competition from their Dutch, French and Spanish equivalents, all selling Indian cotton goods alongside other wares, British traders were requested by British manufacturers, and encouraged by mercantilist state policy, to promote English cloth and to seek market feedback for its quality and saleability. Writing to William Hollier of the African Company in February 1750, Thomas Norris, a merchant from Chorley wrote of the bafts[101] he sold to the Company, '[he] should be extremely glad to have them [the bafts] *compaired with India Bafts* at the same price & if the committee of Company of Merchants trading to africa would make further tryall by sending a few pieces in different ships to different parts of the Coast, that would be the readyest way *to find out which goods have the prefference*, at the same time giving orders to their factors to take notice how such goods was approved of by the negroes.'[102]

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[97] Inikori, *Africans and the Industrial Revolution,* p. 435
[98] Ibid., p. 437
[99] Styles, Product Innovation in Early Modern London, *Past and Present*, No. 168, August 2000, 124-169
[100] Maxine Berg, Quality, Cotton and the Global Luxury Trade, in Giorgio Riello and Tirthankar Roy, *How India Clothed the World*, p. 391
[101] Bafts or Baftas or Baffetas is 'a generic term for plain calico of Gujarat, varying in quality from coarse to fine,' John Irwin and P.R. Schwartz, *Studies in Indo-European Textile History*, Calico Museum of Textiles, Ahmedabad, 1966, p. 59
[102] Ibid., Letter from Thomas Norris to William Hollier, Secretary to the African Company, 25 February 1750 [italics added]

In May 1751, William Norris enclosed a letter along with a consignment of 'Superfine Cotton Bafts' and wrote about the cargo, 'I make not the least doubt but they will be *very agreeable if compaired with India Bafts* that are 2 or 3 pence a piece Higher & I should be greatly obliged to you to *promote their being Compaired*[.] If they are opened I beg you'll write upon them Chorley Superfine Cotton Bafts… I here inclose you two portions & Beg you'll *shew[show] them to some of the knowing ones*[.] we are making a large Quantity of them for the Liverpool Merchants and are rather to [too] Backwards with our orders or would have sent a Piece of Each sorte by way of Sample.'[103]

Attached to the letter are two sample cloths. The first is an imitation of a striped niccanees[104] and the second is a chequered cloth with the added description 'Superfine Chellow[105] 18 yards @ 1li 10s 0d.'[106]

[103] TNA, T70/1517, Letter from W Norris to William Hollier, Secretary to the African Company, 7 May 1751 [italics added]

[104] Niccanees is a striped calico patterned in the loom, made in Gujarat and bought for the slave markets, Irwin and Schwartz, *Studies in Indo-European Textile History*, p. 69

[105] Chellow or Chelloe or Chillaes is an inexpensive Indian cloth, possibly scarf or handkerchief, with red, blue or black stripes, patterned in the loom, Florence Montgomery, *Textiles in America, 1650-1870*, p. 197; Irwin and Schwartz, *Studies in Indo-European Textile History*, p. 61-62

[106] TNA, T70/1517, Letter from W Norris to William Hollier, Secretary to the African Company, 7 May 1751; Parthasarathi, *Why Europe Grew Rich*, p. 135; Kazuo Kobayashi, *Indian Cotton Textiles in West Africa: African Agency, Consumer Demand and the Making of the Global Economy, 1750-1850*, Palgrave, 2019, p. 11

Figure 1: *Samples of cloth for trade on the Guinea Coast (1751)*

Source: T70/1517 Letter from Thomas Norris to Company of Merchants Trading to Africa, 7 May 1751

The letters and the samples confirm that imitations of Indian cottons were made while using them as the benchmarks for final cloth quality and finish. Direct references to comparisons with Indian cloths pertaining to quality and market appeal demonstrate that Indian cottons were indeed the yardstick by which cotton cloth made in England was assessed. Market feedback offered crucial insights to English manufacturers into aspects in which their cloth was lacking in comparison to Indian cloth. This was important feedback from the perspective of product development and improvement. In this instance, it pertains to the yarn quality and composition of the cloth as the vendor stresses the 'Superfine Cotton' character of the textile.

Another letter from Thomas Norris to William Hollier, dated 3 December 1751, shows him compelled to stress, '[I] have sent yesterday as below which I doubt not but will Please, & *there is not a thread in them that is not Cotton*, these pieces by not being a pack will stand you dearer'[107]

In a similar vein, a memorial written by the Merchants of Liverpool trading to Africa in March 1765, and addressed to the Commissioners of His Majesty's Treasury with a view to being

[107] TNA, T70/1517, Letter from Thomas Norris to William Hollier, 3 December 1751 [italics added]

allowed to buy goods from other European countries for trade in Africa, refers to 'checks & other goods made at Manchester in imitation of East India Goods, when the latter are at high prices, or not to be got, but *some they cannot imitate & their imitation of many kinds is but indifferent*.'[108]

Underscoring British imitations of Indian textiles to serve the African market, on 28 December 1750, James Johnson, a trader from Spitalfields, wrote to Captain Bassett of the African Company, enclosing a price list for the cotton wares, emphasising that he was, 'Offering *English goods [in] Imitation of East India* [goods].'[109]

In line with Berg's view on the connection between market demand, imitations and technological innovations, according to Wadsworth and Mann, traders engaged in the West African trade were the first to support inventions in spinning cotton yarn. They provide the examples of Samuel Touchet and James Johnson who were interested in 'cheap yarn of a quality comparable with that from India,' their interest being 'evidently great enough to encourage them to take considerable risks in the hope of obtaining it.'[110]

2.4 Conclusion

Two lines of enquiry emerge from this overview of the history of the British cotton industry. Firstly, linen-cottons were the existing manufacture over which import substitution of Indian cottons could, and did, logically emerge. Secondly, linen-cotton manufacture had to evolve into cotton manufacture if suitable, market-oriented imitations of Indian cotton goods were to be produced. The symbolic thread of yarn quality, and therefore quality of final cloth led by pre-existing market-demand for the benchmark Indian cottons, runs centrally through both. It indicates that the focus in the British cotton industry was on improving cloth quality, to match that of Indian cottons, resulting in sequential learning. This allows for the development of the hypothesis that sequential learning was first related to the making of the all-cotton cloth followed by the making of the fine all-cotton cloth.

[108] Memorial of the Merchants of Liverpool Trading to Africa to the Commissioners of His Majesty's Treasury, 16 March 1765, quoted in Inikori, *Africans and the Industrial Revolution*, pp. 441-442 [italics added]
[109] TNA, T70/1516, Letter from James Johnson to Captain Bassett of the African Company, 28 December 1750 [italics added]
[110] Wadsworth and Mann, *The Cotton Trade*, p. 425

Chapter 3: The Making of the Cotton Cloth: Contemporary Accounts

Abstract

This chapter re-assesses the evolution of spinning in the early British cotton industry using contemporary accounts. It shows that refinements in cloth quality, guided by the imitations of competitor and benchmark cotton products from India, underpinned the impulse towards the refinement of machinery for spinning cotton yarn in the early British cotton industry. It highlights entrepreneurial motivation for the making of the all-cotton cloth, and subsequently the fine all-cotton cloth, encompassing quality improvements in yarn making, especially for the warp. It analyses the role of the political economy and institutional endeavours upon the growth of the industry, particularly in relation to the imitation of Indian cotton goods.

3.1 Rationale for Sequential Learning

All-cotton cloths of different varieties, as produced and exported widely across the world by Indian textile makers from as early at the 13th century, constituted both cotton warp and weft, resulting in a light, pliable, wearable and washable fabric base that lent itself to distinctive imprinting and painting.[111] The literature on the origins of cotton manufacture, discussed in the previous chapter, refers to early imitations of these Indian cottons in Britain during the 17th and 18th centuries on a cloth comprising linen warp and cotton weft. We also know that by 1770 the all-cotton cloth was being manufactured in Britain with fine cottons able to compete with Indian muslins by the 1780s. The initial development of the industry within a linen-cotton manufacture and the subsequent shift to a cotton manufacture, with mechanisation further facilitating the fabrication of finer cotton goods, lends itself to the development of the following hypothesis. Once introduced in the British market by the English East India Company in the beginning of the 17th century, Indian cottons were imitated domestically, with this imitation allowing sequential learning to be generated and absorbed across the industry, leading to the shift from the linen-cotton fabrics to all-cotton fabrics and ultimately to the fine all-cotton fabrics.

[111] Beverly Lemire, *Fashion's Favourite*, p. 38; Parthasarathi, *Why Europe Grew Rich*, p. 94-95; Riello, *Cotton*, p. 224-227

This chapter identifies the problems faced by British textile manufacturers in the process of imitating the all-cotton Indian cloth and refining the quality of the British product to match that of the Indian originals. It argues that this process of imitation offered targeted opportunities for the development of mechanised solutions to key obstacles in the path of successful British cotton manufacturing. It sets out the historical background alongside written evidence to chronicle sequential bottlenecks in the British cotton industry. It establishes that the expansion of these mechanised solutions to, firstly, the manufacture of the all-cotton cloth, and subsequently to the manufacture of fine all-cotton cloth, precipitated the move towards the targeted development of technology along the lines of product quality improvements, leading to sequential mechanisation. While mechanical developments may be seen as endogenous to British manufacturing, the stimulus for these technical pursuits was exogenous, motivated by the impulse to imitate the quality of Indian cotton goods and to successfully compete against them in the domestic British markets as well as overseas.

3.2 The Pursuit of Quality: Contemporary Accounts

Do contemporary accounts of stakeholders of the British cotton industry demonstrate an impulse of comparative learning from the Indian cotton goods? This study looks at the archival records of Richard Arkwright, the inventor of the waterframe, Samuel Crompton, the inventor of the mule or the muslin wheel, Samuel Oldknow, one of the first and most prominent English muslin makers, and Samuel and William Salte, Oldknow's London agents. It also uses historical accounts and commentaries by Edward Baines, Robert Guest, Andrew Ure and Thomas Ellison, who were some of the first commentators and historians of the British cotton industry, to piece together contemporary accounts regarding the influence of Indian cottons on the infant British cotton industry. Historical accounts of British cotton manufacturers and traders, as well as commentators writing about the cotton industry, show a sustained comparison with Indian cottons. The comparisons are rooted in quality considerations, frequently deploying the language of fineness and the inability of British cottons to match that of the Indian goods.

The trend towards the improvement in cloth quality in the early British cotton industry begs a key question – why at all this sustained focus upon the improvement of cloth quality enabling technological developments in its wake? If the imitations of Indian cottons on British linen-cottons were deemed satisfactory, then what explains this decided pursuit of finer all-cotton cloth and improved cotton cloth quality? I argue that the technological growth in the British cotton industry was a product of the quest to resolve two sequential bottlenecks faced by the industry as it attempted to match the quality of Indian goods. The first was the ability to make the all-cotton cloth and the second the ability to make the fine all-cotton cloth.

3.2.1 Making the All-Cotton Cloth: the First Bottleneck

The inability of English spinners to hand-spin commercially viable fine yet strong cotton warp yarn was the first bottleneck in getting the quality of the English cotton cloth right. The use of linen yarn for warp in the early linen-cottons was a result of the inability of English textile manufacturers of the 17th and 18th centuries to make adequate cotton warp. Warp yarn, being the longer foundation yarn tied to the loom through which shorter wefts intersect, needed to be stronger and longer than the weft yarn, but equally fine, if lightweight all-cottons were to be produced.[112]

Before the spinning jenny arrived upon the scene and revolutionised yarn spinning, spinning was a manual job undertaken largely by the women of pre-industrial Britain in their homes. The spinning jenny, invented by James Hargreaves in 1764, was initially used primarily for spinning woollen yarn, and continued to be favoured by the woollen industry.[113] Before long, it was deployed for the making of coarse cotton weft. Hargreaves' move to Nottingham has been described as significant in the development as well as improvement of the spinning jenny. The favourable environment for innovation that this town offered was primarily because of the hosiers who had begun using cotton hose and sought mechanical ingenuity for the production of cotton yarn.[114]

Spinners in Tewksbury were able to spin fine cotton weft (but not warp) for the hosiery industry, as they were accustomed to short staple Spanish wool, which was characteristically somewhat similar to the short staple raw cotton from India and the Levant. This posed a problem for their competitors, the Nottingham hosiers. Women spinners in the mid-counties, who were familiar with long staple wool, 'could not be brought to spin a thread that would bear

[112] Baines, *History of the Cotton Manufacture*, p. 52
[113] Aspin and Chapman, *James Hargreaves and the Spinning Jenny*, p. 56
[114] Ibid. p. 31-33

the least resemblance to India cotton.'[115] Nottingham hosiers were thus forced to import Indian spun cotton yarn of 'much superior quality.'[116]

Further, Aspin and Chapman note, 'Every Nottingham artisan knew that a new technique with commercial potential would readily command support.'[117] The interest in the production of cotton fabrics was such that the jenny, deployed without delay for the spinning of cotton weft, quickly gained popularity amongst the spinners of the region. Despite its widespread take-up, Henson notes that 'cotton yarn spun by Hargreaves, though much superior to the Nottingham spinning (by the local spinsters), was still a poor article, being full of tender thin places, bumps and burs, and was with difficulty wrought into stockings.'[118] The fundamental problem was that the jenny was able to make cotton weft but it was not of an even, desirable quality. It certainly couldn't spin fine cotton yarn suitable for warp for the making of all-cotton goods.

The humble beginnings of cotton yarn spinning in Britain may have found their first roots in the hosiery industry, however cotton yarn since its earliest days was compared to and assessed against Indian handmade yarn. Indeed, quality considerations comprised some of the earliest discussions within the textile industry in Britain. It is also evident that Indian yarn acted as the quality benchmark for the earliest mechanical developments for cotton spinning, as did their subsequent improvements.

Even as the English cotton manufacturers attempted to imitate the Indian all-cotton fabrics, it was recognised early on that there was a crucial bottleneck with regards to the spinning of the warp yarn essential for an all-cotton cloth. For Baines, the 'rudeness of spinning machinery' offered the vital obstacle to the weaving of fine all-cotton goods.[119] Historical sources offer many references to shortage of suitably spun good quality yarn, especially that for warp.

According to Baines, the two factors that 'impeded the progress of the Cotton Manufacture [were] the rudeness and tediousness of the modes of working [and] the cost of the raw

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[115] Gravenor Henson, *History of the Framework-Knitters in Europe and America*, Richard Sutton, Bridlesmith-Gate, Nottingham, First published 1831, 359-64 [italics added]
[116] Aspin and Chapman, *James Hargreaves*, p. 34; It is worth noting that contemporary historians, including Ure, considered the spinning jenny to be but a slight modification upon the Indian wheel. The implications of this will be discussed further in chapter on technology.
[117] Ibid. p. 31
[118] Henson, *History of the Framework Knitters*, p. 366
[119] Baines, *Cotton Manufacture*, p. 102

material…'[120] Further, he goes on to note, 'Cotton yarn was considerably dearer than linen yarn. At the same time, it was greatly inferior in tenacity; because cotton, from having a shorter, feebler and more elastic fibre than flax, needs to be much more firmly twisted, in order to make a strong thread … therefore, it was impossible, at least for Europeans, to make cotton yarn combining strength with fineness. The yarn, when spun fine, was loose and flimsy; it could not be made strong, without being heavy.'[121]

Two issues are of special note in the above passage – the price of cotton yarn and the inability of British manufacturers to spin a fine yet strong cotton yarn with the existing technology. With regards to spinning fine cotton yarn, Baines notes of the 17th century, 'Owing to the rudeness of the spinning machinery, fine yarn could not be spun, and of course fine goods could not be woven. Fustians, dimities, and other strong fabrics were made; but calicoes and the more delicate cotton goods were not attempted.'[122]

According to Ellison, Indian yarns imported by the English East India Company were normally used for making finer goods.[123] He refers to comparisons with Indian yarns for quality and fineness, indicating that Indian cloth and yarn provided the comparative standards of quality.[124] Baines too, while providing detailed accounts of the early mechanical inventions of the period, observes that, 'The water frame spun a hard and firm thread, calculated for warps; and from this time the warps of linen yarn were abandoned, and goods were, for the first time in this country, woven wholly of cotton. Manufactures of a finer and more delicate fabric were also introduced, especially calicoes, imitated from the Indian fabrics of that name.'[125]

Underscoring the urgent need for the development of domestic manufacture of good quality cotton warp as well as weft in Britain, Ure noted, 'The cotton business of Manchester, till Arkwright furnished it with cotton water twist for warp, in lieu of linen yarn, was a mongrel manufacture, and should hardly be admitted to form an integral part of a history of the cotton trade; because any value assigned to it is chiefly due to the flax constituent. The cotton weft was undoubtedly a yarn of most irregular and indifferent quality, as we may infer from the

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[120] Ibid. p. 52
[121] Ibid
[122] Ibid. p. 102
[123] Thomas Ellison, *The Cotton Trade of Great Britain*, E. Wilson, London, 1886, p. 16
[124] Ibid.
[125] Baines, *Cotton Manufacture*, p.163-164

urgency with which it was sought after, and the avidity with which it was bought up by the weavers from spinsters of every degree of skill.'[126]

According to Baines too, the drive to produce the all-cotton cloth was forceful and focussed – it spurred efforts in the direction of tackling this particular challenge, ultimately resolved by innovations in the production process with the introduction of the spinning jenny and the water frame.[127] Indian cottons provided the competitive stimulus for the refinement of the production processes. Equally, they offered prototypes of quality standards to be met by the early British cotton manufacturers.

3.2.2 Making the Fine Cotton Cloth: the Second Bottleneck

All-cotton cloths come in many varieties, depending chiefly upon the quality of the yarn. Indian muslins, especially those originating from the Bengal region, have historically attained prominence as the finest cotton cloths to be spun and woven. They are thin and sheer, woven to varying degrees of fineness depending upon the quality of yarn as well as the skills of both spinner and weaver. The finest muslins were woven exclusively for members of the Mughal court while the coarser varieties were produced for the local market and overseas trade.[128] Ashmore notes that muslins have a mythical reputation, their praises having been sung equally by poets, saints, travel writers and historians since the 13th century.[129]

Once muslins were introduced in Europe as part of the overseas trade of the European East India Companies, they became the most coveted cotton textile commodity on any cargo destined for European ports.[130] As with other varieties of Indian cottons, British manufacturers, like their European counterparts, set out to imitate the finest of these Indian cotton goods. While early imitations of calicoes on English fustian cloth were possible by deploying the linen yarn as warp, if not entirely successful, imitation of muslins required fundamental changes in the production process and technological capabilities, with a strong yet fine warp cotton yarn being its pre-requisite. The ability to manufacture English muslins that could compete with the

[126] Ure, *The Cotton Manufacture*, Vol. 1, p. 189-190
[127] Baines, *Cotton Manufacture*, p. 83
[128] Sonia Ashmore, *Muslin*, V&A Publishing, London, 2012, 8
[129] Ibid.
[130] Daniels, *Early English Cotton Industry*, p. 18

quality of Indian muslins, therefore, may be seen as the ultimate technological advancement allowing for the making of the finest of all-cotton cloths.

Arkwright's invention of the waterframe in 1767 for spinning cotton warp enabled the long-awaited production of British all-cotton cloth. The waterframe made possible the manufacture of English calicoes and greatly improved the manufacture of other cotton goods. In 1781, when Arkwright's claim for a carding patent was disallowed, it effectively opened up the roller-spinning process, and the ability to make all-cotton goods, to all interested textile manufacturers.[131] Yet mechanical innovations until this time were inadequate for producing fine all-cottons of the kind produced in India.

Muslins symbolised the pinnacle of cotton manufacture, evident in the high market demand for these products.[132] Historical evidence suggests that the drive towards refining the quality of cloth to match that of the benchmark Indian cotton goods provided the impulse for the establishment of muslin manufacture in Britain. According to Unwin and others, the greatest ambition of British textile manufacturers was to succeed in the production of muslins.[133]

Samuel Crompton's invention of the Mule in 1779, which combined the mechanisms of the spinning jenny and the water frame, enabled the manipulation of the spun yarn to the required thickness and strength. It was only right that the Mule first came to be known as the 'Muslin Wheel,' being the first machinery that enabled the manufacture of this fine fabric. Crompton himself described it as 'that piece of mechanism that has produced and increased one of the first manufactories in Europe viz. the fine Muslin and cambric, and also the extention [sic] of many Sorts of cotton goods that were made in an inferior manner before, all of which would have been lost to us without this Machine.'[134] Ure described the mule as 'the parent of the muslin manufacture,' and credited it for enabling the successful imitation of, and competition against, this category of Indian cotton products.[135]

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[131] F.S. Fitton, *The Arkwrights: Spinners of Fortune*, Manchester University Press, Manchester, 1989, P. 97-100; Baines, *Cotton Manufacture*, p. 187-189
[132] Ashmore, *Muslins*, p. 34-35, 40-51
[133] George Unwin, *Samuel Oldknow and the Arkwrights; The Industrial Revolution at Stockport and Marple*, Manchester University Press, Manchester, 1924, p. 3
[134] Letters of Samuel Crompton, in Daniels, *The Early English Cotton Industry*, p. 169
[135] Ure, *The Cotton Manufacture of Great Britain*, p. 262

According to Crompton, he invented the Mule to improve the quality of cotton yarn being produced in Britain. Setting out his reasons for devoting several years towards the making of the machine, Crompton wrote, 'About the year 1772 I Began to Endeavour to find out if possible a better Method of making Cotton Yarn than was then in Generall Use, being Grieved at the bad yarn I had to Weave.'[136] It took Crompton six years to plan the invention and another additional year to execute it. Being a weaver himself, he first used the yarn he spun for his own warp and weft requirements; from 1780 onwards he devoted himself entirely to spinning fine cotton yarn.[137] It is important to recognise that Crompton himself situates the reasons for the invention of the mule within considerations of yarn quality. Crompton's benchmark is the fine cotton warp from India, which was used for the manufacture of finer cotton goods.

A petition presented to the House of Commons on 5 March 1812 with a view to soliciting compensation and recognition for Crompton for his contribution to the British cotton manufacture read, 'The Mule … not only removed the pre-existing defects in the art of spinning, by being capable of producing every then known description of weft as well as twist [warp] of a superior quality, but gave birth to a new manufacture in this country of fine Cambrics and Muslins, by producing yarns of treble the fineness, and of a much more soft and pleasant texture, than any which had ever before been spun in Great Britain.'[138]

In considering the evidence pertaining to Crompton's petition, the Committee interviewed several spinners, weavers, merchants and manufacturers for their views on Crompton's Mule and its impact on cotton manufacturing in Britain. John Pilkington, a merchant and manufacturer from Bolton noted, 'Previous to the invention of Mr Crompton's Machine, the muslin manufacture had been attempted, but without success; since that period it has been progressively advancing.'[139]

The committee witnessed unanimous agreement upon the significance of the Mule for the making of muslins and other fine cotton goods in Britain. Thomas Ainsworth testified that Arkwright's machine was capable of producing a 'hard thread, fit only for warps' whereas Crompton's mule was capable of producing both warp and weft of any specification. He added,

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[136] Daniels, *The Early English Cotton Industry*, p. 167
[137] Ibid.
[138] Ibid. p. 173
[139] Ibid. p. 186

‘By being of so very fine a fabric, such fine yarns being wanted for that manufacture beyond what would be wanted for the heavy cloth we manufacture in Lancashire. I do not know how the Scotch manufacture would ever have been carried on without the yarn Mr. Crompton’s Machine produces, particularly book muslins.’[140]

The committee concluded Crompton’s testimony by questioning, ‘You have said, that the Mule spins a finer kind of yarn than the other machinery, and enables the manufacturer to make a finer species of goods than could have been otherwise made?’ The answer was an unequivocal ‘Yes.’[141] The only ‘finer species of goods’ that could be taken as the benchmark for this period were Indian fine cottons and muslins.

3.2.3 The Muslin Manufacturer and his London Agent

The views of an English muslin manufacturer help put this technological discussion on the need for the mule within the context of cotton manufacturing in Britain. One of the first cotton manufacturers to avail of the opportunity opened up by the muslin wheel/mule was Samuel Oldknow, who came to be known as the greatest English muslin maker.[142] Born in Lancashire in 1756 and apprenticed to a draper in Nottingham, he set up his muslin business in Anderton in 1781. By 1789, he was the most successful of muslin manufacturers in Britain.[143] His correspondence with his London brokers Samuel and William Salte throws an interesting light upon Oldknow’s decision to persevere with the muslin manufacture especially, during the troubling decades of 1780s and 1790s, when the unrest in Europe and the Napoleonic wars resulted in fluctuations in supply of raw materials and demand for finished goods. What comes out strongly from the correspondence is the guidance or market insight provided by Samuel Salte to Oldknow by virtue of Salte’s proximity to the cotton trade in London, especially pertaining to the very real threat of competition from Indian muslins.

Writing to the Saltes in 1783 with a view to soliciting his advice on the matter of devoting his enterprise exclusively to the manufacture of muslins, Oldknow enquires, ‘If I could be certain of the Muslin trade continuing with us hear [sic] I shd not require a moment to determine what

[140] Ibid. p. 190; Ashmore notes that book muslins are fine muslins folded like a book, *Muslins*, p. 35
[141] Daniels, *Early English Cotton Industry*, p. 191
[142] Ashmore, *Muslins*, p. 35
[143] A.C. Howe, Samuel Oldknow, *Oxford Dictionary of National Biography*, https://doi.org/10.1093/ref:odnb/37821 accessed 19 July 2021

to do. The prospect is at present very propitious (but at a time when East India Muslins are exceedingly scarce and in all probability will not long continue so – it may not be) but how will it be when East India Muslins are more plentiful. I do think that there are some sorts of very broad muslins we have the lead in and in all others we are daily improving – fine spinning is what we are most shot [short] of & even that we are on the road to procure.'[144]

The observations in the letter throw up two key concerns plaguing Oldknow with regards to his cotton manufactory - competition from Indian muslins and the quality of English muslins. Oldknow, during this period, was buying twist (warp) from Arkwright and does not appear to have branched out to the mule, which was a competitor to Arkwright's waterframe.[145] In response to the advice Oldknow sought in his letter, the Saltes invited Oldknow to visit London to discuss and settle matters for 'mutual interest.' They advised, 'We have a Muslin Sale next month – we can, if you come to London, shew you Pattrns and give you directions which a letter cannot convey properly.'[146] Again, on 23 May 1786, alluding in no uncertain terms to comparing and learning from Indian goods, Salte wrote, 'Our next India Muslin Sale is fixed for the 29th June, if you wish to have a peep at the Goods you must come to town a week before.'[147] Underscoring both the demand for the India goods as well as the learning Oldknow could obtain by seeing these Indian wares, on 5 June 1786 he added, 'We expect you in Town about the 20th or you will be too late to see the goods at India house.'[148]

In addition to this general advice, Salte stresses upon specific directions that Oldknow's manufacture could potentially take for greater commercial success. He particularly dissuades Oldknow from engaging in the manufacture of calicoes and prints, to the extent that he advises Oldknow to stop the looms until his weavers can improve the quality of goods produced. Comparisons with Indian goods, especially muslins and printed cottons, are central to the commercial advice and market insight offered by Salte to Oldknow. A letter dated 23 April 1785 states, '… we hope you wil improve the Golden Opportunity that now presents itself, of improving every Article to the Uttmost.'[149] In his role as a trusted advisor and stakeholder of

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[144] Unwin, *Samuel Oldknow and the Arkwrights*, p. 10
[145] Draft letter from Samuel Oldknow to Samuel and William Salte, May 1783, in Unwin, *Samuel Oldknow and the Arkwrights*, p. 10, 70
[146] Letter from Samuel and William Salte to Samuel Oldknow, 24 May 1783, in Unwin, *Samuel Oldknow and the Arkwrights*, p. 12
[147] Ibid
[148] Ibid. p. 67
[149] Ibid. p. 69-60

Oldknow's enterprise, Salte guides on 1 December 1786, 'Drop the Chk Trade, & all branches that a common Manufacturer can do better. Keep & confine yourself to the improvement of Muslins particularly. You will have rivals enough to contend with - & your Work must be superior.'[150]

On 4 March 1786 he writes, 'the Napkins are too short & narrow must be made larger each way, & to imitate the India a Red Stripe or border at each end, observe this in future…' He goes on to instruct, 'Turn your Weavers to Muslins. [To] forward this Manufacture we now enclose you some patterns drawn [from] Different articles of Muslins, come over as presents to the People of Fashion. We also enclose two patterns of Muslins, the patterns are written under to describe to you how they are Worked…'[151] While the actual samples and patterns have not survived, the general drift of the letter leaves little to speculation or conjecture – comparisons with Indian goods were key to the growth, indeed survival, of English muslin manufacture. The letter from 10 May 1786 notes, '…turn the Loom to something Else. They are not fine enough for people of Fashion… Arkwright must lower his Twist & he must Spin finer … We hope to see you in town soon & shall collect all the new hints in our power to improve the Manufacture of Muslins.'[152]

The Saltes were not the only agents of Oldknow's requesting a refinement in the quality of his products. Another client, returning a cloth sent by Oldknow, stresses, '… you cannot send us anything too fine.'[153] Emphasising the fact that quality, and not price, was the significant determinant, in the subsequent list of new goods required he adds, '1 [ ] – 6/4 + spott good at any price but the finer the better.'[154] A letter from December 1787 from a client Benjamin Gibson reads, 'I am sorry that the demands for your Muslins which I think superior in general to any other British or Indian has not answered my expectations.'[155] He follows this gently rendered negative feedback with a request for the finest muslins Oldknow could make, clearly indicating an existing and growing market demand for fine cotton products.[156]

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[150] Ibid. p. 83
[151] Ibid. p. 60
[152] Ibid. p. 65
[153] Letter from [ ] Burnett to Samuel Oldknow, undated, SO/1/51, The Oldknow Papers, John Rylands Library, Manchester
[154] Ibid.
[155] Letter from Benjamin Gibson to SO, December 1787, SO/1/106, The Oldknow Papers, John Rylands Library, Manchester
[156] Ibid.

Underscoring both the stiff competition from Indian goods as well as the urgent need to improve quality of own manufacture, Samuel Oldknow writing to his brother in October 1787 informs of a glut in the market owing to the arrival of India goods and the need for them to stop manufacturing competing articles until the Indian stock was eased out of the market. He writes, 'Nobody will buy till the India sale is over … We must make finer goods & we must be doubly carefull in all respects – and not make more but rather fewer than we now do – for it is almost incredible the quantity that will come into the Market of India Muslins in the next 4 Months. The private Trade sale began to day [sic] and very fine thin goods sold high – so that very fine thin goods we must make our aim.'[157]

It is worth noting here that not only was Oldknow concerned about the competition from Indian goods, he was also strategically calibrating his business and production plans in response to this competition. His focus on improving the quality of his product stems from his inability to compete against the mainstream products - the printed calicoes – which were over-supplied by this time in the evolution of the British cotton industry. As Salte observes to Oldknow in November 1787, 'We are sorry the prospect looks so dark upon British Manufactures – the Private Trade Sale is Over & Goods in general cheap enough but we dread the large Company Sale.'[158] Competition from Indian goods, and from their quality, was responsible for re-shaping the commercial strategies as well as the trajectory of technological innovations within the early British cotton industry.

3.2.4 The Self-Acting Mule: the Pursuit of Consistent Quality

Crompton's mule successfully enabled the spinning of fine-quality cotton yarns and brought in the era of English muslins. It enabled the mechanised production of what had previously been an expensive, hand-produced, imported textile product. While the invention itself was led by the pursuit of product quality, it also involved higher wages to highly skilled mule operators. Further, it resulted in uneven quality of the final product, dependent as it was on the mechanical skill and efficiency of the mule operators.[159]

[157] Unwin, *Samuel Oldknow and the Arkwrights*, p. 97
[158] Ibid. p. 100
[159] G. N. Von Tunzelmann, *Technology and Industrial Progress: the Foundations of Economic Growth*, E. Elgar Publishing Co., Aldershot, England; Brookfield, Vt, USA, 1994, p. 110

Compared to the mule, the waterframe allowed for continuous spinning drawing, twisting and winding of yarn.[160] Operators intervened only to piece broken yarn and to replace bobbins. The mule, on the other hand, required constant supervision, from setting and regulating the mule speed, winding the cops of yarn, and pushing the carriage back.[161] All of these operations required skilled operators commanding higher wages but also impacting the quality of the final product through variations in skill levels and operational capacity.

In 1825 and 1830, Richard Roberts was granted patents for developing the self-acting mule. It bypassed the dependence on mule operators and ensured an evenly spun yarn. The self-acting mule was the first instance of industry leaders commissioning an engineer to design a machine that would mechanise the entire process of spinning yarn, ensuring uniform quality as well as reduced reliance on labour.[162]

If manufacturers' choices pertaining to product and technology are determined by the skills of the available labour to operate existing machinery, then this argument may be extended to the first adoption of mechanisation to spin cotton warp.[163] Labour skill - both before the advent of mechanised technology and until machinery evolved to the stage where labour inputs were limited to starting and stopping the machine - was a key determinant of final product quality. The very inability to spin adequate cotton warp may be viewed as a skill deficiency within the locally available labour force, mitigated by mechanisation in the absence of avenues of skill acquisition or training. In this, technological choices are influenced by local conditions, which are a function of relative factor costs as well as local technological path dependence. Yet, historical sources suggest that in the early British cotton industry, technological shift was also a result of the pursuit of matching the quality of Indian handmade cottons - an exogenous stimulus. This effectively enabled existing handmade products to steer the path of machinery development to mimic the quality of handmade goods, leaving in their wake a 'soft determinism'[164] in the course taken by technological developments in the British cotton industry.

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[160] A.M. Huberman, *Escape from the market: negotiating work in Lancashire*, Cambridge University Press, Cambridge, 1996, p. 23
[161] Ibid. p. 42
[162] Harold Catling, *The Spinning Mule*, Lancashire County Library, 1986, p. 63
[163] Joan Roses, The Choice of Technology: Spanish, Italian, British and US cotton mills compared, 1830-60, in, Sevket Pamuk and Jeffery G. Williamson (eds), *The Mediterranean Response to Globalization before 1950*, Routledge, 2000
[164] Nathan Rosenberg, *Exploring the Black Box*, p.14

That competition against Indian cotton goods, especially muslins, drove the pursuit of product quality improvement may be illustrated by a concrete historical example. The chief technical problem that had confronted Oldknow was to obtain finer twist/warp of regular quality in large quantities and at affordable prices.[165] Until the time that Oldknow was buying warp from Arkwright, this problem had persisted, mainly as the waterframe was only able to produce hard or stringy warp, unsuitable for muslins. By 1788, Oldknow had deployed the Mule at his factory in Stockport and by 1791 he was successfully producing fine warp and weft of No.120.[166]

And yet, writing in 1835, Baines observed that 'The Indian hand-spun yarn is softer than the mule-yarn of England and the muslins made of the former are much more durable than those made of the later.'[167] Further he observes, 'Indian women, whose sense of touch is most acute and delicate, produce yarns which are finer and far more tenacious than any of the machine-spun yarns of Europe.'[168] Microscopic analysis in the next chapter shows that Baines' observation is empirically verifiable and borne out by the surviving material evidence. Indian muslins continued to surpass in fineness their British and European counterparts well into the second half of the 19th century.

Whether the Indian cotton makers benefitted from 'vertical specialisation' as described by Roy or the British technological advancements were still on their way towards emulating the quality of hand-spun yarn despite continuously calibrating their warp against the fine hand-spun yarn from India, the fact remains that coming up towards the end of the 18th century, prohibitive tariffs were seen as the only way to protect domestic cotton textile production in Britain and many other European countries.[169] Ellison points out that at the time of the Calico Act of 1736, no one had contemplated the possibility of all-cotton goods being produced in England.[170]

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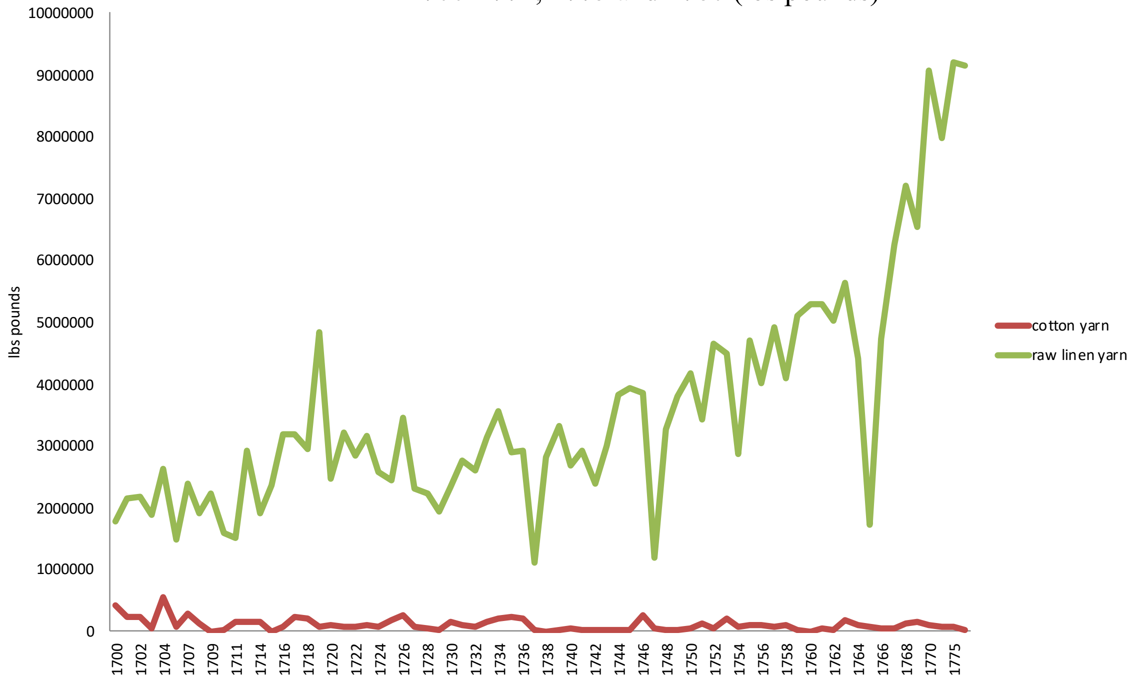
[165] Unwin, *Samuel Oldknow and the Arkwrights*, p. 71
[166] Ibid.
[167] Baines, *Cotton Manufacture*, p. 60
[168] Ibid. p. 68
[169] Tirthankar Roy, Knowledge and Divergence from the Perspective of Early Modern India, *Journal of Global History*, 2008, Vol. 3(3), 361-387; Baines, *Cotton Manufacture*, p. 115
[170] Ellison, *The Cotton Trade*, p. 22

3.2.5 The Decline of Linens and Fustians

A pertinent corollary to the growth of the British cotton industry is the decline of the fustian manufacture. Did the fustian industry suffer as a result of the growth of the cotton industry? Evidence suggests that there was substitution of linen by cotton during this period and a comprehensive overtaking of linen consumption by that of cotton.

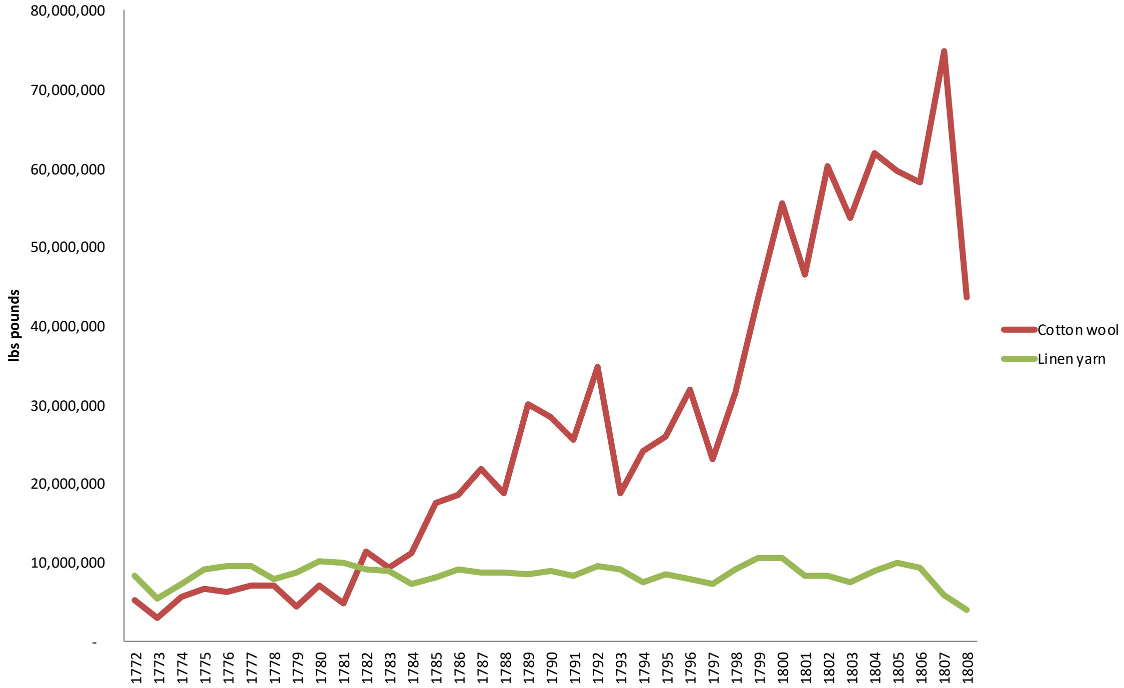
Figure 2: Total quantity of British import of cotton and linen yarn 1700-1771, 1775 and 1780 (lbs pounds)



Source: Elizabeth Schumpeter, *English Overseas Trade Statistics,* Clarendon Press, Oxford, 1960

The British overseas imports from the beginning of the 18th century up until its third quarter reveal that for this period, import of linen yarn exceeded that of cotton yarn significantly. This ties in with Baines' view that imported cotton yarn was used to weave the finest cotton goods in Britain. Fustian manufacture, however, continued to grow steadily. How much of it was driven by the new calico imitations is not directly indicated, though an upward trend from the middle of the 18th century points in the direction of increased total output.

Figure 3: Total quantity of British imports of cotton wool and raw linen yarn 1772-1808 (lbs pounds)



Source: Elizabeth Schumpeter, *English Overseas Trade Statistics,* Clarendon Press, Oxford, 1960

Figure 3 shows that cotton wool imports were in tandem with linen yarn imports until the watershed year of 1781. Until 1781, while the technology to make the all-cotton cloth had been developed, it was not available to all manufacturers due to patent restrictions. In 1781, a major shift in production allowed not only for linen to be substituted by cotton but also for it to be completely overtaken by it in production. Cotton imports soared even as linen imports continued without much variation until the beginning of the 19th century.

The major event of 1781, which for the first time enabled a reversal of fibre import trends between cotton and linen was the coming to an end of Arkwright's patent for the use of the roller spinning method for cotton spinning.[171] This was a critical juncture in the emerging cotton industry as for the first time since the possibility of making the all-cotton cloth - which materialised in 1767 with the invention of the waterframe - all interested entrepreneurs were able to use the technique of roller spinning to establish their own cotton manufactories. In less than two years from the lapsing of the patent, cotton manufactories sprung across the north of England, eager to claim their share of monopolistic gains in the industry. According to Chapman, a conservative estimate suggests that at least 208 new mills came up in Yorkshire,

[171] Ellison, *The Cotton Trade*, p. 25

Cheshire and Derbyshire after 1781, entirely a result of the successful legal challenge to Arkwright's patent.[172]

Technological growth was a result of the quest for quality, yet the pursuit of monopolistic gains through the manufacture of differentiated goods underpinned this endeavour. A letter from Arkwright to his business partner Jedediah Strutt from March 1772 highlights that Arkwright was very much conscious of the commercial possibilities of roller spinning, not just for fustians but also for calicoes, other all-cotton goods and even worsteds.[173] It is no surprise, then, that other entrepreneurs awaited the lapse of his patent eagerly.

The Calico Acts of 1721 and 1736 were legal obstacles to the manufacture of cloth utilising cotton warp. In a petition against this legal obstacle which allowed only half-cotton textiles to be manufactured and consumed in Britain, Arkwright and his partners explained that under the patent granted to Arkwright in 1769, cotton warp was now spun on machines, and 'with such Warps, there are wholly made in Great Britain, from raw Materials, Velverets, and a Variety of other Goods, particularly a new Manufacture of White Cotton Stuffs, adapted for Printing.'[174] The petition added that duties imposed upon this all-cotton cloth were 'to the great Prejudice of a new and promising British manufacture.' It added that 'Cotton goods so made wholly of Cotton will be greatly superior in Quality to the present Species of Cotton Goods made with Linen Yarn Warps, and will bleach, print, wash and wear better.'[175]

The above testimony deploys arguments based solely upon the idea of improvements in cloth quality for its justification, emphasising the pursuit of quality as the driving force behind technological innovations. The waterframe, developed in 1767 by Arkwright, was able to overcome the first bottleneck of spinning warp yarn in the early British cotton manufacturing, and commercially viable all-cotton cloth was first woven after Arkwright's invention. Subsequently, the fine all-cotton cloth was made, overcoming the second bottleneck, with machinery that combined the early advances of the jenny and the waterframe, i.e., the mule.

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[172] S.D. Chapman, *The Cotton Industry and the Industrial Revolution*, p. 27
[173] Letter from Arkwright to Strutt, March 1772, in Fitton and Wadsworth, *The Strutts and the Arkwrights*, p. 67-68
[174] Quoted in Fitton and Wadsworth, *The Strutts and the Arkwrights*, p. 69
[175] Ibid. p. 70

3.3 Political Economy, Incentives and Technological Growth

As discussed in the previous section, market demand for Indian cottons provided the key competitive stimulus for entrepreneurship and technological change. Astute recognition of the economic merits of investment in the cotton industry was widespread, enabling institutional support and an environment conducive for entrepreneurial and technological drive.

3.3.1 Public Incentives

What motivates entrepreneurs to pursue the development of new technology? While this thesis accords primacy to market demand for a pre-existing product, and the inability of the local workforce to make that product, as the main motivators for technological innovations in spinning machinery, in addition, public incentives as well as a favourable political economy may be seen as offering the environmental inducements for innovations in the production process for meeting the quality-led market demand for cotton goods.

The early British cotton industry is interesting for the fact that while some key innovations came from industry insiders or those who were engaged with spinning and weaving routinely, some other vital innovations were brought about by complete industry outsiders, like Richard Arkwright, a barber by training, and Edmund Cartwright, a clergyman by profession but famous for his invention of the power loom. This begs the question - why would individuals who had no connection with cotton machinery, or indeed any aspect of textile manufacturing, be interested in technical innovations within the cotton industry? I argue that the push towards technological innovation came not only from entrepreneurs who saw the economic potential of cotton but also from the very political economy that was experiencing unprecedented changes from the introduction of exotic foreign goods.[176]

According to Mantoux, The Society for the Encouragement of Arts, Manufacture and Commerce (now the RSA), in London looked upon the issue of innovation in cotton spinning, as in other disciplines of manufacturing and commerce, as a competition - a means of opening the innovation process to as many interested minds and hands as possible. The society offered a reward to anyone who could create a new device, which was able to, 'spin six threads of

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[176] Parthasarathi, *Why Europe Grew Rich*, p. 104

wool, flax, Cotton, or silk, at one time, and that will require but one person to work and attend it.'[177] Dossie, writing in 1768, was of the view that the Society 'attempted to improve the practice of this art in England, and to introduce the spinning [of] those finer kinds of threads, or cotton yarn, which we are at present furnished with from foreign countries.'[178] To that end, 'premiums for spinning fine were claimed each successive year, from 1759 to 1766 inclusive.'[179]

Dossie notes that the initial purpose of offering premiums was to encourage domestic imitations of foreign goods. Once this purpose was fulfilled, the focus of the premiums turned towards the refinement of domestic processes, including incorporation of labour efficiency and user ease in machinery.[180] It may be stressed that the very existence of premiums for warp yarn refers to the recognition within the economy that at the time the British manufacture was unable to match the quality of the Indian goods and the realisation of the importance of matching the quality of Indian cotton goods.

The premiums offered by the RSA are evidence of institutional recognition of the need for improvement of yarn quality in Britain. The premium offered in 1758 specifically called for 'spinning not less than five hundred pounds weight of cotton yarn, nearest to the sort called Surat or Turkey cotton yarn.'[181] Reflecting upon this requirement, the Society's premium itself sets Surat or Turkey yarn as the benchmark or standard against which English prospective yarn was to be measured. Several premiums were also offered for imitation of dyes for printing especially related to madder red and indigo.

Griffith, Hunt and O'Brien, using patent data, have shown that product innovation was the chief motivator for inventions until 1790, after which mechanical techniques were applied to fabrics involving factor-saving inventions.[182] Data for non-patented inventions shows that 78

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[177] Paul Mantoux, *The Industrial Revolution in the Eighteenth Century: An Outline of the Beginnings of the Modern Factory System in England* (Cape, 1961) p. 215
[178] Robert Dossie, *Memoirs of agriculture and other oeconomical arts,* Vol I, J Nourse, London, First printed in 1768, p. 94
[179] Ibid.
[180] Ibid. p.93-99
[181] Premium offered by the Royal Society of Arts, Manufactures and Commerce, London, 1758 advertised widely in, for example, *The Universal Magazine of Knowledge and Pleasure*, December 1758, p. 208
[182] Trevor Griffith, Phillip Hunt and Patrick O'Brien, Inventive Activity in the British Textile Industry, 1700-1800, *The Journal of Economic History*, Vol. 52, No. 4, December 1992, p. 881-906

out of 97 non-patented inventions had institutional support, 72 of them being supported by the Society of Arts.[183] While patent data often reflects incremental improvements to pre-existing innovations, or designs to evade existing patent restrictions[184] in the case of the British cotton industry it nevertheless provides a useful barometer of the impact of both institutional support and a favourable political economy upon incentivising individuals while at the same time publicising a favourable notion of inventive activities.

What emerges from the above evidence is that there were clear public incentives for innovating machinery for the cotton industry, in addition to tangible commercial opportunities. Public incentives were advanced to encourage those who were not already aware of the prospective profits to be made from streamlining and mechanising cotton manufacturing.

3.3.2 Quality-led Imitations, Monopolistic Competition and 'Enthusiastic Schemes'

Styles has pointed out that the pursuit of quality improvement of cottons was the stimulus for the mechanisation of its production process. [185] Yet manufacturers had no incentive to strive for quality improvements if the market did not demand that quality of product and if gains were not there for the taking by the advancement of quality. The existence of competition against Indian cottons questions the argument of quality for quality sake - the most logical rationale comes via competition from the pre-existing fine Indian cottons, which commanded a premium in the market on the basis of their quality. At the same time, Indian cottons afforded examples of the quality to be emulated. Historical sources have narrated accounts of British manufacturers suffering dearly every time the Company sprung its doors open for a major India House sale of goods. They have also referred to the use of Indian fabrics as samples and prototypes by British manufacturers to base their products on and for conducting regular comparisons of their products against the Indian benchmarks.

Fundamentally, if warp yarn thickness was a problem for the manufacturers in Britain then it was so because it was not comparable to the warp used in Indian all-cotton cloths. What transpired in 18th century Britain was a concerted deployment of machinery for resolving the obstacles facing the cotton industry, enabling the first successful attempt to imitate by machines

[183] Ibid. p. 885
[184] Ibid. p. 889
[185] John Styles, Fashion, Textiles and the origins of the Industrial Revolution, *East Asian Journal of British History*, Vol 5 (2016) p. 186

what the skilled human hands could previously do. The growth of overseas trade in cotton goods fuelled their demand and capital gravitated towards mechanisation in an industry which had a proven market demand. Baines, and other historical writers of the period, while offering a token nod to Indian cottons which preceded the precocious growth of British cottons, fail to acknowledge the crucial role played by the India goods not only in demand stimulation, both domestically and overseas, but also in providing comparable product benchmarks for the manufacturing of cottons in Britain.

Edward Baines, Robert Guest, James Ogden, Thomas Ellison and other writers/historians who have been drawn to the extraordinary growth of the cotton industry in Britain in the 18th century, have had to contend with multiple versions of accounts relating to the specific inventions that heralded the industrial era, pertaining to inventors, patent challenges, court cases and extended business rivalries for this period of cotton manufacturing. It is interesting to note that within a period of five decades, substantial progress was made in the mechanisation of the production process with numerous inventions geared towards improving the quality of production. The cotton industry attracted unparalleled, focussed interest, and sustained commercial attention.

Indeed, it may be argued that the many commercial disputes and contentions were precisely a product of this peculiar attention that the industry received. As is evident in the dispute between Arkwright, Wyatt and Highs as to which one was the inventor of the process of spinning of yarn using rollers, it is clear that each one had been working on the idea of using rollers for spinning, but each mechanism was adequately distinct from the other to be worthy of being acknowledged as an original.[186] This is indicative of the fact that the period was very much abuzz with the idea of the potential of cotton as the commodity most likely to bring commercial success.

Inventors were nurtured in an environment favouring practical inventions suitable for application to the cotton manufacturing process. It is worthwhile to remind ourselves here that cotton was not a plant native to the British Isles and British textile manufacturers had little

[186] Baines, *Cotton Manufacture*, p. 148-153; A conflicting account is offered by Robert Guest, *A Compendious History of the Cotton Manufacture with a Disproval of the Claim of Sir Richard Arkwright to the invention of its ingenious machinery*, Joseph Pratt, Manchester, First published 1823, p. 12-17

practical experience of handling and manipulating this fibre.[187] What then was the source of the growth of this nurturing environment related to the development of an industry based on this alien fibre? What made the commercial opportunities related to cotton textiles clear and evident to the extent that inventions began to be targeted to finding solutions to specific problems troubling this industry, kickstarting the onset of modern economic growth within its clearly foreign foundations? Fustian manufacture, as Figures 2 and 3 show, remained largely constant over the 18th century - what then provided the stimulus for the superseding of fustian manufacture by cotton? The market demand, both domestic and overseas, as demonstrated by the global popularity of Indian cottons, the benchmark cottons of this time, offered new opportunities for commercial growth. Entrepreneurs vied amongst themselves and with the Indian cotton goods, both in the domestic and overseas markets, by differentiating their products for monopolistic gains, as is evident from the Oldknow-Salte exchange.

Thomas mentioned the growth of ‘enthusiastic schemes’ to be able to replicate Indian calicoes in Britain.[188] ‘Enthusiastic schemes’ succinctly sums up the atmosphere of the period. Despite their differences of opinions about specific details of the trajectory of the cotton industry in Britain, one unanimous voice that emanates from authors writing about this period of British history is that of cotton’s latent potential. Thomas describes two ‘schemes’ for the manufacture of calicoes in England in the early 1700s, both of which did not materialise.[189] Yet, they point us in the direction of a sense of commercial excitement about cotton and its use as a fabric, as a fibre for manufacturing exotic, sought after textiles, and as a product highly suitable for overseas trade, especially the slave trade, owing to the demand that this ‘highly speculative commerce’ commanded.[190]

A special reference may be made here of Arkwright, who had no connection to textiles until his foray into the cotton business. He was a barber-surgeon by training and profession and travelled around the north of England collecting hair for his wig-making enterprise. The Cromford Mills Museum in the Derwent Valley, where Arkwright first set up his water mill for spinning cotton, describes him as a man who availed of the opportunities afforded by his time and travels. It notes, ‘1760s: Arkwright comes into contact with Thomas Highs and John

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[187] Riello, *Cotton*, p. 37
[188] P.J. Thomas, *Mercantilism*, p. 40-47, 130-131, 159
[189] Ibid.
[190] Wadsworth and Mann, *The Cotton Trade*, p. 227

Kay and learns of their half-developed roller-spinning machine. Heavily inspired by Highs and Kay, Arkwright develops a better model, and gains a dominant position by patenting it.'[191]

Two issues are of significance from the above quotation. Firstly, Arkwright's travels enabled him to come in contact with people who were already not just talking about but working towards making machinery for spinning cotton. Adequately spun cotton warp, as discussed earlier, was a bottleneck for the British cotton industry during this period, and efforts of Highs and Kay would suggest that those involved in the industry were aware of this bottleneck and were working towards resolving it mechanically.

Secondly, Arkwright saw a commercial opportunity in cotton, and though he had no background in cotton spinning, weaving or printing, he threw himself into the venture. Having a mechanical bent of mind, he was able to adjust and manipulate machinery to make a strong yet fine yarn, long enough to constitute viable cotton warp. Arkwright devoted himself to that singular problem of creating strong cotton warp - the first major bottleneck in the cotton industry of the period. Despite being an industry outsider, he was aware of the one problem that plagued it. This is indicative of cotton's position within the economy as a prime commodity viewed by existing and prospective entrepreneurs as possessing strong commercial possibilities during this period.

It is also interesting to note that sources are agreed on the fact that although Arkwright had a mechanical bent of mind, he was not a trained mechanic.[192] Evidently, being a trained mechanic was not critical; a deep interest in the project and the ability to learn from trial and error, however, were. According to Wilson, 'the new machinery in the textile industry involved no principles that an intelligent merchant could not grasp … the dynamic factor continued to be the sense of commercial opportunity of the directing entrepreneur.'[193] This is also evident from the historical description of Edmund Cartwright, who invented the power loom in 1789. In his own words he remarked, 'As I had never before turned my thoughts to anything mechanical, either in theory or practice, nor had ever seen a loom at work, or knew anything of its

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[191] The Cromford Museum, The Arkwright Experience, Matlock, Derbyshire
[192] Guest, *A Compendious History*, p. 21; Baines, *Cotton Manufacture*, p. 194-196
[193] Charles Wilson, Technology and Industrial Organisation, in, Singer, Holmyard, Hall and Williams, *A History of Technology*, Vol 5, p. 799-800

construction, you will readily suppose that my first loom was a most rude piece of machinery.'[194]

In his description of the cloth business in and around Manchester, Guest makes an interesting reference to 'Commercial travellers … [who] pervade every town, village and hamlet in the kingdom, carrying their samples and patterns, taking orders from the retail tradesmen … being gregarious, the news is readily communicated. The travellers are a body of men exhibiting intelligence and acuteness, combined, in many instances, with self-conceit and the superficial information acquired by reading newspapers.'[195]

Guest's reference to 'samples and patterns' is not an isolated occurrence in the historiography of the industry from this period. It is reminiscent of Salte's samples and patterns from the India House sales for Oldknow.[196] During this period of infancy of the British cotton industry, only Indian cotton textiles could provide comparative 'samples and patterns.' They were the benchmark products for cloth quality, and the patterns for prints and/or weave, used extensively by manufacturers as references for quality and prints.

Further, Guest's description of 'commercial travellers' lends to the argument that towns, villages and hamlets were indeed connected via a network of knowledge exchange about the cotton industry, its requirements, potentials and limitations. In this context, the 'commercial travellers' expedited the spread of the cotton word with far-reaching consequences for the industry, and indeed for modern economic growth. This also ties in with Cromford Museum's description of Arkwright as a keen observer and an astute entrepreneur, picking up useful information during his travels around the country and deploying it towards commercial gain. Zealous entrepreneurs eagerly grasped cotton's global potential and, using the pre-existing benchmarks as their guides, successfully established the world's first machine-driven industry in a matter of decades. The role of the benchmark products and their signposting of market approved quality metrics as 'signals and focussing devices' were crucial in the establishment of this new industry, especially for the course of its growth.[197]

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[194] Edmund Cartwright's letter to Bannatyne, 1785, quoted in Baines, *Cotton Manufacture*, p. 230
[195] Guest, *A Compendious History*, p. 11 [italics added]
[196] Previous p. 50-52
[197] Rosenberg, *Exploring the Black Box*, p.14

3.4 Conclusion

A re-reading of the historical narratives surrounding the growth of the British cotton industry from the perspective of influence of pre-existing Indian cottons reveals that competition against, and learning from, Indian cottons were constant features of the infant British cotton industry. The learning took the form of quality comparisons that drove the refinement of machinery for the spinning of finer cotton yarn, enabling the manufacture of finer cotton goods. The pursuit of quality to match the fineness of handmade Indian cotton fabrics was a key stimulus for the growth and the specific direction of mechanical evolution in the British cotton industry.

Chapter 4: Evolution of Cloth Quality: Material Evidence

Abstract

Historical textual evidence suggests that manufacturers in the early British cotton industry were concerned about cloth quality vis-à-vis Indian cottons and that there was a shift towards improvements in cloth quality, especially for the making of the cotton warp yarn. Does material evidence from the period under consideration corroborate this view? This chapter analyses British and Indian cotton cloths from 1746-1866 to check if there is a visible upward shift in the quality of British cottons and assesses how their quality compares with handmade Indian cottons. Microscopic analyses of textile swatches from the Barbara Johnson album and the John Holker manuscript corroborate the textual evidence of quality-driven shift in the British cotton industry, with a decided preference for all-cotton fabrics. The John Forbes Watson volumes of Indian pre-industrial textiles are used as a comparator; they show that Indian handmade muslins continued to be finer and superior in quality despite the quality-focussed improvements in mechanisation in the British cotton industry.

4.1 Introduction

The account of comparisons with Indian cottons that led to learning from them suggests that there should be some tangible evidence towards a push for improvements in cloth quality and fineness over the period of study. Is such a push, in fact, visible from the surviving cottons of this period? Do the material cotton textiles of this period show a trend towards improved, finer yarns and final products? To test this, I study two distinct manuscripts that have preserved English cotton textile samples from this period. I then compare them with a third manuscript containing surviving Indian handmade cottons from the period under study. The yarn composition and thread count of selected fabrics spanning six decades from the first manuscript, which intersect with the time-period under consideration (1746-1816), are studied with a view to establishing the evolution of their quality over time. The second manuscript offers highest quality textile samples from 1755-56, enabling a further analysis of quality of cotton textiles from this period, as well as a cross-examination with the first. The third enables comparisons with contemporaneous Indian cotton cloth. It also shows that the highest quality of cotton cloth – fine muslins - remained handmade and from India, corroborating John Forbes Watson's comparative assessment of the highest Indian, British and French muslins in 1866, where he found that Indian muslins were of highest quality combining fineness and strength. This finding, alongside textual evidence that the British manufacturers were aware of a quality differential, permits us to infer a causal link between the initial gap as well as the direction and pace of spinning innovations in the British cotton industry.

Final cloth quality is a function of its two key components - yarn quality, which determines the base cloth quality, and print quality (where applicable), which is itself determined, to a large extent, by the yarn or base cloth quality. Fine, uniform yarn results in a fine and uniform cloth conducive to good, clear print registration. This chapter deals with the first component of quality involving the pursuit of yarn quality for the making of calicoes and muslins. This sequential evolution is evidenced by the two successive quests in the early British cotton industry to overcome the two main bottlenecks – the first is for the making of the all-cotton cloth (calicoes) and the second is the quest for the fine all-cotton cloth (muslins).[198]

This chapter addresses the evolution of cotton spinning in Britain as witnessed in the quality of the final cloth produced as the industry attempted to successfully imitate the quality of handmade Indian benchmark cottons. It is useful, therefore, to set forth a definition of what 'benchmark' means in the context of cotton cloth quality. As the narrative in the previous chapter has shown, the 'benchmark' in cloth quality itself shifted over time, from 1740 to 1790. The first benchmark was the all-cotton cloth from India. Once that quality threshold was met through the invention of the waterframe, the next benchmark was the fine Indian all-cotton cloth.

4.2 Isolating Cloth Quality: Methodology

According to the discussion in the previous chapter, early attempts at imitating Indian cottons resulted in mixed cotton-linen cloths of qualities that were unable to match those of the handmade Indian cottons. Equally, the drive towards matching the quality of Indian goods is taken as the impulse for technological advancements in the early British cotton industry. The pursuit of improving the quality of English cottons to match competitor Indian cottons was the

[198] A third definition of cloth quality pertains to the weave of the cloth through woven designs. In Western Europe, the mechanisms for producing patterns on looms developed without any apparent link with the Indian manual way of obtaining similar woven designs on cloth. These added to the quality of cloth but were unconnected to Indian methods, hence remain necessary qualifications that must be acknowledged.

driving force for technological innovations in the British cotton industry. To that end, Indian cottons acted as the benchmarks for both products as well as their final quality, by first acting as the benchmarks for the all-cotton cloths and then for the fine all-cottons. The single most significant obstacle - the inability to manufacture viable cotton warp yarn - spurred a sequence of mechanical innovations that revolutionised textile making.

It is vital, therefore, to be able to isolate a measure of 'quality' and ascertain what it constitutes in the context of cotton textiles. There are several industry standards for assessing the quality of textiles. At its most basic, cloth quality may be measured as the yarn/thread count of a particular fabric, which is the warp and weft count in a square centimetre or inch of fabric. A modern variant of this method takes thread count as only warps per inch of a fabric or ends per inch. This measure is unsuitable for archival textiles, which don't always have an even/equal warp-weft count or when identifying the warp itself may be difficult because the surviving piece might be a small off-cut or fragment. Another common method for measuring the quality of yarn is that of yarn count, which is expressed as length per unit mass. This measure requires a unit length of the fabric to be measured and weighed – something that is not possible with archival fabric samples which are often stuck on to paper or cardboard. Many other methods exist for quality assessment of present-day textiles, but these are unsuitable for analysing historical textiles. The most crucial impediment is the significantly limited ability to touch with human hands any historical textile specimens, effectively ruling out several more advanced yet intrusive or destructive methods of textile analysis.

While archaeologists often use threads per centimetre as a measure of textile warp and weft, there is no accepted standard in this regard.[199] The approach adopted in this study is to enumerate the basic warp and weft count of a square inch of a swatch of fabric. The thread per inch count or TPI is used as it is the industry standard to measure fineness of textiles and to provide a representative measure of both small and large fabric samples as the English imperial unit was the unit of measurement of the period as evidenced in historical accounts of the period.[200] The thread per inch count or TPI is taken as the basic measure for quality – the higher the TPI, the finer the yarn and therefore the finer the cloth. For select textiles, an estimated

[199] For use of the metric system, see Gleba and Harris, The first plant bast fibre technology: identifying splicing in archaeological textiles, *Archaeological and Anthropological Science*, vol. 11 (2019) p. 2329-46

[200] Florence Montgomery, Holker's Livre d'Échantillons, p. 216

indicative yarn count (length per unit mass) is given, based on a formula that allows for a computation of yarn count from the number of warps or ends per inch of fabric, to be able to generate comparability and dialogue with existing literature on cloth quality. Further, quality may be seen both as the fineness of the yarns constituting warp and weft, as well as the fineness of the fibres of the yarns constituting warp and weft. An all-cotton cloth will have a different (usually finer, but not always) final quality from a cloth made with linen warp and cotton weft. Therefore, the study uses microscopic analysis to identify basic yarn composition of specific archival textiles alongside their TPI counts to establish a measure of their quality.[201]

For this study, a portable Dino-Lite Premier Digital Microscope AM4113T has been used to magnify textile swatches up to sixty times (60x) with a view to understanding their warp-weft compositions. Dino-Lite is a handheld digital microscope, which has previously been used by archaeologists as well as textile and economic historians like John Styles, Giorgio Riello, Stefan Hanss, Margarita Gleba and Suzanna Harris to assess archival textile pieces.[202] In addition, a thread counter enabling ten-fold (10x) magnification has been used to determine the thread count as a measure of the fineness of the samples.

In all, 445 textile samples have been analysed from three different sources using the microscope, and their thread per inch count established. The remainder of the chapter first looks at the main source of English cottons, setting out the evolution of cotton cloth quality in the British cotton industry. The next section corroborates the evidence from the first source using a second source for English cottons. The narrative then compares the quality metrics for English cottons with contemporary cottons from India. The last section sets out the main findings and concludes.

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201 A limitation of the methodology is the magnifying power of the portable microscope, which cannot provide details and granularity of, for example, the fibre id of each individual spun yarn. However, this is not a critical limitation for this study as the focus here is on overall quality of the fabrics and thread per inch count. The thread count numbers (TPI) would remain the same in laboratory settings, allowing for the possibility of a small margin of error for individual yarn fibre id.

202 Stefan Hanss, Digital Microscopy and Early Modern Embroidery, in Giorgio Riello and Anne Gerritsen, *Writing Material Culture History* (London, 2020); Gleba and Harris, The first plant bast fibre technology

4.3 The Barbara Johnson Album, 1746-1823

The evidence of cloth quality for the period 1746-1816 is obtained through a study of selected textile swatches compiled in the Barbara Johnson Album at the Victoria and Albert Museum, London.[203] The album contains some of the earliest known imitations of Indian cottons in Britain as well as some of the earliest surviving and identifiable British all-cotton cloths. Lemire has used this album to show the changing fashion preference from fibres like linens, woollens, silks and their combinations towards lightweight cottons.[204]

Barbara Johnson was born in 1738 in Olney in Buckinghamshire. Her father was a reverend and she had three younger brothers.[205] The album itself appears to have been begun by her mother in 1746 as a record of the clothing worn by Johnson in her early years, to which Johnson kept adding swatches of fabrics she consumed until her own death. The album is a complex archival piece and of immense historical significance not only for the samples of clothing cut out and stuck upon it, with dates of purchase and price paid in some instances, but also for contemporary fashion engravings that Johnson obtained from magazines of the period and included in the album.

Another structurally interesting aspect of the album is the fact that it was not a new notebook used for this purpose by Johnson. Before its use by Johnson, the album was previously used as an account book by a George Thomson from 1738-1748, providing a fascinating social history of the life of a young man during this period.[206] It is unclear how Johnson came to own Thomson's album; what we do know is that she put it to good use by attaching her cloth and fashion samples on top of its pre-used pages.

The album is a unique, assorted collection of textiles from 1746-1823. It constitutes a random sample in that it includes a variety of textiles that comprised the wardrobe of one woman in Britain through her lifetime that intersected with the period under study. Textile swatches in her album are apt for this study as her wardrobe may be read as representative of textiles commonly worn by women during this period in British social history, since she came neither

[203] The Barbara Johnson Album, T.219-1973, V&A
[204] Beverly Lemire, Fashion's Favourite, p. 38-39, 111-114
[205] Natalie Rothstein, *Barbara Johnson's Album of Fashions and Fabrics*, The Victoria and Albert Museum, 1987, p. 9
[206] Ibid. p. 147

from an impoverished family nor one that may be considered exceptionally wealthy. Johnson's album has been studied by art and textile historians in the context of understanding the evolution of everyday style of dressing of an average woman during this period.[207] Lemire notes that Johnson was from a middle-class family while Dyer describes her as an 'unmarried woman of the middling sort.'[208] It may, therefore, be taken as an authoritative and representative source for commonly consumed and popular textiles of the period.

In addition, Johnson's assortment of swatches gives a singularly insightful random cross-section of textiles available in the English markets during this period - an advantage that pattern books created by manufacturers lack owing to their compilations being the work of single manufactories. Since the album constitutes the retail availability of fabrics in the domestic English market during this period, it may be inferred that it reflects the variety of products and their qualities available for popular consumption.

A general overview reveals that the swatches in the album exhibit a trend towards a preference for lighter fabrics over heavier ones. In the later years of the album, Johnson shows a preference for cottons and other lightweight fabrics over linen-cotton fabrics and other heavier mixed-fibre fabrics. In this, the evidence from the album corroborates received views that there was indeed a shift towards lightweight and cotton fabrics, as discussed in the previous chapter.[209] Another important finding is that there is a distinctive shift towards printed fabrics. This itself may be read as an influence of Indian textiles since prior to the introduction of Indian cottons, printed textiles were rare in the British textile repertoire. A category conspicuous by its near absence in the album is woollens, considered the mainstay of British manufacturing during this period.[210]

4.3.1 Microscopic Swatch Analysis

This study involves an analysis of selected textile swatches from the Barbara Johnson Album under a digital microscope to understand the evolution of cotton cloth quality in Britain from the middle of the 18th century leading up to the early 19th century.[211] The album contains 121

[207] Lemire, *Fashion's Favourite*, p. 111-113
[208] Dyer, Barbara Johnson Album, p. 110-111
[209] Previous p. 32
[210] Rothstein, *The Barbara Johnson Album*, p. 147
[211] The Barbara Johnson Album, V&A

samples of fabrics in all.[212] Since cotton and printed goods are the focus of this study, microscopic analysis of selected goods was undertaken to verify their yarn composition and thread count.

Out of the 121 samples in the album, 53 have been selected for this study. The 53 swatches are selected for (a) being described by Johnson as cottons or calicoes or muslins, or (b) if they are printed - even if Johnson's handwritten notes describe them as linen or (c) if they resemble in appearance prints or checks from India. The samples have been analysed for their cloth composition (whether linen and cotton or all-cotton/all-linen), thread count (threads per inch or TPI) as well as visible uniformity of yarn.

For the purpose of comparability with yarn quality metric in existing literature, I also provide an indicative conversion of the thread per inch count to the yarn count or length per unit mass of fabric for the Barbara Johnson samples. The formula used to derive the yarn count from the thread per inch count is √count x constant 10 = ends per inch.[213]

Figure 4: BJ/P1/S1(1746) TPI 136
Indicative yarn count: 46[214]

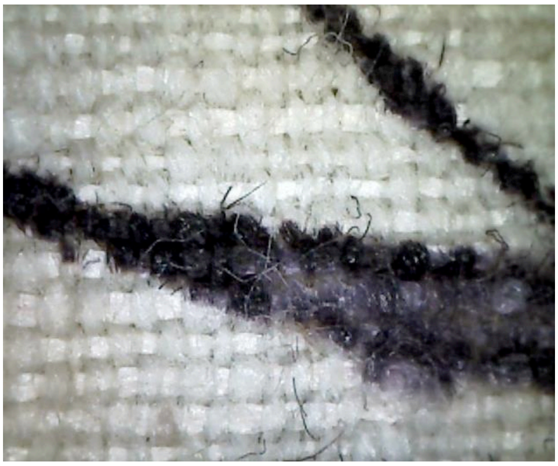

Figure 5: BJ/P1/S1(1746) magnified

[212] According to Rothstein, the 121 swatches can be broken up 54 silks, 37 cottons, 11 woollens, 8 silk and wool mixes, 7 linens, 4 silk and cotton mixes and 1 silk and linen mix.

[213] D.M. Amalsad, *A Textbook on Yarn and Cloth Calculation*. The formula that calculates yarn count from ends per inch (EPI) is $(EPI/10)^2$. Since ends per inch denotes warp ends per inch of fabric, half of threads per inch is taken as ends per inch. Hence, for a cloth of TPI 180, the formula will be √count x constant 10 = 90. Therefore, count = $9^2 = 81$.

[214] The formula $(EPI/10)^2$ assumes an equal warp and weft count, having originally been used to denote the count of mill-manufactured yarn. This was not always the case for handmade, pre-industrial textiles, and especially not for those that deployed different fibres for warp and weft. Further, the formula is used to give an approximate indication of the number of warp and weft in an average plain cloth, using

Figure 6: BJ/P1/S2(1747) TPI 115
Indicative yarn count: 33

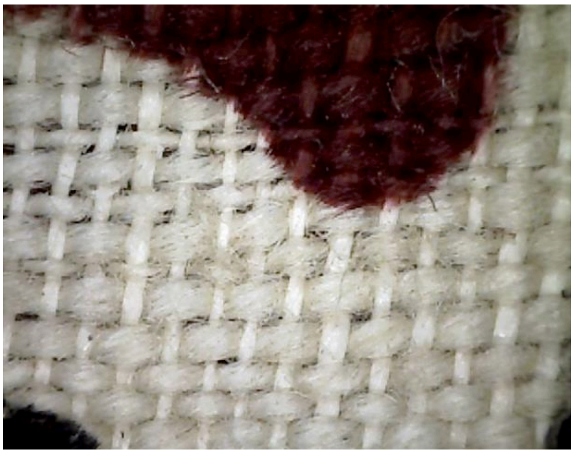

Figure 7: BJ/P1/S2(1747) magnified

Figures 4-7 are from the first page of Johnson's album. The two swatches, from 1746 and 1747 comprise a couple of the earliest surviving English 'calicoes.' Microscopic analysis reveals that they are, in fact, linen-cottons with linen warp. Their bright colours and bold prints are testimony to advances in the English printing industry. Despite the progress in dyeing and printing techniques, the overall quality of both swatches remains non-uniform and low, both for the base cloth as well as for the printing, due to the presence of linen warp and unevenly/coarsely spun yarns.

The thread counts of these two swatches are not vastly dissimilar. The first swatch is a finer, denser weave and the final product (Figure 4) reflects the relative fineness of yarn. The second swatch (Figure 6), on the other hand, is a coarser fabric even to the naked eye, and its uneven yarn quality and weave, seen especially clearly under the microscope, underpins it final overall quality.

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yarn count. For the purpose of this research, I invert its use to derive yarn count from ends per inch computed from threads per inch. Therefore, the calculations must be read with caution and are only indicative in nature, not empirically tested under laboratory settings.

Figure 8: BJ/P25/S3(1782) TPI 184
Indicative yarn count: 85

Figure 9: BJ/P25/S3(1782) magnified

Figures 8-9 are those of a swatch from the middle of the album, from 1782, which constitutes a mid-point between the first and the last cotton swatches under study (1746-1816). Interestingly, its thread count of 184 sits remarkably close to the average of the first and last thread counts of the samples under study, showing a steady increase in thread count, and therefore, base cloth quality.[215] It constitutes a 60% increase in quality since 1747.

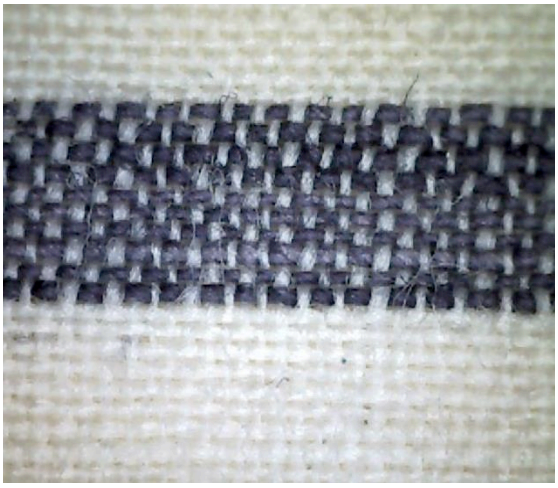


Figure 10: BJ/P67/S2(1809) TPI 213
Indicative yard count: 121

Figure 11: BJ/P67/S2(1809) magnified

[215] 1^{st} TPI=136, last TPI=229, average = 180

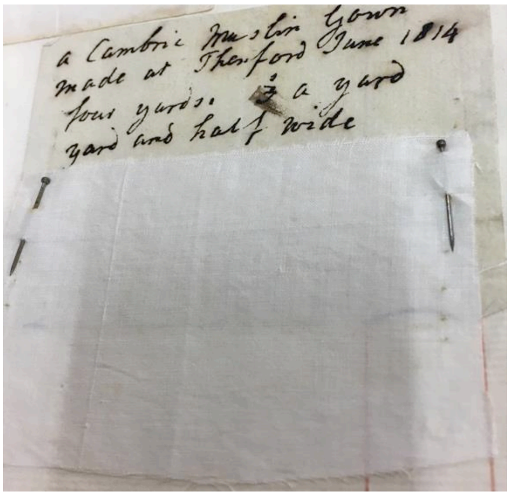


Figure 12: BJ/P77/S3 (1814) TPI 229
Indicative yarn count: 130

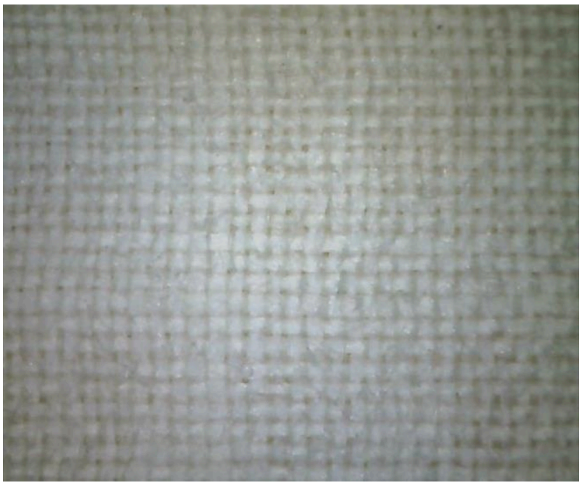


Figure 13: BJ/P77/S3 (1814) magnified

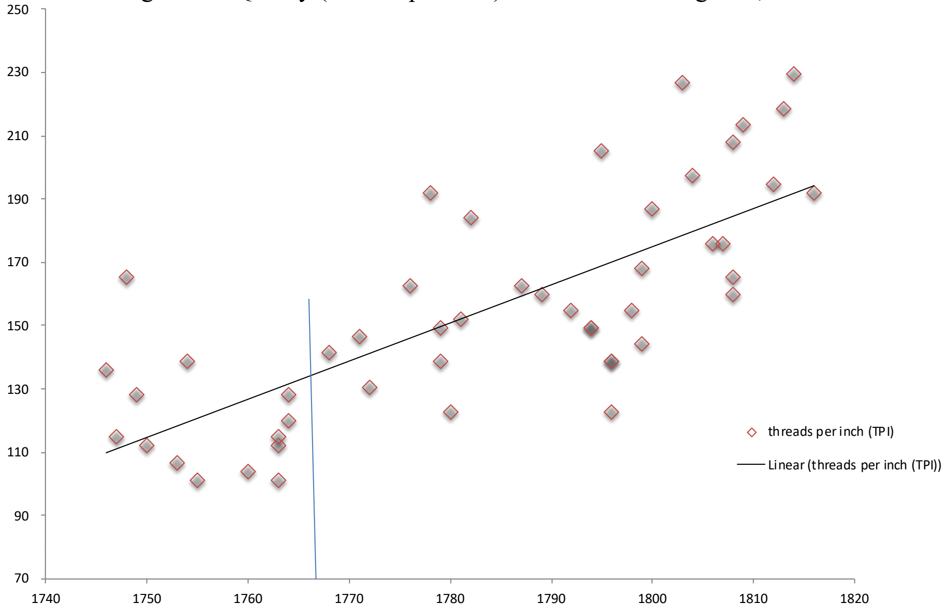
Towards the end of Johnson's album there are several fine cottons. From the samples chosen, Figures 10-13 show the remarkable improvements in final cloth quality since 1746, constituting a 24% increase from 1782 to 1816. While these figures are indicative of one woman's choice of clothing and therefore not reflective of an entire industry, they are indicative of the growing manufacture of finer all-cotton goods towards the end of the 18th and early 19th century. Even within the two swatches shown immediately above, the difference between quality produced in 1809 and 1814 is clearly visible under the microscope.

4.3.2 The Evolution of Cloth Quality: Results

Out of the 53 samples analysed, 28 constitute all-cotton cloth. The earliest all-cotton cloth in Johnson's wardrobe is an Indian cloth from 1764; she notes that it is an 'Indian dimmitty.' The thread count of that swatch is uncharacteristically high for English cloths of this period. Along with the 'Indian dimmitty' two other swatches with uncharacteristically high TPI as well as all-cotton composition have been removed from the final analysis.[216] This is because these are either fabrics made in India or those woven in Britain using Indian hand spun cotton warp, adequate single cotton warp not being spun in Britain during this period.[217] This leaves a final sample count of 50 swatches.

[216] The 3 excluded swatches are: BJ/P10/S2(1764) TPI 187 "A white Indian dimity"; BJ/P10/S3(1764) TPI 181 "A flowered long lawn"; BJ/P13/S1(1769) TPI 187 "A sprigged muslin"
[217] According to Ashmore, the sprigged muslin is most likely of Indian provenance, but the embroidery is likely to have been added in England. Ashmore, *Muslins*, p. 40-41; Lemire *Fashion's Favourite*, p. 80

Figure 14: Quality (threads per inch) of British 'cotton' goods, 1746-1816



Source: Barbara Johnson Album, V&A, London. Thread per inch count of 50 samples from the album from 1746-1816. The blue staggered line depicts 1767, the year of the invention of the Waterframe.

An analysis of the thread count of the 50 samples shows a marked improvement in cloth quality from 1746 to 1816 in Figure 14. The range of threads per inch is wide and reflective of the changing character of the industry during this period. Overall, from the coarse TPI of 115 in 1747 to the finest of 229 in 1816, the percentage increase in quality is a substantial 99%.

Johnson certainly lived in interesting times and her wardrobe presents a unique evolutionary microcosm of the British cotton industry. Not only did Johnson consume a wide range of textiles with varying quality and finish, but her wardrobe also documents the significant shift in textiles by displaying vividly the decided preference for cotton over any other textile fibre. Equally, the range of qualities produced is wide and demonstrates that while overall quality shows a definitive upward trajectory, cloths of a variety of thread counts were produced for popular consumption in Britain.

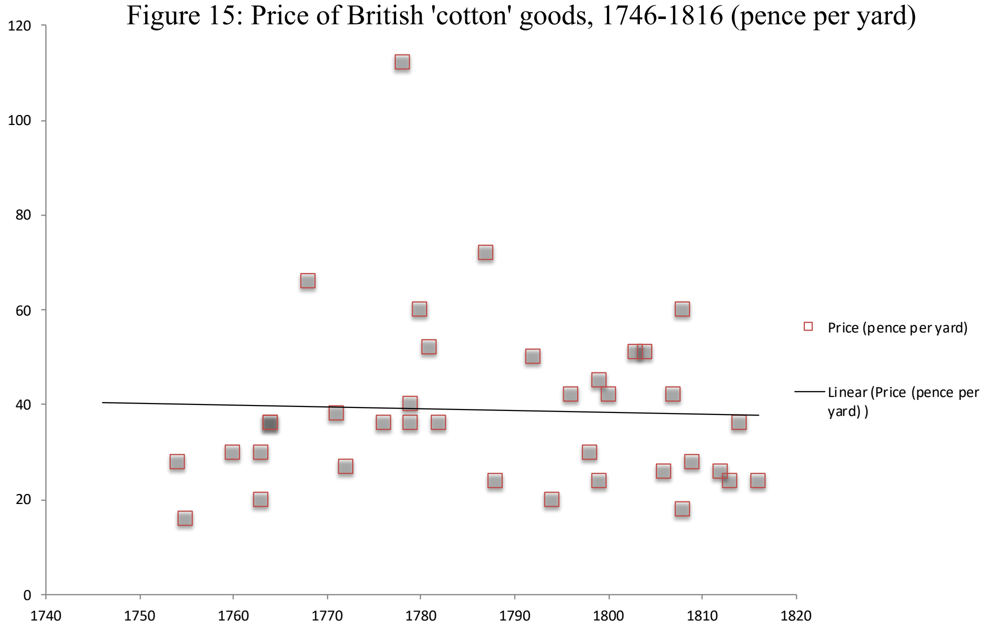
The pursuit of quality, or refinement of yarn for the production of fine cloths is clearly evident from Figure 14. Refinement in yarn is directly connected to a higher thread count in a fabric constituting a measure of higher quality. The uniformity and evenness of yarn also increases in the second half of the samples. The archival nature of the fabric samples does not allow for yarn uniformity to be measured quantitatively but visual evidence from the album clearly suggests that overall yarn and cloth quality improved remarkably over the 70 years under consideration.

In Figure 14, the first major peak in 1748 (TPI 165) is from an all-linen swatch. Linen yarn, as we have seen earlier, was imported extensively into Britain from Ireland as well as the Continent.[218] 14 samples out of the 50 comprise all linen fabrics or linen woven with another non-cotton fibre (wool or silk). These are included in the overall sample since they are printed to imitate Indian cottons. It is interesting to note that out of these 14 all linen or linen-mixed (but non-cotton) fabrics, 10 are from before 1770 and only 4 from after. After 1779, Johnson does not add a single new linen or linen-mix fabric into her wardrobe; her preference is decidedly for the lighter, airier all-cottons. This corresponds with the linen yarn and raw cotton import trend witnessed in Figure 3.

There are several examples among the swatches entailing imitations of Indian printed cottons or calicoes. The first two swatches in the album are prime examples of early Indian imitations, both being printed cotton-linen fabrics. These two are also, as far as we presently know, a couple of the earliest extant examples of British 'cottons.' The album also contains several linens printed in the calico style, showing a trend of continued imitation of Indian cottons not only through the making of the cotton cloth but also through printing and dyeing in Indian colours and patterns. This aspect of imitations of Indian cottons is discussed further in Chapters 6 and 7.

[218] Wordsworth and Mann, *The Cotton Trade*, p. 8, 11, 20-22

Figure 15: Price of British 'cotton' goods, 1746-1816 (pence per yard)



Source: Barbara Johnson Album, V&A, London. Retail price of 40 fabrics based on availability of data.

The album also supplies important, if somewhat broken, data for the retail prices paid for these fabrics. Figure 15 shows the price paid by Johnson for her purchases in the market. While the price data obtained from the album fluctuates too much for any predictive analysis, it does show that over her lifetime, Johnson appears to have paid less, over time, for better quality cloth. Also, it is worth noting that while prices decreased, quality increased at a greater pace.

A clear anomaly in the price trend emerges in 1778 when Johnson pays 2 guineas (112 pence) for a 4.5 yard piece of what she calls ‘a white printed chintz,’ when the price range of the other textile samples analysed in this study from her album is between 20-60 pence a yard depending on the fineness of the fabric (Figures 16-17). Microscopic analysis reveals the swatch to be of high thread count (192) but very uneven, coarsely spun cotton yarn both ways, bringing attention to the complexity of any measure of quality. The redeeming quality of the fabric sample is its print – it is aesthetically pleasing with multiple colours on a white background alongside proportional design elements; this could well have been the reason why Johnson paid an uncharacteristically high price for it. Chapter 5 charts the evolution of colours in the British calico printing industry and discusses further the popularity of polychrome prints. That quality, and hence price, comprise more than just the value for the thread per inch count and include elements of subjective preference of the consumer is clear in this instance.

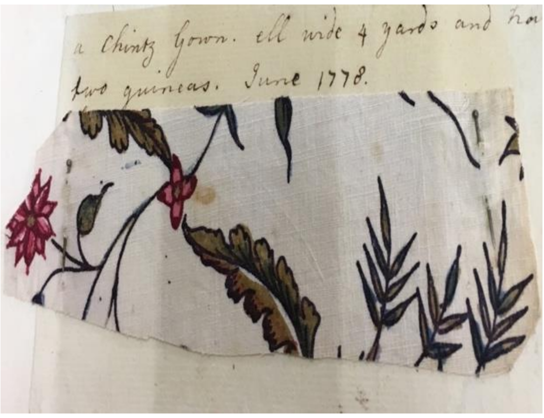


Figure 16: BJ/P19/S1 (1778) TPI 192

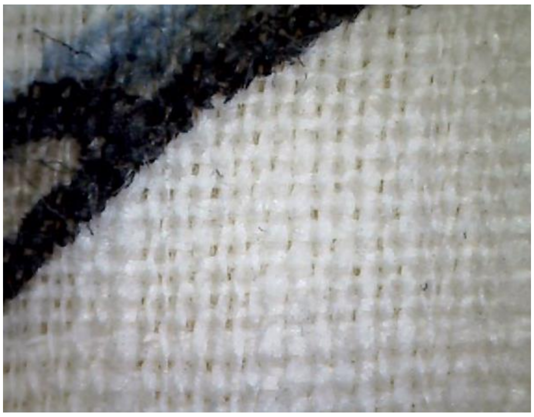


Figure 17: BJ/P19/S1 (1778) magnified

4.4 John Holker's Livre d'Échantillons

How representative is the thread count of the early cottons/cotton-linens in the Barbara Johnson album? Another source of British textile samples from the period under consideration is assessed to corroborate the quality metric of cottons manufactured in Britain. The Livre d'Échantillons is a manuscript compiled by an English Jacobite John Holker for Marc Morel, a French inspector for cotton manufactures in Rouen. Indian printed cottons had made their appearance in France in as early as 1587, laying the foundations of a domestic cotton manufacture in imitation of the Indian products.[219] The purpose of the compilation was to facilitate the development of cotton manufacture of Lancashire type within the nascent calico printing industry in France.[220] The volume, estimated to have been compiled between 1750 and 1751, was a product of collaboration between Holker and Morel. Holker collected the samples in and around Manchester and provided price and usage information; Morel put it all together to construct the volume and was the undersigning official to present it to the Royal Academy of Science in Paris.

The Holker manuscript is a unique compilation of assorted British textile samples from this period. It has been studied by both Riello and Styles microscopically for better understanding the British cotton manufacture of the period.[221] It is a one-of-a-kind collection of a cross-section of textiles selected at one point in time with the specific purpose of demonstrating, from the manufacturers and seller's perspectives, the varieties of cloth that were made in Britain during the period. In this, it contrasts diametrically from the Barbara Johnson Album, which is a compilation from the consumer's perspective. While both data sets may be treated as random collections of textile samples from this period, unlike the long time-period over which the Barbara Johnson album was compiled of materials sourced from various places, the Livre d'Échantillons is a carefully curated collection of samples chosen by Holker during his visit to Manchester sometime between 1750 and 1751 to showcase the best of British textile manufactures. The aim of the venture was to entice the French into allowing him to set up an

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[219] S.D. Chapman and S. Chassagne, *European Textile Printers in the Eighteenth Century*
[220] Styles, John Holker's *Livre d'Échantillons*; For the emerging calico printing industry in France see Chapman and Chassagne, *European Textile Printers in the Eighteenth Century*, p. 13-14
[221] Riello, *Cotton*, p. 153

English styled manufactory in Rouen. His mission may be considered a success since in 1752 Holker established his first manufactory at Darnetal in Rouen.[222]

The Livre d'Échantillons contains 137 samples of various textiles collated by Holker mostly from Manchester but some also from Norwich and Spitalfields.[223] In the original manuscript, swatches of fabrics are accompanied by a description, in French, of the place of manufacture, the uses for which the cloth was intended and the fibre-composition of the fabrics. Florence Montgomery divided the swatches into 20 distinct categories based on their yarn composition, weave and design.[224] One category, conspicuous by its absence, is that of muslin. This finding is in line with the previously discussed fact that fine all-cotton cloth was not manufactured in Britain until Crompton's invention of the mule in 1779.

4.4.1 Microscopic Swatch Analysis

For the purpose of this study, 21 printed textiles are studied from the John Holker manuscript. These are categorised as 'handkerchiefs' and 'chintz cotton printed' within the manuscript. Viewed under the microscope, the early printed English chintz reveal that they are mixed cotton-linen fabrics. The prints and colours used are vivid – a testimony to advances in printing and dyeing - with patterns selected to please a French audience. Some samples, especially the ones that have gone through the process of calendaring, offer less clear images under the digital microscope. Where such an issue arises, the image under the thread counter is also attached to provide clearer assessment of fabrics.

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[222] Florence Montgomery, John Holker's Mid-Eighteenth-Century Livre d'Échantillons, in Veronica Gervers (ed) *Studies in Textile History,* Royal Ontario Museum, Ontario, 1977, p. 214-231
[223] Harris, *Industrial Espionage and Technology Transfer: Britain and France in the eighteenth century*, Aldershot, England, Scolar Press, 1997, p. 60
[224] Montgomery, *John Holker's Livre d'Échantillons*, p. 216

Figure 18: JH/P65/S88 (1755-56) TPI 125

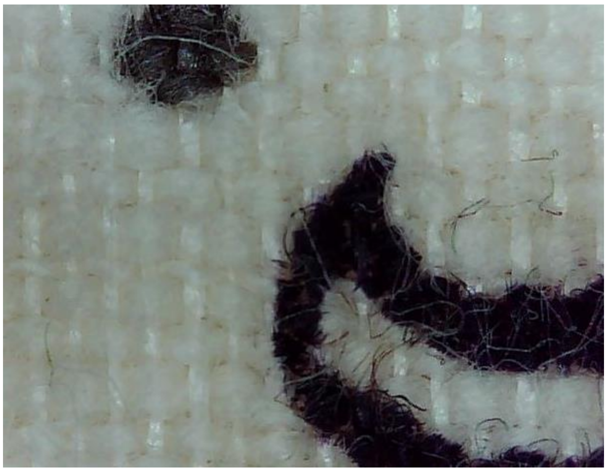

Figure 19: JH/P65/S88 (1755- 56) magnified

Figure 20: JH/P65/S89 (1755-56) TPI 123

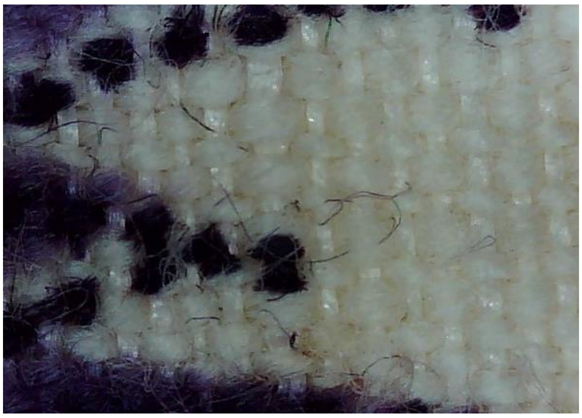

Figure 21: JH/P65/S89 (1755-56) magnified

Figure 22: JH/P69/S93 (1755-56) TPI 115

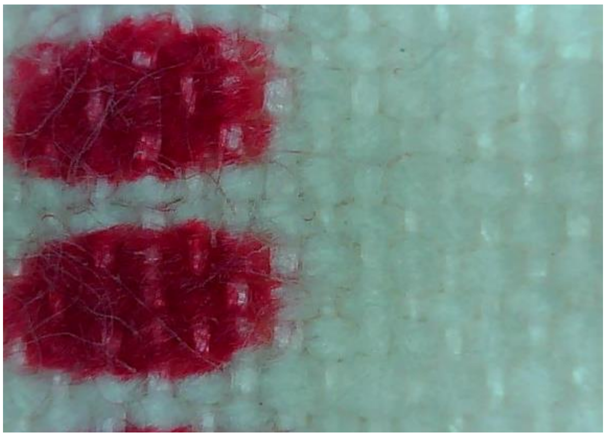

Figure 23: JH/P69/S93 (1755-56) magnified

Figure 24: JH/P73/S97 TPI 144

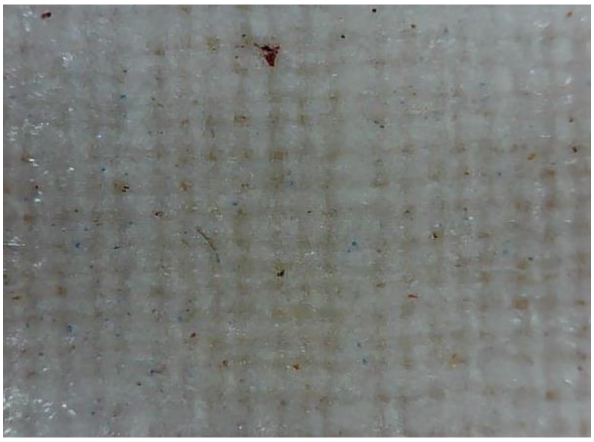

Figure 25: JH/P73/S97 TPI 144 magnified

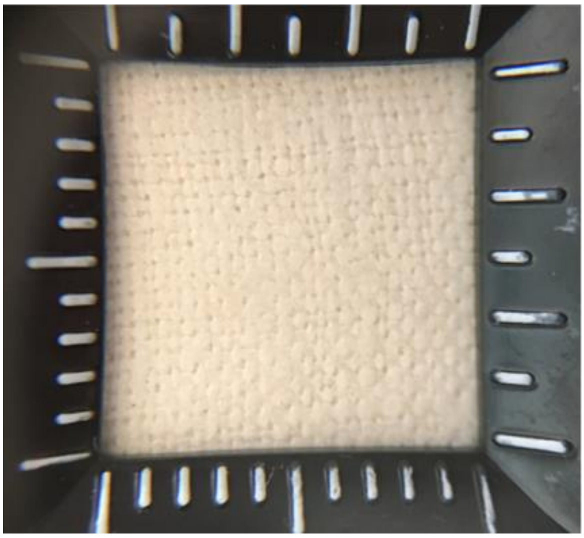

Figure 26: JH/P73/S97 TPI 144
(under thread counter)

Figure 27: JH/P73/S98 TPI 149

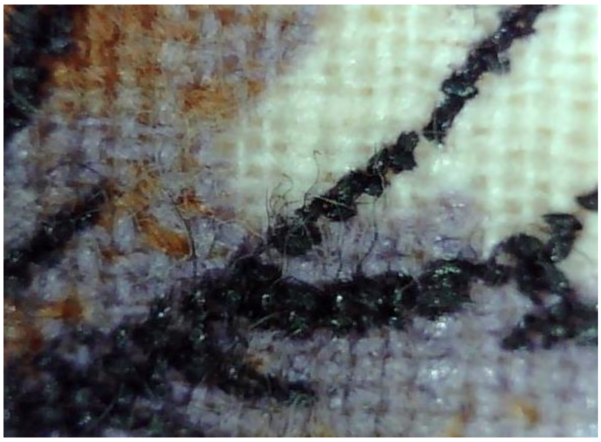

Figure 28: JH/P73/S98 TPI 149 magnified

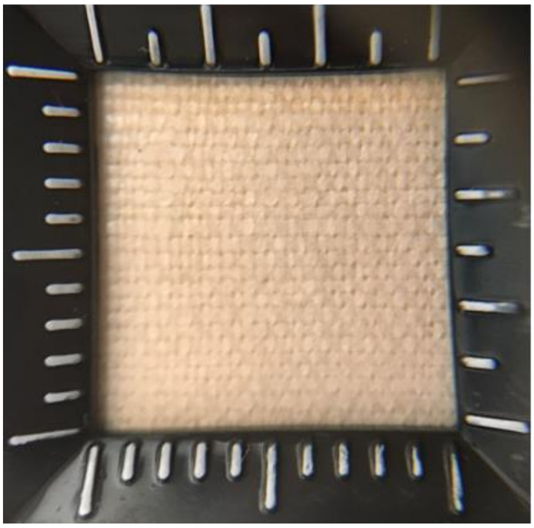

Figure 29: JH/P73/S98 TPI 149
(under thread counter)

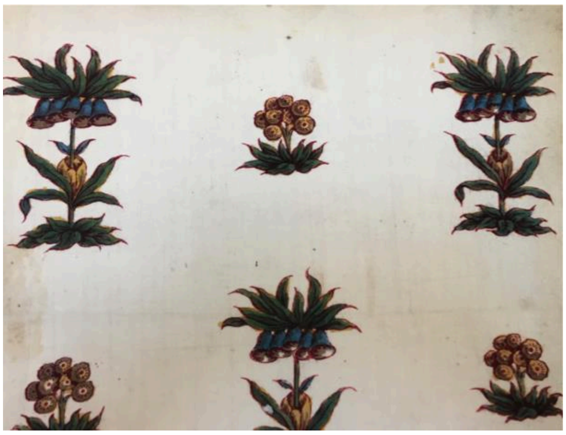

Figure 30: JH/P75/S99 TPI 141

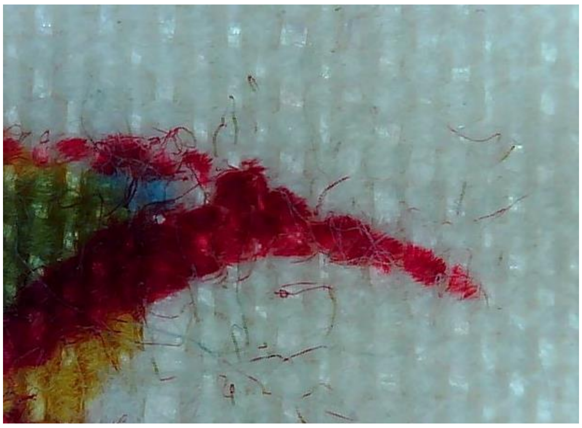

Figure 31: JH/P75/S99 TPI 141 magnified

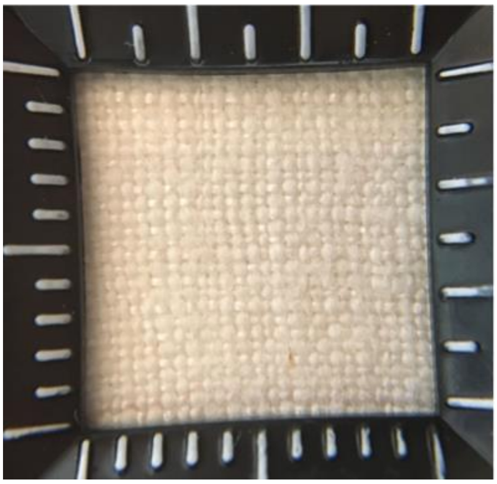

Figure 32: JH/P75/S99 TPI 141
(under thread counter)

Figure 33: JH/P75/S100 TPI 139

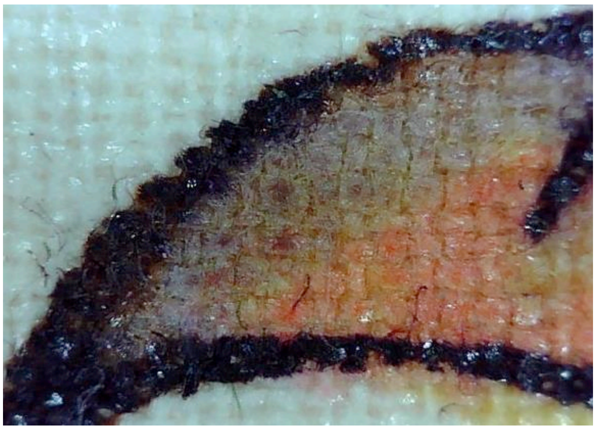

Figure 34: JH/P75/S100 TPI 139 Magnified

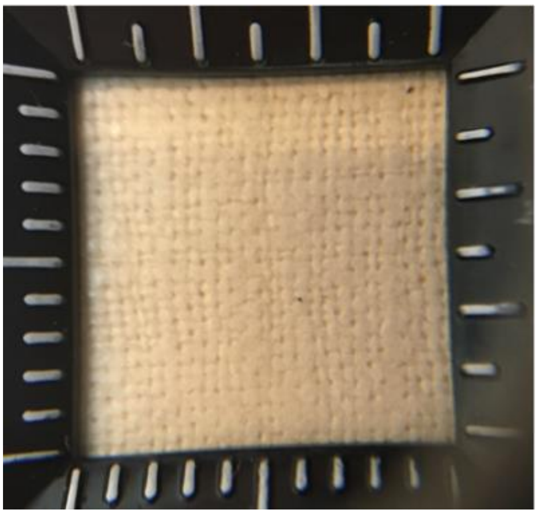

Figure 35: JH/P75/S100 TPI 139
(under thread counter)

It is worth noting that samples 97-100, except 99, (Figures 24-35, except 30-32) the ones with the highest TPI in the chintz category in the Holker manuscript, are all-cottons with Z-twist warps and wefts. These were, in all likelihood, calicoes imported from India and printed in England.[225] The process of calendaring flattened the fibres resulting in an even, flat, glossy surface of the kind found in Indian printed cottons, a result of a finishing technique known as the 'India gloss.' The 'India gloss' referred to a finishing technique used by Indian manufacturers wherein printed cottons were rubbed with glass or shells to produce a glossy surface for the sought-after chintz cotton fabrics. In a letter dated 18 September 1786, Samuel Salte, the London cloth agent, wrote to Samuel Oldknow, the muslin manufacturer, 'We want

[225] I am most grateful to reviewer 2 of this paper submitted to the Economic History Review for sharing this piece of information.

a Glaze or Dress upon the goods not yet accomplished, & upon every sort. There is a new invented Cylinder made of paper that does wonderfull [sic] well & gives muslins the *India Gloss*.'[226]

Further, Holker noted that the price of the fabrics increased in proportion to their finesse.[227] These four samples were clearly chosen by Holker to showcase the best of 'British cotton' manufacture, both because of their finish as well as relative uniformity of yarns. Given that Holker was a calenderer by training and sought to promote this particular textile finishing technique in France, the inclusion of these samples in the manuscript is unsurprising.

The manuscript also contains the following samples of linen handkerchiefs, made in clear imitation of Indian tie-dye patterns. *Bandhej* or *Bandhani* or Indian tie and dye prints have been part of the Indian printers' repertoire for centuries with different regions specialising in varied patterns deploying the same technique. In addition, the manuscript includes a blue indigo resist dyed fabric sample, also inspired by Indian patterns.

Figure 36: JH/P55/S80 TPI 189

Figure 37: JH/P55/S80 TPI 189 magnified

[226] Unwin, *Samuel Oldknow and the Arkwrights*, p. 73
[227] Livre d'Échantillons de John Holker, Musée des Arts Décoratifs, Paris, p. 64

Figure 38: JH/P55/S81 TPI 181

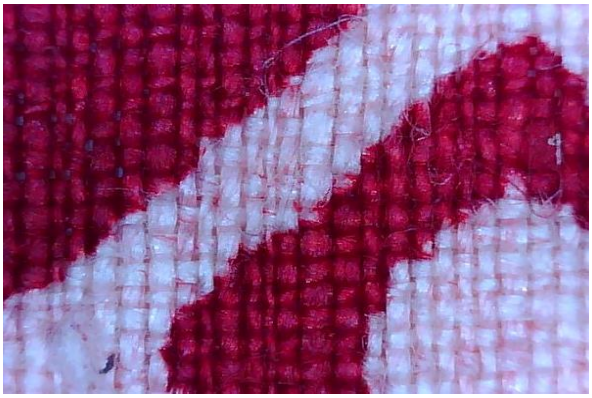

Figure 39: JH/P55/S81 TPI 181 magnified

Figure 40: JH/P57/S83 TPI 200

Figure 41: JH/P57/S83 TPI 200 magnified

Figure 42: JH/P59/S84 TPI 176

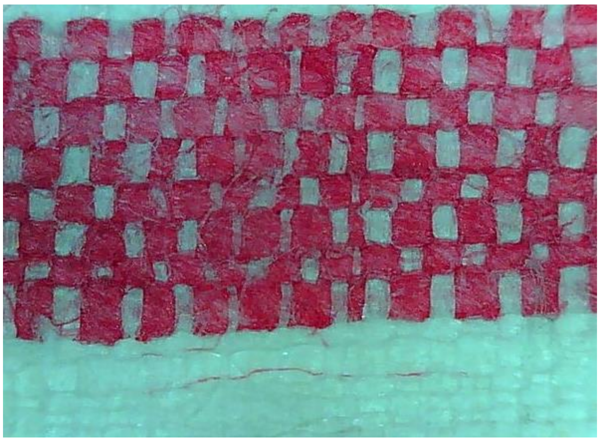

Figure 43: JH/P59/S84 TPI 176 magnified

Figure 44: JH/P103/S131 TPI 125

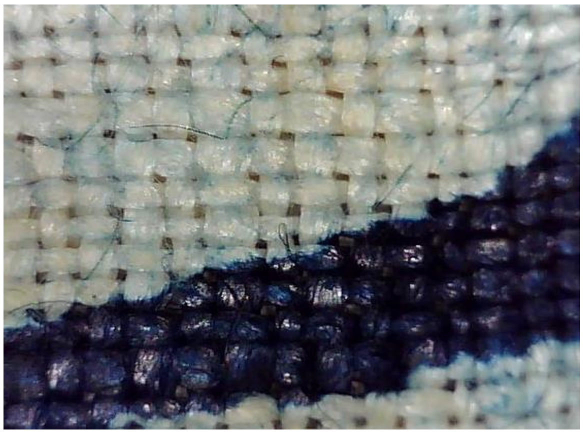

Figure 45: JH/P103/S131 TPI 125 magnified

4.4.2 Comparative Analysis of Johnson and Holker Volumes

A comparative analysis of the Barbara Johnson Album and the Holker Manuscript reveals corroborative findings. The thread per inch count of printed chintz/calicoes in the Holker manuscript matches the thread per inch count of the early cottons in the Johnson album. This validates the quality estimates of the samples from two distinct historical sources. It is noteworthy that the average thread count of the finest examples of English cloth manufacture collated by Holker match the average TPI of the random selection of one consumer in the Johnson album.

Table 2: *Comparative thread counts in Barbara Johnson and John Holker manuscripts*

Manuscript	*Years*	*Average TPI – All samples*	*Average TPI – printed chintz/calico*	*Average price (pence per yard)*	*All-cotton fabrics?*	*Fine all-cotton fabrics/ muslins?*
Barbara Johnson	1746- 1816	146	145	40	-	-
Barbara Johnson	1746-1760	123	128	29	No	No
John Holker	1750-1751	116	129	37	No	Three, likely Indian
Barbara Johnson	1780-1816	153	167	39	Yes	Yes

Source: Barbara Johnson album, V&A, London; John Holker manuscript, Musée des Arts Décoratifs, Paris.

Unlike the average TPI counts, the price averages for the two sources vary greatly. This is primarily because price data for many of the early Johnson samples is missing and only two coarse swatches from prior to 1760 supply their price information. On the other hand, the

Holker manuscript's price data essentially comprises numbers that Holker deemed reasonable to include in his presentation, extolling the economic gains that Britain was enjoying due to the cotton manufacture. Bearing also in mind that Holker was displaying the finest of British printed calico manufacture of the period, which may not necessarily correspond with the goods available, accessible, or preferable to Johnson in her capacity as a retail consumer.

Muslins, as noted earlier, are missing from the Holker manuscript. Their absence corroborates the assessment that during this period British manufacturers were beginning to come to grips with the ability to make the all-cotton cloth; certainly, the fine all-cotton cloth was a few decades, and a handful of technological innovations, away.

4.5 The Textile Manufactures of India, 1866

How do the samples of English cloths in the two sources studied above compare with Indian fabrics of the period? In order to comparatively analyse the material evidence, this study now examines surviving cotton textiles from India.

The Textile Manufactures of India (TMOI) is an ambitious compilation of 18 volumes comprising several varieties of samples of fabrics manufactured in pre-industrial India. John Forbes Watson, Reporter of the Products of India at the India Museum, compiled these in 1866 out of Indian fabrics already in the India Museum collections. The volumes were put together with a view to showing British manufacturers the types of fabrics made in South Asia with the explicit aim of enabling their reproduction in Britain.[228] In Forbes Watson's words, the compilation contains '*700 working samples or specimens*' put together to 'enable the manufacturer to reproduce the article.'[229] The TMOI is the most famous example of an extensive compilation of Indian fabrics put together with the sole purpose of promoting their imitations in Britain. Swallow and Skelton have demonstrated how this compilation, and the meticulous details about Indian textiles contained within it, facilitated the penetration of the Indian markets by British textile manufacturers.[230]

In all, there are 700 textile samples assembled within the pages of the 18 volumes of TMOI. These include fabrics made of cotton, silk, wool and various combinations of the three fibres. 20 sets were made of the 18 volumes, 13 were distributed amongst textile manufacturing centres in Britain and 7 sent to key trade centres in India to facilitate agent/merchant-manufacturer trade operations.[231] This study was undertaken by analysing the 18 volumes located at the Harris Museum in Preston, Lancashire.

The TMOI offers a useful comparator for assessing the quality of English cotton manufacture despite the later date of its compilation. Although Forbes Watson put the volumes together in 1866, a large proportion of the fabrics had been part of the India Museum collections compiled

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[228] John Forbes Watson, *The Textile Manufactures and the Costumes of the People of India*, The India Office, George Edward Eyre and William Spottiswoode, London, 1866, p. 1

[229] Ibid. Italics in original

[230] Deborah Swallow, The Indian Museum and the British-Indian Textile Trade in the late Nineteenth Century, *Textile History*, 30:1, 1999; Robert Skelton, The Indian Collections: 1798-1978, *Burlington Magazine*, CXX, No. 902, May 1978

[231] TMOI p. 8

of objects gathered by the English East India Company officials since before 1798.[232] To these, subsequent curators of the India Museum - T. Horsfield followed by Forbes Royle and ultimately Forbes Watson - added pieces sourced from India over time.[233] Further, while this period signified an era of dynamic and constant mechanical changes in Britain, the manufacturing processes and final products remained largely unchanged in India until the middle of the 19th century.[234] Despite there being some evidence of new design motifs being developed as a result of integration of markets across India from the middle of the 19th century, these remained rooted in the traditional methods of manufacture until the establishment of the first functional cotton mill in Bombay in 1854 and the introduction of synthetic dyes in the 1870s.[235] The family and caste-based nature of craft training in India ensured that traditional methods persisted well into the 19th century and later, alongside modern techniques of production, with the advent of machine spun yarn in the second half of 19th century bringing structural change.[236] Therefore, despite the dates of the TMOI being significantly later than the Barbara Johnson and John Holker volumes, the persistence of traditional methods of manufacturing in India makes it a valid Indian comparator against the two British compilations.

Forbes Watson was clear in his intentions for creating the TMOI. He viewed the 20 sets of 18-volumes each as portable 'Twenty Industrial Museums' facilitating manufacture of textiles in Britain that would sell in India, given India's potential as a 'magnificent customer.' In the text companion to the sample volumes, he called the 700 specimens 'working samples' for the purpose of imitation and copying. [237] Despite his focus on the imitation of these textile goods, Forbes Watson was cognisant of the limitations of machinery and was of the view that British manufacturers would likely be unable to compete with the handmade, very fine and intricately decorated Indian textile goods. His advice to the British manufacturers was to focus on producing low-medium-high qualities of fabrics for the masses in India, rather than the very fine varieties for the luxury segment of the Indian market.[238]

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[232] Robert Skelton, The Indian Collections: 1798-1978, *Burlington Magazine*, CXX, No. 902, May 1978
[233] Forbes Watson, *The Textile Manufactures of India*, p. 8; Swallow, The India Museum, p. 37
[234] Ibid. footnote †, p. 3
[235] Tirthankar Roy, *The Crafts and Capitalism: Handloom Weaving Industry in Colonial India*, Routledge, Abingdon, 2020, p. 53-54
[236] Karuna Dietrich Wielenga, *Weaving Histories: The Transformation of the Handloom Industry in South India*, 1800-1960, Oxford University Press, 2020, p. 8-9, 53-55
[237] Forbes Watson, *The Textile Manufactures of India*, p. 2
[238] Ibid. p. 7

Forbes Watson's views are reflected in the assortment of textiles compiled in the TMOI – very fine and highly decorated fabrics, both in cotton and silk, are excluded from the volumes. The only exception to this is in the category of muslins. That muslins were of great significance not only to Forbes Watson but also to British cotton manufacturers is evidenced by the large numbers of muslins included in the samples, including some very fine qualities - as well as the disproportionately large number of pages devoted to this particular commodity in the text companion to the fabric sample volumes. The interest in muslins - and the competition against Indian muslins - was so strong that Forbes Watson went so far as to organise comparative scientific analyses of European and Dhaka muslins to ascertain, once and for all, which were finer. Muslins will be discussed at length in the subsequent pages.

4.5.1 Comparative Analysis of TMOI with English Samples

Out of the 18 volumes containing 700 samples, the first 12 volumes, comprising 480 samples were analysed for the purpose of this study. The remaining volumes are made up of woollens and silks exclusively.

There are 402 all-cotton fabrics within the TMOI.[239] These can be broken down into 79 muslins, 65 printed cottons, 3 long cloths and 11 kerchiefs. Some muslins are also printed and therefore the two categories overlap somewhat. The remaining 244 are an assortment of *lungis*, *dhotis*, *saris*, towels, rugs and doilies. 31 of these have been removed from the sample size due to lack of TPI data.[240] This leaves a total sample size of 371.

Table 3 shows that the range of thread counts for all categories of cloths is wider in the TMOI than the Johnson or Holker samples. This is indicative of the vast varieties of cloth qualities produced and consumed within India, as the TMOI was specifically compiled to allow the British textile manufacturers to learn about, and supply to, the mass markets of India. The TMOI samples are not indicative of trade textiles exported from India to Europe and Britain. They represent the textiles consumed domestically by the mass population in India. Arguably, the textiles exported from India, the famous Indian trade cottons of the pre-industrial period,

[239] Some are cotton fabrics with silk in borders and what Forbes Watson calls "principal end" which is the decorated end of a sari - the *aanchal* or *pallu*. These have been included in the sample size since they are primarily cotton fabrics and silk is used in ends only as decoration.
[240] These are mainly towels, napkins, rugs, and doilies. Individual samples are as follows: Vol 3-118, Vol4-148, Vol 6-236, Vol 8-307, Vol 11-419-440, Vol 12-455-456, 472-474, 479-480.

were of higher quality than the cloth consumed domestically. The figures above corroborate received views that over time, British printed cotton goods competed well with similar Indian cottons intended for mass consumption. Since high end Indian printed and painted cottons, usually meant for export and consumed within India by the elites are not included in the TMOI, this, therefore, remains a qualified assessment between Indian and English cotton textiles, comparing some of the finest British cotton manufacture against less than the finest of Indian cotton manufacture.

Table 3: *Comparative thread counts and ranges of Barbara Johnson album, John Holker manuscript and TMOI*

Type of fabric	*TMOI Number of samples*	*TMOI Average TPI*	*TMOI TPI range*	*Barbara Johnson TPI range*	*John Holker TPI range*
Muslins	79	158	83-291	176-229	NA
Printed cottons	65	129	64-264	101-227	115-149
Kerchiefs	11	175	104-221	NA	109-200*
Long Cloths	3	260	187-357	NA	NA
Others (lungis, dhotis, saris etc)	213	130	53-251	NA	NA

Source: Barbara Johnson album, V&A, London; John Holker manuscript, Museé des Arts Décoratifs, Paris; The Textile Manufactures of India, Harris Museum, Preston
*These are linens, not cottons.

Quality figures for finer and higher quality goods of one specific variety - muslins - show that Indian handmade muslins continued to challenge machine-made cottons by exhibiting higher thread counts and overall quality well into the second half of the 19th century. The debates surrounding the superiority of Indian muslins over any similar machine-made product manufactured in Europe led Forbes Watson to organise comparative scientific microscopic testing of two of the highest quality muslins from India and two of the best exhibited at the exhibitions in 1851 and 1862 from Western Europe – one from Britain and the other from France.

A series of tests were undertaken to determine the diameter of the thread, the number of filaments in the thread, and the diameter of the filaments themselves.[241] In addition, tests were conducted to ascertain the diameter of the threads without any starch or sizing, as well as the

[241] Forbes Watson, *Textile Manufactures*, p. 60

number of twists in an inch of sample threads. The express aim of these laboratory experiments was to establish which muslins were the finest yet at the same time durable and washable.

Table 4: *Comparative assessment of European and Indian muslins, 1866*

Muslin	*Mean diameter of threads*	*Mean number of filaments in thread*	*Mean diameter of filaments*	*Mean diameter of threads (no sizing/starch)*	*Mean number of twists in thread per inch*
French muslin[242]	.002220	13.8	.000642	.0019	68.8
English muslin[243]	.002167	14.9	.000539	.0018	56.6
Dacca muslin[244]	.001526	9.0	.000803	.0013375	101.1
Dacca muslin[245]	.001896	8.6	.000719	.0015625	80.7

Source: John Forbes Watson, *The Textile Manufactures and the Costumes of the People of India*, The India Office, George Edward Eyre and William Spottiswoode, London, 1866, p. 61-63

These tests were conducted to determine conclusively whether European machine-made muslins were 'finer' than the Indian hand-made variety and could successfully compete against them. Experiments revealed that the diameters of the Indian yarns were less than those of the finest European muslins and had far greater numbers of twists per inch of thread resulting in finer yarns. In addition, despite their fineness, Indian muslins were considered more durable and lent themselves to repeated washing, unlike European and English muslins. According to Forbes Watson, this was because of the stronger individual filaments of the short staple Indian cotton in comparison to the less robust yet long stapled American Sea-Island cotton used for making European muslins. The strength of the individual Indian short-stapled cotton filaments enabled finer spinning by hand through greater twisting resulting in the deployment of fewer fibre filaments per thread.[246]

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[242] Made by M. Thibel Michon of Lavare, of 440s thread spun by Thomas Houldsworth & Co. Shown at the International Exhibition of 1862. Forbes Watson, *Textile Manufactures*, p. 61

[243] Made of 540s yarn (Forbes Watson doubted the accuracy of the yarn count claimed). Shown at International Exhibition of 1851. Forbes Watson, *Textile Manufactures*, p. 60-61

[244] Mulmul Khas from India Museum. Length = 4 yards, width = 1 yard (for computation). Warps per inch = 100, weft per inch=92. Weight 566.8 grains, 406s yarn, Forbes Watson, *Textile Manufactures*, p. 60-61

[245] Mulmul Khas. Exhibited in Indian section of International Exhibition of 1862. Length = 10 yards, 12 inches, width = 1 yard. Warps per inch =104, wefts per inch = 100, weight = 1565 grains, 380s yarn, Forbes Watson, *Textile Manufactures*, p. 60-61

[246] Ibid. p. 61-63

The intense focus on the quality and overall fineness of muslins merits greater attention. The very competition was against Indian muslins - the benchmark to emulate and eventually surpass was the Indian muslin, the finest cotton cloth produced in India. Evidently, Indian cottons continued to be the yardstick against which the quality of British and European cotton goods were tested even as late as 1860s.

Forbes Watson's recognition that the finest quality of handmade textiles could not be replicated by machine is itself evidence of the view that machinery in the British cotton industry evolved with a view to refining quality to imitate that of the handmade cloth. On the matter of muslins, he concluded by saying, 'However viewed, therefore, our manufacturers have something still to do. With all our machinery and wondrous appliance, we have hitherto been unable to produce a fabric which for fineness or utility can equal the "woven air" of Dacca – the product of arrangements which appear rude and primitive, but which in reality are admirably adapted for their purpose.'[247]

4.5.2 Comparative Microscopic Swatch Analysis

Swatch analysis of the fabric samples from the three sources with the highest TPI count is undertaken with a view to ascertaining cloth quality within the British mechanised and Indian handmade cotton industries. The two main categories assessed are printed cottons and muslins. All sample sources are finally assessed for determining the cotton cloth with highest thread count.

4.5.2.1 Printed Cottons

Amongst the three sample sources, the printed cloth with highest thread count belongs to the TMOI. It is a printed cotton *palampore* with a TPI of 261. A note may be made here of the printed linens in the Holker manuscript, which show remarkably high thread counts - swatch 83 goes up to a TPI of 200. It begs the question, if fine linens were already being manufactured by 1751, then why the sustained endeavour towards mastering the all-cotton cloth? Why were technological innovations not directed towards refinement of linen fabrics; what prompted the fixed pursuit of the cotton cloth? The only logical rationale comes via consumer preference for

[247] Ibid. p. 64

all-cotton fabrics and potential monopolistic gains-driven focus of British manufacturers to imitate the sought-after Indian cotton goods.

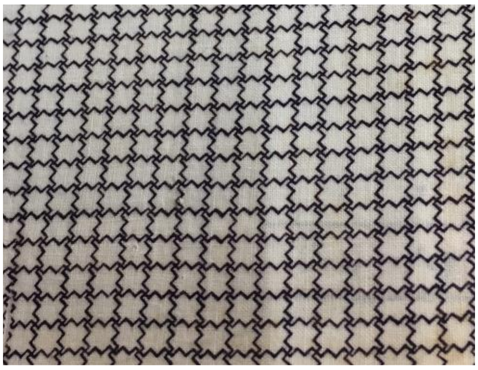

Figure 46: A purple and white cotton BJ/P55/S1, TPI 227

Figure 47: BJ/P55/S1 - magnified

Figure 48: Chintz cotton printed (cotton and linen) JH/98, TPI 149

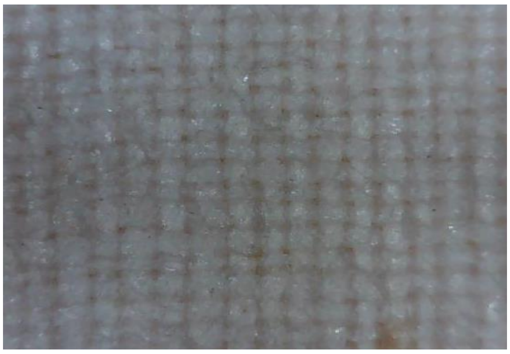

Figure 49: JH/P65/S88 magnified

Figure 50: Cotton Palampore: TMOI Volume 4/154, TPI 264

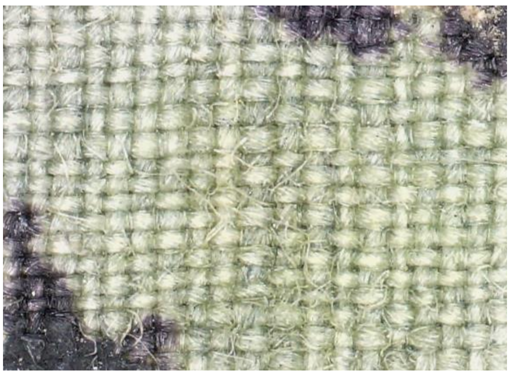

Figure 51: TMOI Vol4/154 magnified

4.5.2.2 Muslins

In the category of muslins, only the Johnson album and the TMOI supply samples. The highest thread count comes from a checked fine muslin with a TPI of 291 from the TMOI. It is a fine muslin, described by Forbes Watson as one of 'superior quality' from *Chanderi* in Bengal. It is worth noting that in several samples of medium to fine cottons in the TMOI, double warp threads are used lending both to the woven pattern as well as structural strength and integrity of the fabric.

Figure 52: A Cambric Muslin
BJ/P77/S1/1814 TPI 229

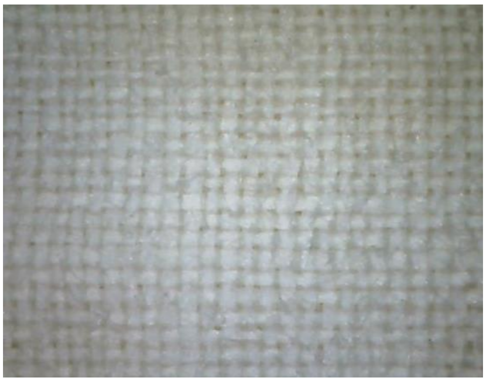

Figure 53: BJ/P77/S1/1814 magnified

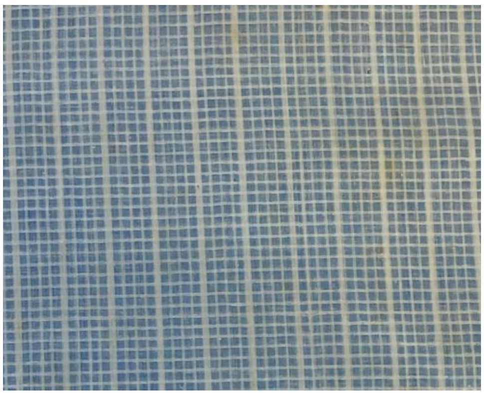

Figure 54: *Charkhana* checked muslin.
Superior quality
TMOI/Vol8/285, TPI 291

Figure 55: TMOI/Vol8/285 TPI 291
magnified

4.5.2.3 All Cotton Goods

Interestingly, despite the intense focus upon muslins, the highest thread count amongst all cotton fabrics analysed in this study, both Indian and British, does not belong to the category of muslins. A custom-made Indian long cloth, noted by Forbes Watson for its high quality, takes the prize with a thread count of a substantial 357 yarns per inch. Long cloth is typically Indian cloth made in long pieces, often to specified lengths. This particular sample was made in Rajamundry in the Madras Province of colonial India.

Figure 56: Long Cloth: Cotton, fine quality
Made to order
TMOI/Vol12/463/ TPI 357

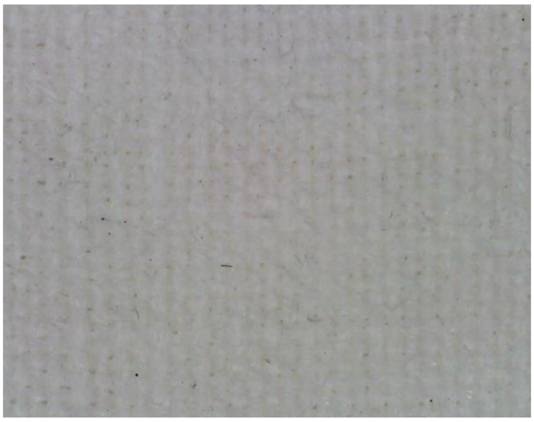

Figure 57: TMOI/Vol12/463/ TPI 357 magnified

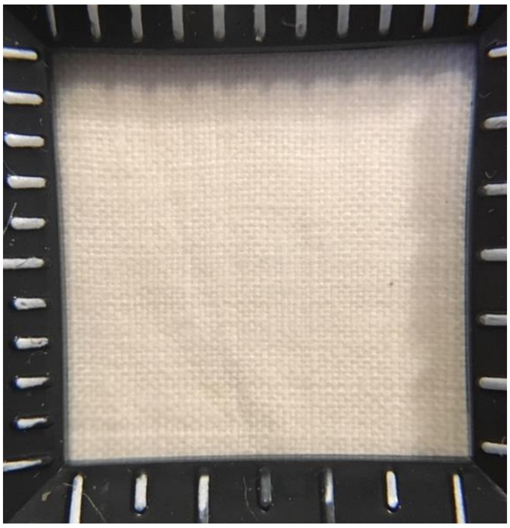

Figure 58: TMOI/Vol12/463/ TPI 357 (under thread counter)

Despite having a wider range of thread counts, and despite being a compilation of cottons goods aimed at the mass Indian market rather than the high-end affluent elites, the TMOI contains the finest cotton cloths of this period, both printed and plain muslins amongst the three sources studied. This evidence suggests that machine imitation of pre-existing higher quality handmade Indian cottons was a rational and logical choice for artisans and textile manufacturers in Britain in their quest to compete against Indian trade cotton goods. Equally, Forbes Watson's views and scientific analysis both demonstrate that Indian handmade goods continued to be finer and more hardwearing despite consistent imitations by machine technology.

4.6 Conclusion

This chapter, along with textual evidence from the previous, has demonstrated the British manufacturers' awareness of an early quality differential between the British and Indian cottons followed by a convergence of quality of the British cotton manufacture with that of Indian cottons over time. The material evidence analysed corroborates the textual evidence which suggests that the growth of the British cotton industry through its early phase in the 18th century, up until the latter half of the 19th century, was a product of a focussed approach towards the improvement of product quality in line with the competitor product, the Indian cottons. In the process, market-approved Indian cotton goods were taken as the prototypes for quality and finish, standing as yardsticks for characteristics of cloth quality. Microscopic analysis of English textiles from the period shows a distinctive improvement in cloth quality over the seven decades from 1746-1816. Historical sources support the view of a targeted pursuit of improvement in cloth quality through competition against the Indian cotton goods, while simultaneously providing evidence of comparative learning from Indian goods. Comparisons with Indian cottons of the period reveal that contrary to popular views, machine-made cotton goods were unable to surpass the quality and durability of handmade cottons.

Therefore, by setting the quality standard, Indian cotton textiles 'soft-determined' the evolutionary trajectory of the British cotton industry, to use Rosenberg's terminology. Technological growth in the industry was channelled towards the pursuit of quality standards set by the benchmark Indian cottons. Mechanisation, therefore, cannot be fully understood without an assessment of this pursuit of cloth quality to match that of handmade Indian cloths. Improvements in machinery in order to create a product that previously existed marks the shift brought about in response to an exogenous stimulus, the pre-existing Indian cottons. Several endogenous factors impacted the growth and evolution of mechanisation yet this simultaneous exogenous stimulus remained significant throughout the infancy of the British cotton industry and well into the second half of the19th century.

Chapter 5: Evolution of Spinning Technology: The Impact of Imitations of Indian Cotton Textiles

Abstract

This chapter argues that mechanisation in spinning in the British cotton industry was a result of the pursuit of quality to match that of Indian cotton textiles. Evidence from the analysis of the working mechanisms of spinning machinery over time demonstrates that producing improved quality of spun yarn was a key driving force for new machinery. This mechanical evidence corroborates the quality-focussed findings from the material textile evidence. It also shows that the three key spinning machines were fundamentally path dependent, with the jenny and the mule based on the Jersey wheel technology of Indian origin and the waterframe upon the Saxon wheel technology from Europe. Further, it argues that the skill to use a technique successfully is a key component of any technology, and a combination of a technique and the skill required for its use alongside a particular fibre staple determine the quality of yarn and final cloth, not the staple of the fibre in isolation.

5.1 Introduction

Textual and material evidence suggest that the pursuit of quality, to match that of benchmark Indian cotton textiles, shaped the evolutionary trajectory of the British cotton industry. This chapter asks two questions. Firstly, is the quality-related shift from linen-cotton cloth to the all-cotton cloth and finally to the fine all-cotton cloth, as shown by the material evidence, corroborated by an examination of the mechanical sources? In other words, what was the purpose of the mule if productivity gains were the main motivations for technological innovations? Secondly, if quality-led imitations of Indian cotton textiles were the motivation for mechanisation, then is there a technological connection between the mechanised British cotton spinning and the old Indian spinning technology? In other words, are the jenny, the waterframe and the mule examples of technological change or mechanisation of pre-existing technologies?

This chapter situates mechanisation in the British cotton industry within the European historical mechanical or methods innovation tradition and argues that in addition to productivity gains, improvement of product quality merits serious consideration as a motivator for technological innovations. It demonstrates that mechanical innovations in spinning were motivated by an external catalyst - the Indian cotton cloth – in pursuit of cloth quality. It shows that quality-led mechanical innovations made rational economic sense, allowing British manufacturers to produce, and compete against, the vast varieties of cotton products manufactured in India. The evolution of mechanisation of spinning in the British cotton industry sits within a trajectory towards increased automation, ranging from the earliest use of only human hands to spin fibres to the automated self-acting mule.

The chapter also identifies the India connection as fundamental to the evolution of mechanised spinning. Charting the evolution of spinning since antiquity, it shows that the technology remained largely constant – the Indian spinning wheel, known as the Jersey wheel in Britain and Europe – was the base technology upon which mechanised spinning evolved. Mechanised spinning is, therefore, identified as fundamentally path dependent, and its evolution as motivated by the pursuit of quality to match that of the benchmark Indian cotton goods.

Situating the first industrial revolution within the global tradition of technological evolution is not a novel idea. Historians studying the global history of cotton have consistently articulated the European and global linkages of evolutionary technological change through knowledge transfer, trade, migration and exchange of ideas as well as artefacts.[248] In contrast to historians of technology who focus on continuations and connections with the past, economic historians tend to view new techniques as signifying critical breaks from the past, underscoring disconnections and divergences.[249] The economic and social changes brought about by the industrial revolution are temptingly large scale to justify the amplification of the idea of a break from the past. Yet a closer examination of the history of mechanisation in the British cotton industry shows clear and well-documented continuities both with the European as well as Asian techniques and technological paradigms. Highlighting these continuities is not to dispute the significance of innovations in mechanical operations, but to situate them within an inter-linked trajectory of technological transformations where connections are clearly evident, aiming at

[248] Riello, *Cotton,* p. 224-227; Parthasarathi, *Why Europe Grew Rich,* p. 98, 103-113; Beckert, *Empire of Cotton*, p. 64-65; Basalla, *Evolution of Technology,* Cambridge University Press, Cambridge,1988, p. 29-30; White, Tibet, India and Malaya as sources of Western Medieval Technology, *The American Historical Review,* Vol 65:3, April 1960, p. 515-526

[249] For continuity in the history of technology, see Singer, et al, *A History of Technology*, Volumes 1-5; Derry and Williams, *A Short History of Technology*. For technological change as a shift or divergence from the past see, Pomeranz, *The Great Divergence*, Allen, *The British Industrial Revolution*; Broadberry and Gupta, Lancashire, India and Shifting Competitive Advantage.

reducing human inputs and increasing the automated productivity of the manufacturing process.

The conventional response to technological change in cotton spinning in Britain is the 'challenge and response' model related to the invention of John Kay's flying shuttle in 1730. According to the argument, the use of the shuttle sped up weaving and hence conveyed pressure upon the spinners to deliver more yarn.[250] Evolution of spinning machinery and the 'wave of innovations' that followed, according to this argument, are in response to an induced stimulus from one domestic invention in weaving to another in spinning.

The idea of induced innovation in spinning because of innovation in weaving is a logical proposition though unsupported by historical facts. O'Brien, Griffiths and Hunt reject the 'challenge and response' model on the basis of three reasons. Firstly, their data on patented and non-patented inventions showed no clustering of innovations around particular stages of production in related time-periods. Secondly, the shuttle's invention itself cannot be explained in terms of earlier advances in cloth finishing techniques or greater and cheaper supply of yarn. Thirdly, the impact of Kay's shuttle was too circumscribed to be realistically deemed responsible for the subsequent technological advances in spinning.[251] O'Brien, Griffiths and Hunt convincingly refute the argument that the later 'wave of innovations' in spinning, and subsequently industrialisation in the British cotton industry, relied upon the invention of the shuttle. Indeed, Robert Kay, son of John Kay, writing in 1760, noted that the shuttle had not witnessed a strong take-up owing partly to the hostility towards it stemming from inexperience with the new mechanism and a tendency of many local weavers to discard the invention before training themselves in its use.[252] Induced innovation in spinning because of innovation in weaving is also a limiting argument as it focusses only on productivity gains from mechanised spinning, ignoring other factors such as the pursuit of fine yarn spinning, as factors potentially motivating mechanisation. It also ignores historical facts by overlooking the pursuit of mechanised and improved spinning of cotton and other fibres pre-1730.

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[250] Baines, *History of the Cotton Manufacture*, p. 116
[251] Patrick O'Brien, Trevor Griffiths, Philip Hunt, Technological Change during the First Industrial Revolution: The Paradigm Case of Textiles, 1688-1851, in, Robert Fox (ed), *Technological Change: Methods and Themes in the History of Technology*, Routledge, London, 1996, p. 163-164
[252] H.T. Wood, The Inventions of John Kay, 1704-1770, *Journal of the Royal Society of Arts*, Vol 60, No. 3081, 1911, p. 73-86

Having rejected the ‘challenge and response’ model of Kay’s flying shuttle as the induced innovation motivator for spinning technology, O’Brien, Griffiths and Hunt offer two motivating contexts for the births of the spinning jenny, the waterframe and the mule situated within the political economy of the period. First is the import substitution of domestic Indian calicoes and the second relates to the fluctuations to the supply of Irish linen yarn for the production of fustians in Lancashire.[253]

On the other hand, Macleod shows that improving the quality of products and capital-saving were the two strongest motives professed by patentees for their inventions.[254] In addition, data on the patentees’ stated aims of inventions shows an increasing tendency to describe the inventions as motivated by import substitution until 1769, and from 1760 onwards there is an increase in the trend for the rationale of quality improvements as innovation motivators.[255] Together, both O’Brien, Griffiths and Hunt’s findings from patent data, which show that 43% of the inventors stated that their motivations for invention were related to improving the quality of new and import substituted foreign products, as well as Macleod’s findings related to the motivations and timings of specific patents,[256] support the examination of change in spinning technology through the lens of quality improvements in order to match the quality of the benchmark cotton products of the period.

According to von Tunzelmann, time saving rather than labour saving changes signify mechanisation during the early phase of mechanisation in the British cotton industry, emphasising the productivity gains rationale for mechanisation.[257] On the other hand, according to David, skill and expertise acquired by experience-linked improvements through ‘learning by doing’ are responsible for improvements in both product quality and productivity.[258] While assessing post-industrial revolution adoption of spinning technology in Britain, Spain, Italy and the US, Roses shows that technological choice, far from being technologically determined, is

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[253] O’Brien, Griffiths and Hunt, The Paradigm Case of Textiles, p. 164

[254] Christine MacLeod, *Inventing the Industrial Revolution: The English patent system, 1660-1800*, Cambridge University Press, 1988, p. 159

[255] Ibid, p. 160

[256] Ibid.

[257] G.N. von Tunzelmann, Time-Saving Technical Change: The Cotton Industry in the English Industrial Revolution, *Explorations in Economic History*, Vol 32, 1995, p. 1-27

[258] Paul A. David, Learning by Doing and Tariff Protection: A Reconsideration of the case of the Antebellum United States Cotton Textile Industry, *The Journal of Economic History*, Vol. 30, No. 3, 1970, p. 521-601

influenced by local conditions, especially availability of 'skilled' labour developed over time through familiarity and experience with the new machinery.[259] Simultaneously, Roy contends that skill embodied in the artisan is a form of capital.[260] This allows for the development of the hypothesis that the lack of specific skill would equate to a missing factor of production, paving the way for a change in production methods.

The earliest references to fine cotton spinning in England are connected to the hosiery industry. Here too, the India connection is principal as fine Indian-spun cotton yarn, intended for fine muslins, was the first encounter of the industry with cotton yarn suitable for making stockings.[261] Significantly, fine cotton yarn for the hosiery manufacture began to be spun domestically by the erstwhile wool spinners adept at Spanish short staple wool and who became 'tolerably expert in spinning cotton.'[262] Spinners trained in spinning long staple wool were unable to adapt to the short staple cotton spinning even with moderate skill.[263] Individual highly skilled wool spinners or moderately skilled cotton spinners could not suffice to supply the growing demands for fine yarn within the British cotton industry.

Did the quest to replace the Indian cotton yarn with a domestically manufactured cotton yarn of similar quality motivate mechanical changes in spinning technology in Britain? Textual evidence discussed in Chapter 3 showed references to the inability of British spinners to spin adequate cotton warp.[264] Examination of the material evidence in Chapter 4 revealed that cloth quality in the British cotton industry increased 99% from 1740-1820.[265] For this cloth-quality improvement to be connected to the mechanisms of spinning, we must see a related sequential improvement in machinery aimed at improving the quality of the final yarn.

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[259] Joan Roses, The choice of technology: Spanish, Italian, British and US cotton mills compared, 1830-1860, in, Sevket Pamuk and Jeffrey G Williamson (eds), *The Mediterranean response to globalisation before 1950*, Routledge, 2000, p.140-142
[260] Tirthankar Roy, *The Crafts and Capitalism: Handloom Weaving Industry in Colonial India*, Routledge, Abingdon and New York, 2020, p. 16
[261] Gravenor Henson, *History of the Framework Knitters*, David and Charles Limited, Wiltshire, First published 1831, then 1970, p. 164-165
[262] Henson, *Framework Knitters*, p. 358-359
[263] Ibid.
[264] Previous p. 44-45
[265] Previous p. 77

5.2 Data and Methodology

Using textual evidence from contemporary observers of the British cotton industry, writers, manufacturers and stakeholders like Edward Baines, Andrew Ure, Richard Guest, as well as the works of recent historians who have adopted a material approach to the study of spinning technology, such as R.L. Hills, Charles Singer, Julia de Mann Lacy, as well as historians of technology writing about cotton machinery such as Musson and Robinson, Morton and Wray as well as Derry and Williams, I chart the evolution of spinning machinery and the yarn quality potential of the key spinning machines of the British cotton industry – the jenny, the waterframe and the mule. Comparative assessment of the mechanical and material evidence is conducted, which shows that each mechanical innovation was motivated by quality improvements and resulted in more refined quality of cotton yarn. Using customs data from 1777-1806, I show the increase in the varieties of cotton goods exported from Britain, especially finer cottons and muslins. Using firm-level data from the fine spinning firm McConnel and Kennedy, I show that fine spinning provided greatest productivity gains vis-à-vis Indian yarns and the pursuit of fine spinning was an economically rational decision by British entrepreneurs.

The remainder of this chapter attempts to answer its main questions first through a historical survey of the machinery used for spinning fibres, especially cotton, since antiquity, into the early modern period. A comparative assessment of the machinery is next conducted with a view to testing the hypothesis of quality-led mechanical innovations based on both mechanical and material textile evidence. It then demonstrates the economic rationale and impact of quality-led mechanical innovations. The next section undertakes a systematic analysis of the working mechanisms of the three key spinning machines associated with industrialisation – the spinning jenny, the waterframe and the mule – to assess for path dependence. The penultimate section re-assesses the path dependence of the spinning technology with relation to the labour skill gap, skill differentiation and the staple of raw cotton. The final section concludes.

5.3 A Historical Survey of Spinning Technology

Looking back historically at the machinery used for spinning animal and plant fibres for weaving into cloth shows that technological change, far from being linear and unidimensional in time and space, demonstrates remarkable characteristics of overlap, stagnation, regress, serendipity, acceleration as well as lateral movement through knowledge transfer via different mechanisms.

The earliest contrivance by which humans manipulated fibres to form twisted lengths of yarn were, in all likelihood, the two hands of the spinner. One hand would hold the mass of the fibre and the other would pull and twist, periodically, stretches of fibre and converting them into yarn. It is possible to spin only short lengths of yarn this way but, as Morton and Wray show, this is most likely the way humans first began with the idea of transforming loose, short fibres into yarn.[266] The short lengths of yarn thus spun, therefore, introduced the problem of spinning continuous and relatively longer lengths of yarn.

A solution was found, in the obscurity of ancient times, through the mechanism of a spindle attached to a weight called a whorl at its opposite end. The tool is called the drop spindle. There exists evidence of a wooden spindle from Kahun in Egypt, dated 1900BC.[267] A small length of hand spun yarn could be attached to the spindle, which would spin by virtue of being attached to the whorl. The whorl, suspended above the ground, would spin through the weight of gravity once set in motion. The spinner, holding in one hand the loose bunch of fibres, attached to the spindle, could guide the stretch of the fibres with the thumb and forefinger of the other hand by gently pulling on the roving to bring required lengths of fibres into the twist provided by the spin of the whorl.[268] The skill of the spinner is significant in guiding or drawing out the fibres from the lose bunch, a process technically known as drafting, and ensuring the twist is adequate – too much and it would lead to patches where the fibres are scarce, resulting in breakage; too little and the yarn would not be strong enough for the purpose of weaving. For spinning of the finest qualities of yarn, Indian spinners regulated this problem by resting the lower end of the drop spindle in a smooth shallow shell, or other similar object, to ensure just the right amount of drafting tension.[269]

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[266] W.E. Morton and G.R. Wray, *An Introduction to the Study of Spinning*, Longmans, Green and Co. Ltd., London, 1962, p. 133-134

[267] Derry and Williams, *A Short History of Technology*, p. 79

[268] Technically, a bunch of cotton would first be combed or 'carded' to form a 'roving' for spinning from, but loosely spun yarn which is meant for the purpose of spinning finer yarns from is also known as roving. Ibid.

[269] Morton and, *Introduction to Spinning*, p. 135

Figure 59: A wooden spindle whorl, Museum of Science and Industry, Manchester

The spinning wheel was invented and came into circulation in India sometime between 500-1000CE.[270] It comprises a wooden frame with a wheel at one end and a spindle at the other. Using the handle attached to the wheel, the spinner rotates the wheel, which in turn, rotates the spindle. This wheel is suitable for spinning all short staple fibres, whether wool or cotton.[271] The main difference between spinning on the drop spindle and spinning on the Indian or Jersey wheel, as it came to be known in Europe and Britain, mainly because it was used to spin wool, is the drafting mechanism. Unlike the drop spindle where the drafting takes place straight in line with the spindle, in the Jersey wheel, the drafting happens at an angle to the spindle, depending upon the required twist in the yarn. The higher the twist required, the higher the angle at which the spinner drafts the roving to be spun into the yarn.[272] This is a skill-intensive process involving a carefully calibrated judgement of the thickness of the roving, length of drawing, amount of twist inserted via the spindle, all the while ensuring a uniform and appropriate twist of yarn. Once a required twist is inserted into the yarn, it must be wound on to the spindle. This process is known as 'backing off' whereby the yarn is wound back up on to the spindle to form a 'cop.'[273]

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[270] Ure, *The Cotton Manufacture*, Vol 1. P. 195; Marsden, *Cotton Spinning*, p. 194-5; Morton and Wray, *Introduction to Spinning*, p. 135; https://americanhistory.si.edu/*collections/search/object/nmah_1200991*

[271] Ure, *The Cotton Manufacture*, p. 195

[272] Morton and Wray, *Introduction to Spinning,* p. 139

[273] Ibid. p. 141

Figure 60: Jersey wheel, Museum of Science and Industry, Manchester

Spinning on the Jersey wheel was, therefore, a two-staged process – the first comprising drafting and inserting twist into the fibres to make the yarn and the second involving backing-off and winding the spun yarn on to the spindle. This two-staged process of spinning remained the chief technology for spinning yarns in Asia and Europe till the 16th century.

A shift from the two-staged process of spinning towards continuous spinning came about in the beginning of the second quarter of the 16th century in Europe, innovated by Johan Jurgen in Brunswick in 1530.[274] The Saxon wheel, also known as the long-fibre wheel, as it was used to spin the longer fibres of flax, hemp or wool, combined the principles of spinning and winding-on.[275]

[274] Usher, *A History of Mechanical Inventions*, p. 273
[275] Morton and Wray, *Introduction to Spinning*, p. 50

Figure 61: Saxony wheel, Smithsonian National Museum of American History, Washington DC

The spinning mechanism on the Saxon wheel was different from that deployed on the Jersey wheel. The spindle was attached to a wooden whorl, which received its motion from the wheel moved by a foot treadle. The bobbin, on which the yarn would be wound, was mounted on the spindle shaft, flanked on two sides by the flyer through which the spindle was attached. Drafting of fibres on the Saxony wheel is done the same way fibres would be drafted on a simple spindle, with the fibres being directed through the spinner's hands but into an opening in the spindle through to the hooks on the flyers which guide it to be wound on to the bobbin.[276] During this journey, with each revolution of the flyer around the spindle shaft, one turn of twist is inserted into the length of the yarn. The spinner is able to guide the yarn into the opening at the tip of the spindle with both hands.

Continuous spinning on the Saxon wheel required careful attention of the spinner to maintain constant twist of yarn on the bobbin. Without the attention of the spinner, each revolution of the bobbin would result in an increase in the diameter of the bobbin as yarn continued to be

[276] Morton and Wray, *Introduction to Spinning*, p. 151

wound on to it. This would result in decreased twist in the yarn, resulting in increasingly softer yarn as spinning continued. The problem was solved by the adjustment of the tension on the band that connected the large wheel to the spinning apparatus.[277] Mechanical assessments also indicate that the method of the Saxony wheel is inconducive to the making of fine yarn, even by a skilled and experienced spinner, because the centripetal force of the bobbin pulls strongly on the yarn. It is technically impossible to spin fine or loosely twisted yarn on this type of wheel.[278]

Productivity increased two-fold with the use of the Saxon wheel, but in select fibre categories of some woollens and linens.[279] The Saxon wheel remained an additional, complimentary spinning mechanism to the Jersey wheel – it did not replace it as the prominent spinning device. It was adopted in several parts of Europe including Germany, Switzerland, and Belgium.[280] The fact that the Saxon wheel was used to spin longer fibres was largely responsible for its complementarity to the Jersey wheel, which was used to spin short staple fibres.

Continuous spinning, and the idea of perpetual motion on which the Saxon wheel technology rested, are important developments in the history of mechanisation in textile manufacture. According to White, the concept of perpetual motion came to Europe from India. White traces the concept back to AD 1150 and credits the Hindu astronomer and mathematician Bhaskara for the idea of gravitational *perpetua mobilia*.[281] For White, such an idea was rooted in the 'Hindu belief of the cyclical and self-renewing nature of all things.'[282] According to White, from here it was picked up by Islam, followed by the Europeans. White writes, 'We may thus be sure that about AD 1200 Islam transmitted the Indian concept of perpetual motion to Europe, just as it was transmitting at the same moment Hindu numerals and positional reckoning: Leonard of Pisa's *Liber Abaci* appeared in 1202.'[283]

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[277] Ibid. p. 151-152
[278] Hills, Hargreaves, Arkwright and Crompton: Why three inventors? *Textile History*, 10:1, 116-126
[279] Catling, *The Spinning Mule*, p. 16
[280] Ibid., Usher, *A History of Mechanical Inventions*, p. 273-274
[281] Lynn White, Tibet, India and Malaya as sources of Western Medieval Technology, *The American Historical Review,* Vol 65:3, April 1960, p. 515-526
[282] Ibid.
[283] Ibid. The *Liber Abaci* was one of the first European texts to delineate the Hindu-Arabic numeral system with symbols in line with the modern Arabic numerals.

White goes on to note that once the concept of perpetual motion arrived in Europe, it was greeted with intense and widespread interest, unlike in the Hindu and Islamic traditions where it remained a theoretical concept. European tradition of scientific enquiry took a concept of Indian origin and stretched it further, engaging with it mechanically, to diversify its technological potentials and applicability.[284] One such application of the concept found itself fruitfully deployed in the Saxon wheel.

Significantly, over 200 years elapsed before the next search for continuous spinning technology. The next series of attempts to improve continuous spinning become visible in the late 17th and early 18th century, the most prominent being Lewis Paul and John Wyatt's development of their prototype for spinning by rollers in the 1730s, for which they took out a patent in 1738.[285] The key question then is, what motivated the pursuit of mechanical spinning at this point in history?

5.4 Early 18th Century Innovations in Spinning Technology

Before the successful innovation by James Hargreaves, that led to the creation of the spinning jenny in 1764, attempts had been made to achieve mechanical substitution of the process of spinning, but with limited success, in wool and cotton spinning. Silk throwing, on the other hand, was successfully established in Britain by 1720, with its knowledge clandestinely acquired from Italy.[286] Thomas Lombe's silk mill set up in Derby in 1721, thus, was the first mechanised textile production facility, a trendsetter not only for silk manufacture in Britain but also for the idea of mechanised textile spinning for other fibres.[287]

Evidence of European connections and diffusion of European technology into Britain during this period are plentiful and well-recorded. Alongside knowledge in metallurgy, chemistry, clock and instrument-making, Britain drew on European knowledge and technological developments in printing, paper making in mills, 'new draperies' in woollens, the Saxony wheel, the ribbon loom, and in several other industries like silk, pottery, glassmaking, sugar, brewing etc. Knowledge travelled not only through ideas, written records as well as objects but

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[284] Ibid.
[285] Wordsworth and Mann, *The Cotton Trade*, p. 415
[286] Frank Warner, *The Silk Industry of the United Kingdom: Its origins and development,* London, 1862, p. 199-201
[287] Ibid.

also through free flow of migrant labour from continental Europe into Britain.[288] Arguably, the traffic of knowledge transfer ran both ways. Yet, evidence suggests that in the pre-industrial era, Britain borrowed more knowledge from Europe and the rest of the world than it sent out. On the other hand, unlike Continental Europe, which is connected through a vast contiguous landmass, Britain's island location meant that it had to reach out to the rest of the world, including Europe, for commercial enterprise.[289] Oceanic commerce, hence played a crucial part in enabling the gathering of commercially viable ideas and expertise from around the world.

How much were these technological changes influenced by the introduction of Indian cottons? Wordsworth and Mann refer to a handful of attempts, towards the end of the 17th century and in the first two decades of the 18th century, where enterprising individuals attempted mechanisation of spinning in Britain. These were, according to the authors, typical of the time's two main preoccupations – providing relief through gainful employment of the poor and 'enrichment of the nation by the establishment of new industries.'[290] In 1678, Richard Dereham and Richard Haines were granted a patent for a machine that could operate between six to a hundred spindles when a wheel and crank mechanism was moved by human hand. Haines, who was the developer of the idea and the machine, envisaged the device to be applied to flax spinning by pauper children and criminals.[291] The machine was set up in workhouses around England for the purpose envisioned.

A second attempt at mechanisation, before the advent of the spinning jenny, was made by Elias Barnes between 1720-24. This time, however, the endeavour was clearly stated by the inventor as motivated to spin cotton, especially fine cotton, to rival Indian muslins.[292] The chief aim was to profit from competitive trade against Indian cotton goods in world-wide markets, with a categorical recognition of the commercial potential of such an enterprise.[293] The machine that Barnes invented, however, comprised of small alterations to the spindle of the Jersey wheel, without any multiplication of spindles or application of inanimate power. What he did achieve, on the other hand, was a refined spindle and whorl mechanism which enabled speedier and

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288 Musson and Robinson, *Science and Technology in the Industrial Revolution*, p. 60-61
289 Derry and Williams, *Short History of Technology*, p. 281-282
290 Wordsworth and Mann, *Cotton Trade and Industrial Lancashire*, p. 414
291 Ibid. p. 413-414
292 Ibid. p. 121-124
293 Ibid.

more uniform spinning.[294] The Board of Trade and Plantations, where Barnes submitted his invention for evaluation with the hope of an award, circulated the spinning machine amongst manufacturers and other experts who returned with favourable feedback. However, the delay between Barnes' petition to the Board and its response to him meant that Barnes began to look towards the Continent for options to establish his machine. It was adopted, soon after, at a school in Paris and subsequently in the different provinces in France.[295]

Barnes' improvements to the ordinary spinning wheel to facilitate the spinning of finer yarn is dismissed within the literature because it did not embark upon an industrial career owing to lack of multiplication of spindles or application of inanimate power.[296] However, Barnes' endeavour was the first to recognise the market potential of Indian cottons and the competitive gains to be had from the imitation of fine Indian textile goods. The rationale of his innovation was clearly stated by him as motivated by the urge to replicate the Indian fine cottons. Barnes was one of the first to recognise that the problem of replication of the Indian cotton goods hinged upon the quality gap; he aimed to bridge this gap with the help of the refined spindle - the key innovation in his device.

If Barnes' machine had been adopted in Britain, would there have been a serious attempt to improve product quality by improving the quality of hand-spinning? Would an attempt to replicate by hand the generational skill of the Indian spinner been worthwhile, indeed possible? How long would it have taken for the British or European spinners to hand spin yarn to the quality that could compete with Indian yarn? From the French adoption of Barnes' spinning wheel, we know that it had a limited impact on the French cotton industry.[297]

Another insight may be gained from Barnes' unsuccessful attempt to have his improved spindle taken up in Britain. The temperament at the time in Britain was that of and for mechanisation. Successful silk throwing had opened a pathway for the potential of successful cotton, linen and wool spinning. Machines to employ empty or vagrant hands were much sought-after.[298] This search for mechanisation to employ the skill-less may be seen as indicative of a recognition

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[294] Ibid. p. 414
[295] Ibid. p. 123-124
[296] Ibid. p. 415
[297] Ibid. p. 124
[298] Robert Dossie, *Memoirs of Agriculture and other Oeconomical Arts*, London, 1768, vol. 1, p. 93-94; MacLeod, *Inventing the Industrial Revolution*, p. 159, 161

within the political economy of the existence of unskilled labour and the pursuit of means to gainfully employ this labour force. Contrary to the arguments of 'skilled labour' as a resource that facilitated industrialisation, evidence suggests an abundance of unskilled labour and institutional efforts to provide gainful employment to this labour.[299] That such a need was present and noticed in France as well is evidenced by the application of Barnes' machine in French schools.

Another proposition was sent to the Board of Trade and Plantations in 1723 by Thomas Thwaites and Francis Clifton, to manufacture a yarn made with a mix of wool, flax, cotton and silk, using 'several engines by certain multiplying of wheels.' The stated aim of the invention was to bring 'greater perfection' to the woollen, linen and cotton manufactures of the country.[300] It appears to be a novel take on improving the quality of woollen yarn by mixing it with other fibres, but not much more is known about the principle of the mechanism suggested.

Improving the quality of spun yarn appears to be the central motivation for all three early inventions related to spinning.[301] While Barnes made his proposal explicitly to improve the quality of cotton yarn in Britain and the Continent, Thwaites and Clifton aimed more at improving the quality of spinning in wool. It appears that inventors recognised that yarn quality was a problem and saw their inventions as means of rectifying the problem while simultaneously providing additional justification for their inventions as instruments for delivering poor employment and relief.

The first major commercially oriented attempt to mechanise spinning of wool and cotton was undertaken by the duo Paul and Wyatt in the 1730s, with a patent for spinning of yarn using rollers successfully obtained in 1738.[302] Following the adoption of Barnes' spinning wheel with the refined spindle, there was greater interest in France with regards to the idea of multiple

[299] Parthasarathi, *Why Europe Grew Rich*, 104-105; Griffith, Hunt and O'Brien, Inventive activity in the British textile industry, p. 886, 888
[300] Wadsworth and Mann, *The Cotton Trade*, p. 414-415
[301] Ibid. p. 416
[302] Ibid. p. 424-425; Gilbert French, *Life and Times of Samuel Crompton*, first published in 1859, then 1970, p. 223

spindles.[303] It is interesting, then, that Lewis Paul, the architect of the idea of using rollers for spinning, was of French Huguenot ancestry.[304]

While originally the machine was intended to spin wool, there is no evidence that it spun anything but cotton. A carding mechanism was developed to feed the quantity of carded cotton required by the machine but continued to be mechanically problematic and unsuccessful.[305] Following the debacle of Paul and Wyatt's attempt at mechanising continuous spinning, the general disposition was one of pessimism related to the prospects of mechanised continuous spinning. Much has been written about the support and encouragement offered by the Society of Arts, later Royal Society of Arts, by way of premiums and awards for inventions and innovations in Britain.[306] While the purpose of the society was, and continued to be, to encourage domestic manufacture in Britain, from 1759 onwards the Society offered only premiums for improvements to the spinning wheel, very much of the kind that Barnes had already succeeded in achieving. It stopped such encouragement for machine spinning, convinced that such a thing was unlikely to be practically feasible.[307]

In his Memoirs of Agriculture and other Oeconomical Arts, Robert Dossie, observes 'They attempted to improve the practice of this art in England, and to introduce the spinning of those finer kinds of threads, or cotton yarn, which we are at present furnished with from foreign countries. But the most efficacious, and proper means, by which they essayed to encourage spinning, were the efforts to procure improvements in spinning wheels, and the other instruments subservient to spinning: such as reels for winding, twisting, etc.'[308] Further he notes, 'The Society offered three kinds of premiums, respecting the perfection of spinning-wheels, and the operations subservient to spinning. The first was the greatest improvements in the common spinning-wheel, either for wool, cotton, flax, or silk…These premiums were continued to 1766: and then omitted, to make way for fresh objects of the Society's views.'[309]

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303 Ibid., p. 416
304 Musson and Robinson, *Science and Technology in the Industrial Revolution*, p. 61; Wadsworth and Mann, p. 419; Baines, *History of Cotton Manufacture*, p. 122-123
305 Wadsworth and Mann, *The Cotton Trade*, p. 426-427
306 Griffith, Hunt and O'Brien, Inventive activity, p. 886
307 Wadsworth and Mann, *The Cotton Trade*, p. 447-448
308 Dossie, *Memoirs of Agriculture*, p. 94
309 Ibid. p. 95-96

Not one of the three key inventions in spinning were in response to either state-sponsored rewards or by members of an established trade or craft organisation. It is in a background of general disillusionment with the prospect of continuous mechanical spinning that the spinning jenny and the waterframe were invented. By the time the mule came upon the scene, inanimate power-driven machinery was already successfully operational, awaiting purposeful refinements.

5.5 The Three Key Spinning Machines: Quality-led Mechanisation

Did mechanisation in the British cotton industry sequentially overcome the twin bottlenecks relating to the spinning of the all-cotton cloth and that of the fine all cotton cloth? Is there mechanical evidence of a quality-led motivation for mechanisation? A comparative assessment of the three key spinning machines and the self-acting mule is conducted to establish their spinning ability related to the quality of spun yarn and the products that these categories of yarns could produce.

Table 5: Comparative assessment of cotton spinning machinery in Britain, 1764-1830

Machine	*Year*	*Technical ancestor*	*Key new mechanism*	*Range Yarn Count*	*Quality of yarn*	*Suitability*	*Type of fabrics*
Jenny	1764	Jersey wheel	Multiplication of spindles	Less than 30s	Coarse, loose, breakable	Weft	Coarse fustians
Water frame	1767	Saxony wheel + rollers	Improved drawing and continuous spinning	Less than 60s	Wiry, smooth, tightly spun	Warp	Fustians, cords, hosiery, sewing threads
Mule	1779	Jenny + water frame	Controlled, 2-stage drawing for finer yarns	20s -300s	Soft, downy, strong	Warp + Weft	All-cottons, fine cottons, muslins
Self-acting Mule	1825	Automated mule	Labour inputs largely eliminated via automation	20s - 300s	Like Mule, more uniform	Warp + Weft	All-cottons, fine cottons, muslins

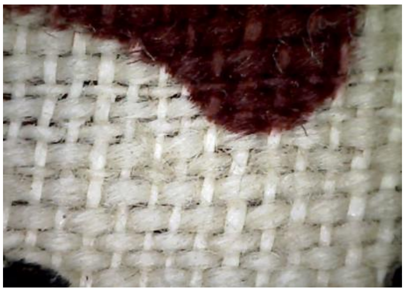
Source: Andrew Ure, *The Cotton Manufacture of Great Britain, Vol I*, First printed by Charles Knight, London, 1836; Edward Baines, *The History of the Cotton Manufacture in Great Britain*. London: Fisher, Fisher & Jackson, 1835; S.D. Chapman, *The Cotton Industry in the Industrial Revolution*, The Economic History Society, Hampshire, 1972; A.P. Wadsworth and J.L. Mann, *The Cotton Trade and Industrial Lancashire 1600-1780*, Manchester University Press, Manchester, 1931; Harold Catling, *The Spinning Mule,* Lancashire County Library, 1986; G.N. von Tunzelmann, *Technology and Industrial Progress: The foundations of economics growth*, E. Elgar Publishing Co., Aldershot, England, 1994; J.L. Mann, The Textile Industry: Machinery for Cotton, Flax, Wool, 1760-1850, in, Charles Singer, *A History of Technology Vol IV: The Industrial Revolution c.1750-c.1850*, Oxford University Press, 1958

Table 5 shows that each new machinery for spinning improved the quality of the yarn and enabled the manufacture of new, finer cotton goods than were possible with the previous mechanism, except the self-acting mule. The waterframe enabled the making of the cotton warp facilitating for the first time the viable fabrication of all-cotton cloth in Britain that could compete in tensile weight and quality with an Indian all-cotton cloth. The mule was needed for the making of the fine cotton yarn, whether warp or weft, in order to be able to replicate and compete against fine Indian cottons.

Table 5 shows that the complexity of each successive machine is related to an increase in the quality of the yarn spun. The jenny was capable of spinning coarse, loose and breakable weft of less than 30s count, suitable for the making of coarse fustians where the warp had to be made of linen. The waterframe could spin a wiry, smooth and tightly strung warp of less than 60s count suitable for fustians, cords, hosiery wear and sewing threads. The mule drastically widened the potential for spinning a variety of counts for both warp and weft, from 20s to 200s. It resulted in a soft, downy and strong yarn suitable for all cotton fabric needs, including the fine cottons and muslins. The move to the self-acting mule did not add a quality increment to the evolving machinery – its single biggest contribution was the automation of the mechanism of the mule by eliminating the input of skilled mechanical labour

What did the cloth made with yarns spun on these machines look like? The mechanical evidence discussed above may be viewed through the lens of the material evidence to see precisely what the improved quality of yarn produced by each incremental spinning machine looked like. None of the samples in the Barbara Johnson Album discussed in the previous chapter supply manufacturer information which could have been used to determine directly the technology used to make the textile products. The dates on the fabric swatches, however, allow some indicative assessments to be made related to the type of base cloth quality produced by each incremental spinning technology. The dates on the samples are dates related to the consumption of the textiles. Therefore, the following swatches display the indicative yarns produced by hand spinning on the wheel before the advent of the jenny up to the yarns produced possibly by the mule.

1746
Pre-Jenny
115 TPI



Figures 62-63: BJ/P1/S2(1747) TPI 115

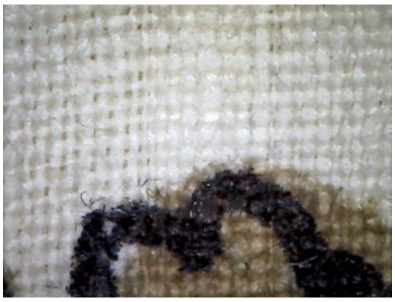
Figures 62-63 from the Barbara Johnson Album belong to a cloth that was consumed by Johnson in 1746. Therefore, this printed textile is certainly from the pre-jenny era, displaying the yarn quality of the fabric and more significantly, the linen warp used for the making of a mixed linen-cotton cloth. It is evidence of the lack of skill to make adequate cotton yarns, especially cotton warp, in Britain during the period. Both warp and weft are hand spun in this sample.

1768
Pre-Waterframe,
possibly Jenny
141 TPI

Figures 64-65: BJ/P11/S1/1768 TPI 141

Figures 64-65 display a fabric consumed by Johnson in 1768. Given that the Jenny was created in 1764 and the waterframe in 1767, and that it took between 1-2 years from yarn spinning to cloth-making to cloth printing to the cloth being available for retail consumption, it is a calculated estimate that this cloth may be pre-waterframe, with weft made on the Jenny. The yarn is more uniform than the hand spun sample immediately above, and the warp is again made of flax, giving greater confidence to the estimate that this fabric is pre-waterframe.

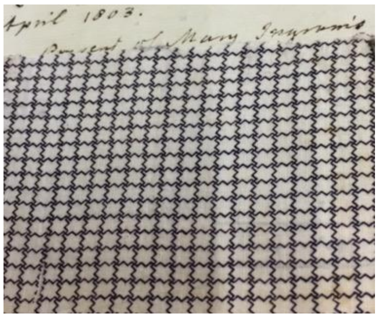
1778
Pre-Mule,
Possibly
Waterframe
192 TPI



Figures 66-67: BJ/P19/S1/1778 TPI 192

Figures 66-67 are from a fabric that Johnson consumed in 1778. Since the mule was invented in 1779, it is safe to say that the sample is pre-mule, and it may be assumed that the cotton warp was spun on the waterframe. The stringy and wiry nature of the warp is evident from the sample lending weight to the assumption that it was spun on the waterframe. The downy nature of the weft, on the other hand, suggests that it may have been spun on the jenny, though there is no way of confirming this assessment.

1803
Pre-Self Actor,
Possibly Mule or
Waterframe
227 TPI



Figures 68-69: BJ/P55/S1/ 1803 TPI 227

Figures 68-69 are from a piece of fabric consumed by Johnson in 1803. The timing of this fabric sits neatly between the advent of the mule in 1779 and that of the self-actor in 1825. The yarn in this fabric may be assumed to be made potentially on the mule or the waterframe as the two coexisted in the British cotton industry for several years. The downy texture of the yarn suggests that it may have been spun on the mule - Johnson describes this as a ‘purple and white gown’ giving no further clues as to its technological origins.

The above evidence suggests that the increase in quality of the spun yarn is closely connected to the increase in the final cloth quality and the types of final cotton products manufactured in Britain. Indeed, the very distinction between different textile product types stems from the difference in the characteristics of the yarn that they are composed of. From the ability to make a coarse linen-cotton cloth in 1746 to the ability to make a fine calico in 1803, new machinery and incremental improvements in mechanised spinning facilitated the manufacture of newer and finer cotton textile products. The quality parameter, as well as the variety of cotton goods that this pursuit of quality allowed to be mastered, are both impulses coming from the Indian cotton textiles. Differences in yarn types materially determined the categories of final textile products manufactured in the British cotton industry.

5.6 Economic Rationale for Quality-led Mechanisation

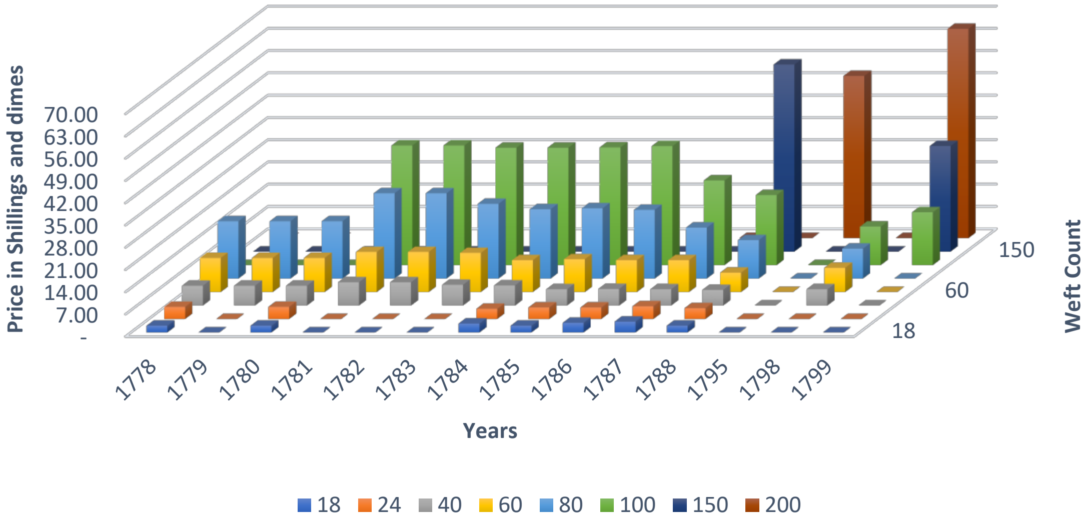
Both material and mechanical evidence suggest that incremental improvements in mechanised spinning were quality-led. Does evidence from other sources corroborate this finding? What is the economic rationale for quality-led innovations? Each successive machine in the British cotton industry between 1764-1779 improved the quality of the yarn produced by its successor, enabling the manufacture of newer, finer cotton goods. The quality motivation, as has been discussed previously, originated from the competition against, and learning from, the Indian cotton goods.

5.6.1 Fine Spinning and Profit Margins

Mechanising the production process made sound economic sense for the entrepreneur. The entrepreneur was investing in the machine, a fixed capital asset comprising the means to create the product. Further, investing in machinery with a view to improving the quality of yarn made rational economic sense as it enabled monopolistic gains from the manufacture of a low volume-high price product, the fine cotton yarn. Herein lay the motivation for the mule, to spin fine yarn and make the finest cotton fabric - the muslins. The pursuit of quality, rather than labour saving, was the primary motivation for the development of the mule.

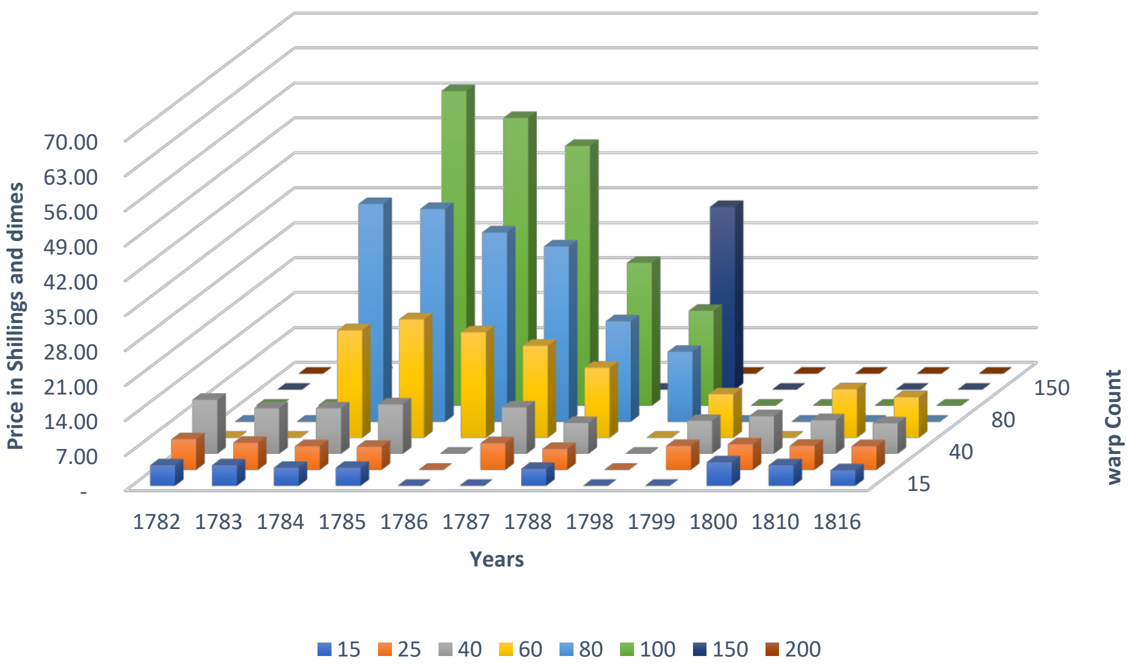
Weft and warp price data for the years between 1778 to 1816 in Figures 70 and 71 shows that the higher the count, the higher the price of the yarn in the market, indicating higher net margins. Price data for the different counts ranging from 18 to 200 shows that while the bulk of the industry was concentrated in the middling ranges from 40 up to 100, prices for higher yarn counts above 100 were much higher. The data shows that a 200s count yarn was sold at 10 times the price of an 18s count yarn, indicating higher profit margins.

Figure 70: Price comparison for different counts of weft yarn, 1778-1799



Source: G.N. von Tunzelmann, *Steam-power and the Cotton Industry*, Oxford University Press, 1978, p. 181

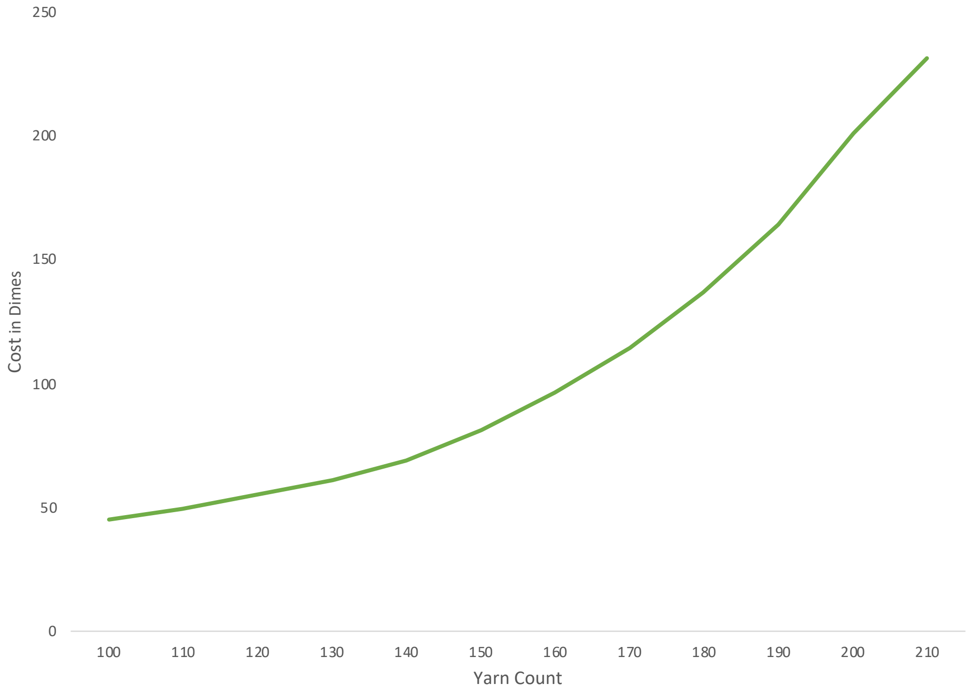
Figure 71: Price comparison for different counts of warp yarn, 1782-1799



Source: G.N. von Tunzelmann, *Steam-power and the Cotton Industry*, Oxford University Press, 1978, p. 181

On the other hand, the cost of production of higher counts of yarn was also higher. Day books of McConnel and Kennedy, a fine cotton yarn-spinning firm in Manchester show the total costs of producing yarn counts above 100 count increased rapidly. The data from McConnel and Kennedy shows a 413% increase in the cost of production of 210 count yarn over 100 count yarn.[310]

Figure 72: Cost of production of different yarn counts, 1819



Source: McConnel and Kennedy, *A Century of Fine Spinning*, first published 1907, p. 53

However, an assessment of the data related to the cost of production of different counts of yarn versus the profit margins available for each count shows that the profit margins for the higher counts were also significantly higher. While the data for net profit margins in Figure 73 is from two different sources, assuming the numbers are representative, net margins for a 170s count yarn were 1062% more than those for 60s count yarn.[311]

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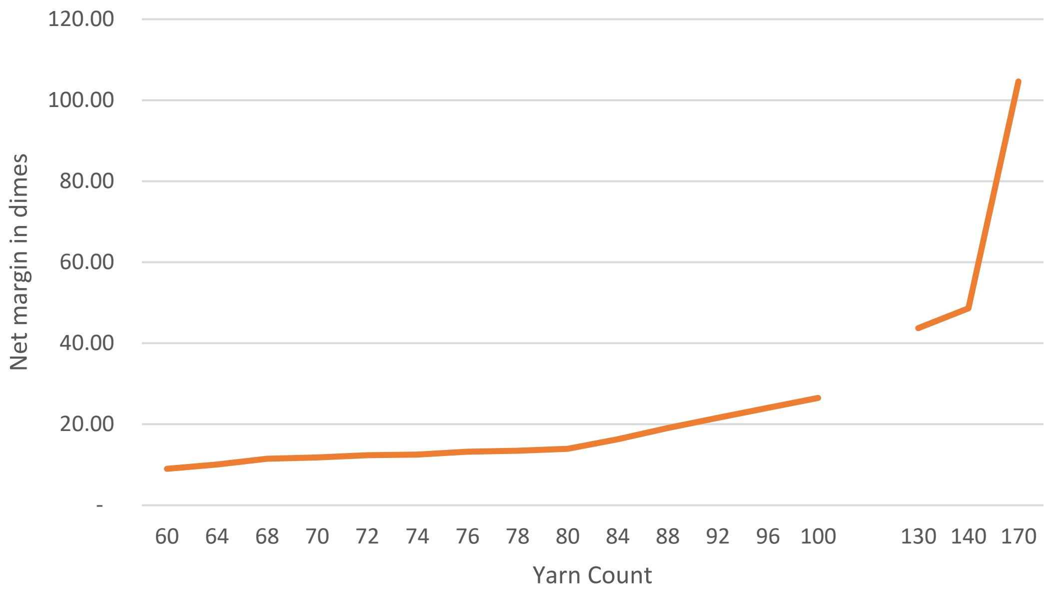
[310] McConnel and Kennedy, *A Century of Fine Spinning*, p.53

[311] Ibid.

Figure 73: Net profit margin for spinning different counts of yarn.



Source: Michael Edwards, *The Growth of the British Cotton Trade*, p. 127; McConnel and Kennedy, *A Century of Fine Spinning*, p. 50. Break in graph shows the data is from two different sources.

Evidently, although the bulk of the demand both domestically and overseas, came from the cheaper and lower count yarns for calicoes and even cheap and coarse muslins, the highest profit margins were attainable from the spinning of fine yarns for fine muslins.[312] McConnel and Kennedy are quoted as saying, 'Spinning numbers below 80 at present price is really such a threadbare trade that there is scarce any room to give way in price.'[313] While cheaper yarns, and consequently cheaper cloth, were subject to constant pressure of price reduction, finer yarn was used to make fine, luxury cloth, for which the market behaved differently and price was not a major concern.[314] Obtaining authentic luxury goods, of high quality and in line with the fashion of the period were more important concerns than price in the luxury market segment.[315] Indeed, Ackermann, a leading shopkeeper of the period, warns discerning customers in the market for luxury cottons that British muslins were being peddled in leading shopping areas as Indian muslins and guides them to shops where the real goods may be obtained.[316]

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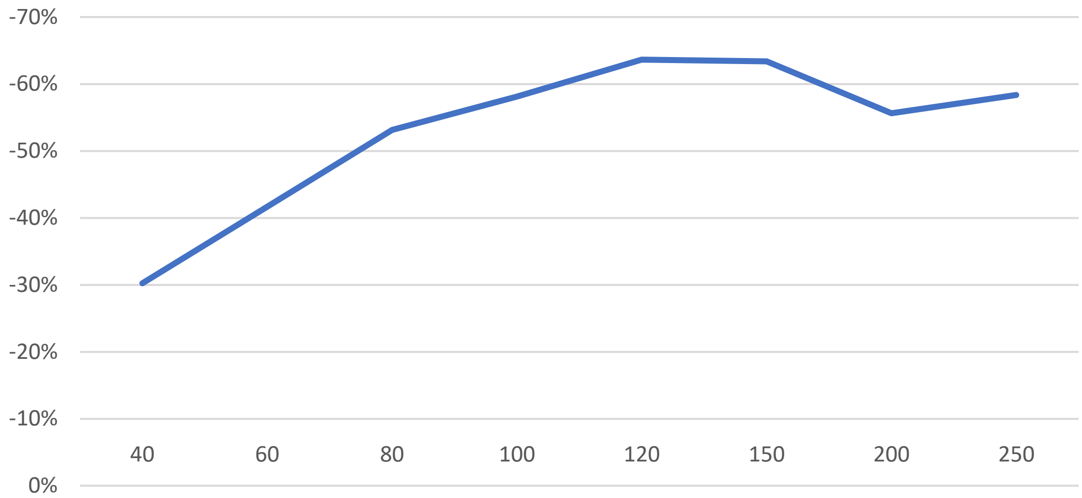
[312] Michael Edwards, *The Growth of the British Cotton Trade, 1780-1850*, New York, 1967, p. 29-30, 44-46
[313] Ibid. p. 127
[314] Ibid. p. 128
[315] R. Ackermann, *Repository of Arts, Literature and Commerce*, Vol. 4, 1810, p. 52-53
[316] Ibid.

Figure 74: Percentage decrease in cost of production of British vs Indian yarn counts



Source: McConnel and Kennedy, *A Century of Fine Spinning*, 1907, p. 53

Comparison with the Indian total cost of production of yarns of different counts also shows that the British advantage of relative cost of production over Indian production processes increased as the yarn count improved. Highest percentage cost advantage against Indian yarns was in the fine 120-150 yarn count categories with 64-63% advantage respectively over Indian production costs for yarn of the same counts.

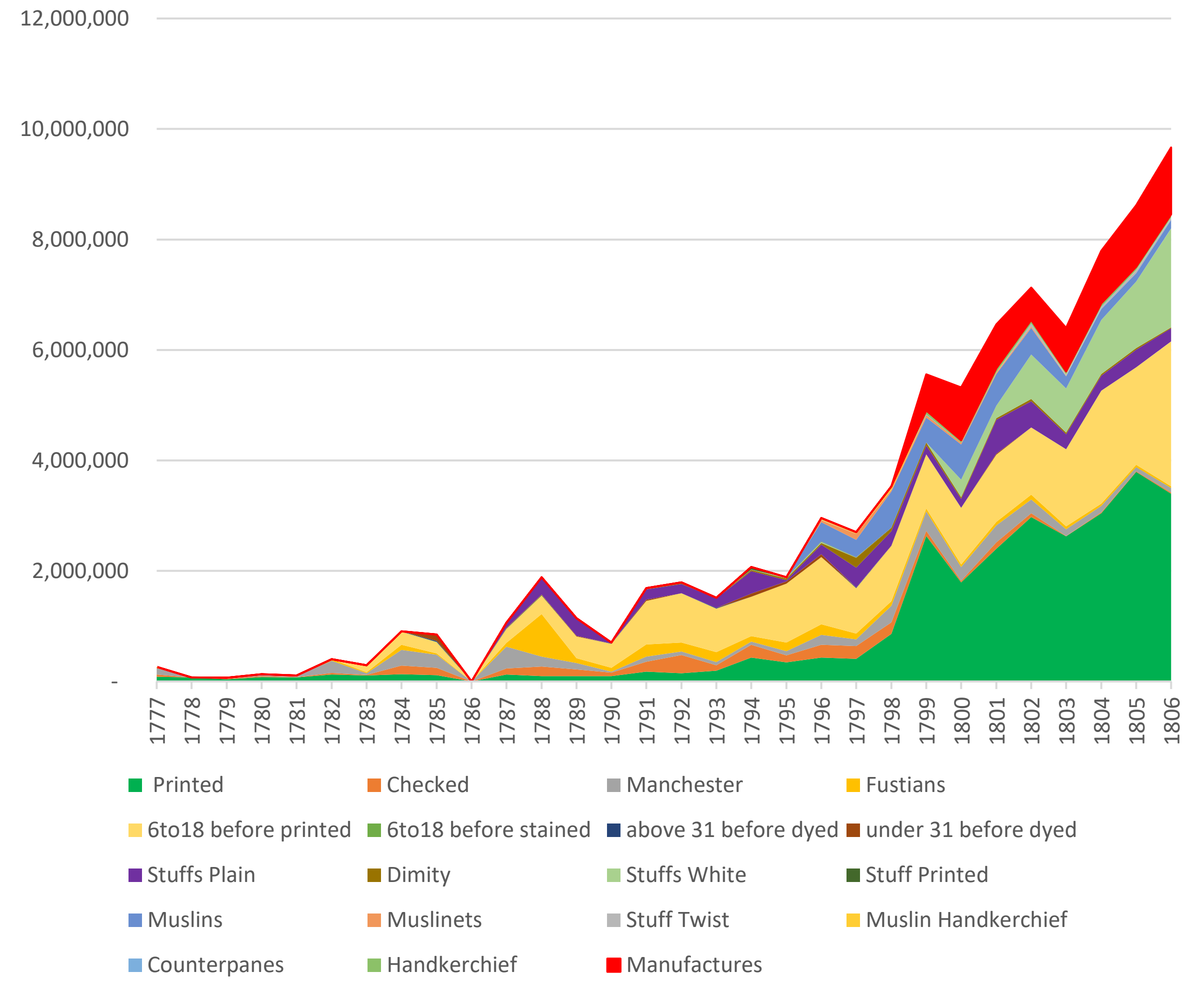
Higher profit margins, therefore, were a clear incentive to entrepreneurs for pursuing fine spinning. Investment in machinery that enabled fine cotton spinning also constituted an economically rational decision. The development of the self-acting mule in the 1820s is indicative of the continued intention of the entrepreneurs to invest in fine cotton yarn spinning despite problems with the workforce attending the hand-operated mules.[317] However, as Figure 74 shows, the competitive advantage against Indian manufacture, while it remained substantially significant for all yarn counts, it was highest for the counts between 120 and 150. Beyond that, it declined. This decline is a direct consequence of the mechanical labour skill required in making finer yarn on the mule. Different in character as the nature of labour skill was in the Indian and British settings, it was still significant enough to impact the final costs of production as well as the quality of yarn.

[317] Huberman, *Escape from the Market*, p. 23; Lazonick, *Industrial relations and technical change*, p. 231-262

5.6.2 Fine Spinning and Diversification of Product Portfolio

The advancement in fine spinning also enabled diversification of final cotton goods and enabled successful competition against the wide varieties and qualities of Indian cottons. A statistical analysis of customs data related to the export of cotton textiles from Britain to the rest of the world shows that the variety of cotton goods increased as mechanisation evolved. The variety of cotton goods is a function of the evolution of yarn quality and hence connected to Indian cottons – the making of finer yarn enabled the making of a variety of finer textile goods.

Figure 75: British cotton textile export values (GBP) 1777 - 1806



Source: The National Archives, CUST17

The total export value of cotton goods sent to the rest of the world grew from £266,181 in 1777 to £9,665,644 in 1806, constituting a 36-fold increase. Figure 75 shows that this increase was a result not only of the increased quantities of printed cotton cloth but also the increasing diversification of cotton products. Evolving spinning technology enabled the manufacture of a large variety of cotton goods previously impossible, such as muslins, muslinets, muslins handkerchiefs, handkerchiefs, counterpanes, and an opaque category of 'manufactures.'

5.7 Mechanised Spinning: Technological Path Dependence

The force of the historical narrative of the 'wave of innovations' in the nascent British cotton industry is such that it overshadows a basic fact – the old technological paradigm comprising the spinning wheel and spinner's skill was ready and available to British spinners, with which they could replicate the Indian product. Barnes' innovation of the refined spinning wheel was one such attempt. Had it been adopted, it would have required a re-negotiation of the old technological paradigm through investment in the skill of the spinner. Lack of skill in spinning cotton yarn using the spinning wheel, however, incentivised the development of machinery invested with the skill to spin, in its wake re-skilling the workforce to operate the machinery.

Were the jenny, the waterframe and the mule dependent upon the Indian spinning wheel's mechanism? Can we trace a technological path dependence within the three key inventions of spinning in the British cotton industry? I conduct a survey of the working mechanisms of the jenny, the waterframe and the mule to test for path dependence upon the Indian spinning wheel or the jersey wheel.

5.7.1 The Spinning Jenny

The spinning jenny was invented by James Hargreaves in 1764, although he applied for a patent only in 1769.[318] It was a simple mechanism whereby one wheel was made to move multiple spindles, replicating the actions of the hand-spinner.

[318] Julia de L. Mann, The Textile Industry: Machinery for Cotton, Flax, Wool, 1760-1850, in, Charles Singer, *A History of Technology: The Industrial Revolution c.1750-c.1850*, Oxford University Press, 1958, p. 278; Aspin and Chapman, *James Hargreaves and the spinning jenny*, p. 13

Figure 76: Spinning Jenny, Quarry Bank Mill, Styal

The entire mechanism was encased in a horizontal rectangular frame. A smaller frame containing bobbins filled with rovings was attached to a bar that moved it up and down the body of the rectangular frame from one end up to three-quarters of the way to the other. A sliver from each bobbin was attached to a corresponding spindle at the other end of the rectangular frame set at an angle inclined towards the spinner. The slivers passed through rails that held them in place. The spinner drew out or drafted the rovings by moving the bar attached to the bobbin frame towards herself while turning the main wheel to turn the spindles. Once enough twist was imparted to the rovings, the spinner moved the bar forward while slowly turning the spindles to wind the yarn back on to them. The spinner could then avail of a faller-wire to guide the yarn being wound on by depressing a lever.[319]

As Morton and Wray note, the jenny was a straightforward development of the short-fibre wheel or the Jersey wheel, with the principles of drafting and twisting being exactly the same in both.[320] Ure, when explaining the mechanism of the common jersey wheel states, 'This is the ancient spinning implement of Hindostan. The first mechanical invention regularly employed with profit upon a manufacturing scale for spinning cotton in England was constructed upon this principle; several spindles, at first eight, afterwards eighty, being made to whirl by one fly-wheel, while a movable frame, representing so many fingers and thumbs as there were threads, alternately receded from the spindles during the extension of the thread, and approached to them in its winding on. This multiplying wheel, called a spinning jenny, was

[319] Ibid., p. 278-279, R.L. Hills, Hargreaves, Arkwright and Crompton: Why three inventors? *Textile History*, 10:1, 1979, p. 114-126
[320] Morton and Wray, *Introduction to Spinning*, p. 142

invented by James Hargreaves, about the year 1764, at Stand-hill, near Blackburn, in Lancashire.'[321]

According to Hill, there were several problems with the jenny, including physical, constructional and technical. He notes that it was a physically uncomfortable machine to work with. Adults had to be bent over to operate it and coordinating the faller wire with the foot was unwieldy. It was difficult to draw out an even yarn and broken yarn needed constant piecing attention. Technically, the jenny was suitable only for weft owing to the way the mechanism was constructed which allowed for some yarn to be running loose from the tip of the spindles to the clasp in the bar, letting the twist run up into the new portion of the roving to be spun. The yarn spun on the jenny was only softly twisted and of lower counts. As Hill points out, while the jenny could be improved, it was fundamentally limited by the type of yarn its mechanism could produce.[322]

Henson, who recorded the oral testimony of Nottingham's framework knitters, notes, 'the cotton yarn spun by Hargraves, [sic] though much superior to the Nottingham spinning, was still a poor article, being full of tender thin places, "bumps and burs," and was with difficulty wrought in stockings.'[323] As discussed previously, Henson states that the very development of the stockings manufacture was based on the use of fine Indian cotton yarn in Nottingham, with domestic unsuccessful attempts to hand-spin similar fine cotton yarn.[324]

One key change that the deployment of the spinning jenny brought about was the transfer of the skill embedded within the fingers of the spinner into the mechanisms of the machine. As basic as the apparatus was, it disconnected the feel, control and dexterity of the spinner's fingers from the spinning process. In the jersey wheel, the quality of the yarn depended upon the feel and skill of the spinner in the production of one single thread at one time.[325] The multiplication of spindles attached to pre-filled bobbins of rovings attached to a large wheel meant the skill of the spinner to manipulate the yarn to a required level of fineness was transferred to the mechanical apparatus. While the spinner, now more aptly described as a basic

[321] Ure, *The Cotton Manufacture of Great Britain*, vol 1., p. 195-196
[322] Hill, Why three inventors? p. 120-121
[323] Gravenor Henson, *History of the Framework Knitt*ers, p. 366
[324] Previous p. 45
[325] Ibid. p. 116

mechanical device operator, exercised some discretion through the number of twists he/she imparted to the stretched rovings, this was determined and limited by the capacity of the machine, not by the skill of the spinner. As Cameron noted about the significance of the jenny, 'For the first time in the making of cloth something which constituted a machine was freely available. A machine is more than a tool in the hand of the workman; it is itself an artificial hand, made by the engineer to reproduce automatically the results of the skilled and dexterous manipulation of the craftsman.'[326] The disconnect with the old technology and skill paradigm, embodied by the Indian method of spinning cotton, had commenced by distancing the skill from the spinner.

5.7.2 The Waterframe

Following closely at the heels of Hargreaves' jenny, came Richard Arkwright's waterframe in 1767. Indeed, there is sufficient evidence to suggest that Arkwright was aware of Hargreaves' trials with the jenny even as he worked on his waterframe.[327] Unlike the jenny, the waterframe stood within a vertically standing rectangular frame with a horizontally placed wooden frame on top holding the bobbins containing the rovings. Rovings from each bobbin passed through two pairs of rollers with the second pair moving faster than the first. This mechanism ensured that the rovings were stretched further. A flyer arm guided the yarn on to the spindle at the base of the machine. The bobbins, standing on the spindle shaft towards the lower half of the rectangular frame and flanked by the flyers, had the yarn thus wound on to them. The spindle and bobbin mechanism of the waterframe is based entirely on the continuous spinning model of the Saxony wheel.[328] Continuous spinning had finally been mechanically accomplished with the twin processes of spinning and winding on completed simultaneously rather than alternately as in the jenny.[329]

[326] H.C. Cameron, *Samuel Crompton*, Batchworth Press, London, 1951, p. 48
[327] Wadsworth and Mann, *The Cotton Trade*, p. 477, Ure, *The Cotton Manufacture*, p. 220-221
[328] Julia de L. Mann, in Singer, *A History of Technology*, p. 277-278
[329] Cameron, *Samuel Crompton*, p. 53

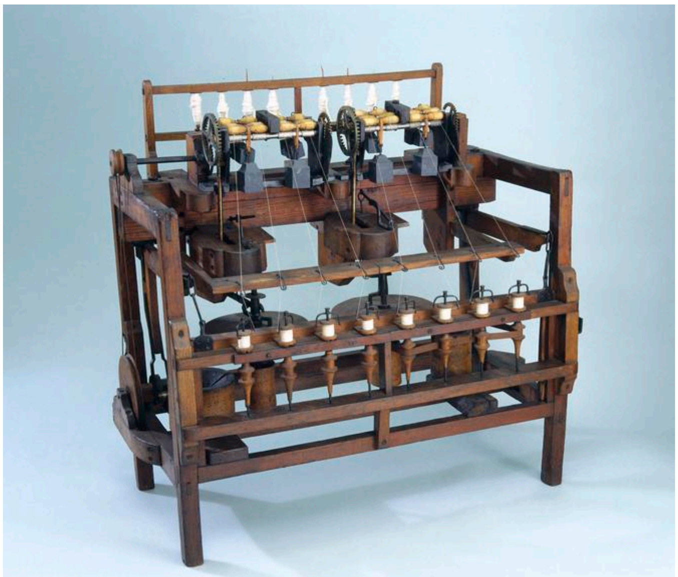


Figure 77: The Waterframe, Museum of Science and Industry, Manchester

While there is ample evidence to suggest that Arkwright 'borrowed' ideas from others who came before him, he is credited for seeing through the mechanical obstacles that prevented his predecessors from making commercially viable machines and using his practical good sense for finding workable solutions to mechanical problems.[330] The method of drafting the fibres using rollers was a crucial new solution adopted, and in large measure responsible for the success of his machine, though even this had been previously used by Paul and Wyatt. The differing speeds of the sequential rollers and the weights attached to them, however, were Arkwright's novel contributions and some of the small tweaks that made a significant difference. The waterframe was driven initially by horsepower but quickly moved to waterpower at the Cromford Mill in 1771, with the yarn it produced thus being called the 'water-twist.'[331]

The waterframe spun a strong and well-twisted yarn suitable for cotton warp as well as for hosiery. It was a smooth, wiry, and less hairy yarn, unlike the loose and soft yarn of the jenny.[332] It was technically usable as warp for all manner of cotton goods such as calicoes, fustians, and cords as well as sewing thread, though its wiry character and limits to fineness meant it was unsuitable for finer cotton goods like fine calicoes or muslins.

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[330] Wadsworth and Mann, *The Cotton Trade*, 427-431, 482; Baines, *The Cotton Manufacture*, 121-146; Cameron, *Samuel Crompton*, p. 52-53
[331] Wordsworth and Mann, *The Cotton Trade*, p. 484
[332] Julia de L. Mann, The Textile Industry Machinery, p. 279; Hills, Why three inventors? p. 123

What was the need for the waterframe if the jenny had already mechanised cotton spinning? Incremental improvements to machinery have recently been identified as the greatest providers of productivity gains, well over the invention of new machinery.[333] The jenny, however, was unable to spin adequate cotton warp, essential for the making of all-cotton cloth, and herein lay the reason for the need and the success of the new machinery, the waterframe. It enabled for the first time a large-scale manufacture of all-cotton goods in Britain, overcoming the first bottleneck in the pursuit of quality vis-à-vis Indian cottons. New machinery was required not for productivity gains, but, in the instance of the early British cotton industry, for the making of a pre-existing handmade product - the all-cotton cloth - which the previous machinery, the jenny, could not make.

Ure, however, notes complaints about the quality of yarn from the waterframe as well as its improved successor, the throstle, claiming that an estimated 40% more of the throstle yarn was used in comparison to the soft warp produced by the common throstle's successor, the Danforth throstle invented in 1829 in America.[334] The waterframe was also unsuitable for spinning short staple wool, and the weavers complained of the rough worsted yarn spun on it.[335] Evidently, the improvements within the mechanism of the waterframe were, in main, driven by the pursuit of better quality yarn. The waterframe, under the name of the throstle, continued to be used for well over a century, with few structural changes. It survived alongside the mule in cotton spinning, but was eventually adapted for flax, jute and worsted spinning.[336]

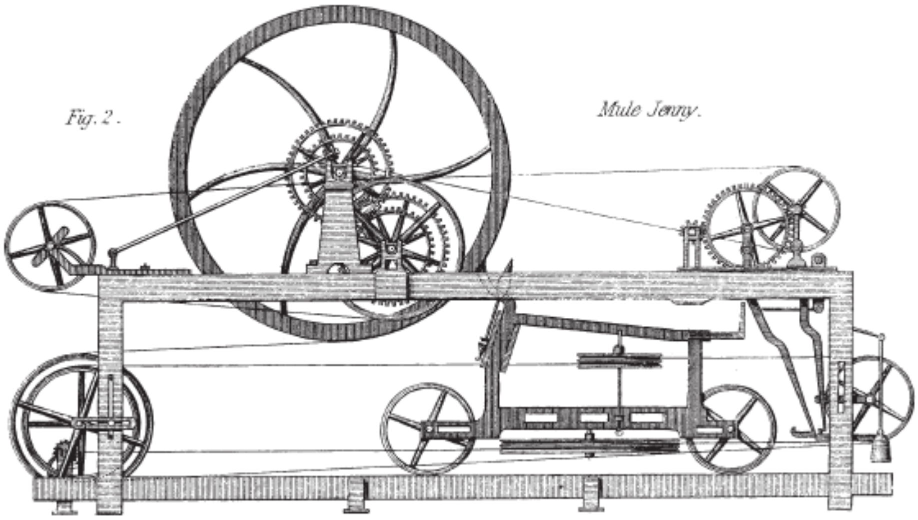
The waterframe further distanced the spinner from the actual process of spinning. There was no specialised skill required in spinning on the waterframe. The job of the operator was to re-fill the rovings, piece together broken yarn ends and remove the bobbins full of spun yarn. Women and children were routinely employed to work on the waterframe.[337] According to Hills, the skill involved in the spinning of cotton yarn had been transferred to the machine builders and fitters, and to the producers of the rovings. [338] Despite the mechanical connection to older technology, in this case the Saxony wheel, the disconnect from the old technological paradigm was further strengthened.

[333] Maw, Solar, Aiden and Kane, After the Great Inventions, p. 1-34
[334] Ure, *The Cotton Manufacture*, vol 2., p. 141
[335] C. Aspin and S.D. Chapman, *James Hargreaves and the spinning jenny*, p. 56
[336] Morton and Wray, *Introduction to Spinning*, p. 155
[337] Pinchbeck, *Women Workers in the Industrial Revolution*, 1750-1850, p. 183
[338] Hills, Why three inventors? p. 123

5.7.3 The Muslin Wheel/Mule

In 1779, Samuel Crompton showed to the public his new spinning invention, the mule. A weaver by training, he began working on his spinning machine in 1772, upon being, in his now famous words, 'Grieved at the bad yarn I had to Weave.'[339] Combining the rollers of the waterframe with the movable carriage of the jenny within a rectangular frame, he put the spindles on the carriage and rollers at the farther end away from the operator. The spinner drew out the carriage with the slivers stretching for a short length at which point the rollers acted like the jenny's clasp and the carriage moved back slowly, continuously twisting the yarn on the spindles. Once the drawing was completed, the yarn was disengaged by turning the spindles backwards and further stretched and twisted. The carriage was then pushed in again to wind the yarn on into a cop, with the help of a faller wire as in the case of the jenny.[340]

Figure 78: The Muslin Wheel/Mule



Source: Edward Baines, *History of Cotton Manufacture in Great Britain*, London, Fisher, Fisher & Jackson, 1835

According to Hills, since the spindles used by Crompton were the plain spindles like those of the jenny, without the flyers, Crompton therefore had to use the jenny's mechanism of drawing out a length of roving, spinning it and then winding it on. Hence the need for a movable carriage. The improvement upon the mechanism of the jenny comprised, in the first part, in the arrangement of the gearing that allowed for calibrated movement between the rollers releasing

[339] Letters of Samuel Crompton, in George Daniels, *The Early English Cotton Industry*, Manchester University Press, Manchester, 1920, p. 159

[340] Julia de L Mann, The Textile Industry Machinery, p. 279-280; Harold Catling, *The Spinning Mule*, p. 33-34

the rovings and the recession of the carriage. During this phase, the spindles were rotated just enough to impart sufficient twist to keep the yarn intact without the fibres disintegrating. At this point, the second phase of the process commenced with the second part of the improvement upon the mechanism of the jenny. First, the yarn was disengaged from the rollers. Then it was further stretched by further drawing out of the carriage which resulted in the yarn getting drawn out against the twist. Spindles were next turned to put in more twist and make the yarn stronger.[341]

Existing literature describes the mule as a combination of the waterframe and the jenny.[342] Indeed, its very name is a nod to its hybrid character. However, the only mechanism of the waterframe that found its way into the mule was the application of the rollers. The rest of the structure and sequence of yarn making remained exactly like that of the jenny, though improved. The mule, therefore, being in large part a successor of the jenny, continued to be plagued by the jenny's main problem - that of winding the yarn back on to the spindle to make the cop. At the end of the second draw and twist, the spinner had to turn the spindles backwards to unwind the yarn until the tip of the cop, where the yarn was to be wound on, was reached. Then he/she had to guide the yarn on to the cop, with the help of the faller wire as in the jenny, while at the same time pushing the carriage in. In this, the mule operator had to exercise his/her judgement and mechanical skill in coordinating the assembly of the yarn on the cop alongside the movement of the carriage.[343]

The transfer of the skill of spinning from the hands of the female spinner to the machine, that began with the jenny and was solidified by the waterframe, was given a new component by the mule.[344] The mule required a new skill from the machine operator – that of astute mechanical ability to navigate through the intricacies of the process of yarn-making on the mule, which had now become rather more complex. According to Hills, the skill in working the mule lay in navigating the spun yarn back through the moving carriage on to the cop and in the building of the cop. While it needed physical strength to be able to operate it, the skill of the spinner in the form of dexterity with fibres had been successfully removed from the spinning process.[345]

[341] Hills, Why three inventors? p.124-125
[342] Ure, *The Cotton Manufacture*, p. 262
[343] Ibid
[344] A gendered lens will highlight that a female skill is passed, in this case, on to the machine, making it a mechanical, male skill.
[345] Hills, Why three inventors? p. 124

Instead a new skill had been imparted to the workforce, and was indeed demanded from it – that of mechanical ability or the skill to operate larger and more complex tools in the form of machines.

Again, it may be asked, what was the motivation for the mule if the jenny and the waterframe and its successors had already succeeded in mechanising cotton warp spinning and enabling the manufacture of all-cotton goods? Increased productivity requirements had already been addressed by the waterframe and later by its improved successor, the throstle. The comparator and benchmark Indian fine cottons provided the quality-based rationale for the development of the mule. If a fine cotton and muslin manufacture had to be established in Britain, then a mechanism was needed to supply the fine yarn in the absence of skilled local labour able to spin fine yarn. The mule was this mechanism.

Daniels describes the invention of the mule as leading to the 'rise of a new cotton manufacture,' that of fine cottons or muslins.[346] According to Baines, Crompton observed that he obtained 14s. per lb. for the spinning and preparation of No 40 yarn (yarns weighing 40 hanks to the pound), 25s per lb. for No 60 and 42s. per lb for the small quantity of No 80 that he spun to test the demand for these yarn in the market.[347] Baines explains, 'These prices were commanded by the unrivalled excellence of the yarn; and it affords a criterion to estimate the value of the machine, when it is found that the price of yarn No 100 is at present day only 2s. 3d. to 3s per lb. including the cost of raw material, which is 10d. or 1s. – this surprising reduction having been effected chiefly by the powers of the mule; and that, whereas it was before supposed impossible to spin eighty hanks to the pound, as many as *three hundred and fifty* hanks to the pound have since been spun, each hank measuring 840 yards, and forming together a thread a hundred and sixty-seven miles in length!'[348] The prices indicate very strong demand for fine quality yarn in Britain during this period.

Baines was quick to recognise the significance of the mule, also popularly called the 'Muslin wheel' because of the manufacture of the particular type of fine cottons that it heralded in England.[349] He noted that while muslin manufacture had been attempted in Lancashire and

[346] Daniels, *The Early English Cotton Industry*, p. 113
[347] Baines, *History of the Cotton Manufacture*, p. 200
[348] Ibid. Italics in original
[349] Ibid. p. 202

Glasgow, it had been unsuccessful, despite the use of Indian hand spun warp. The resultant cloth could 'not be made to compete with those of the East.'[350] Underscoring the competitive and comparative origins of this new manufacture, he notes, 'Bengal, which for some thousands of years stood unequalled in the fabric of muslins, figured calicoes, and other fine cotton goods, is rivalled in several parts of Britain.'[351]

From the above historiography of the three key machines related to industrialisation in the British cotton industry, three clear strands emerge. Firstly, each machine was developed to overcome a problem in the industry. The jenny enabled multiple spindles to operate at the same time, allowing loose and low-quality weft cotton yarn to be spun. This can be seen as mechanised basic cotton spinning. The waterframe enabled the spinning of low-quality cotton warp, allowing for the first time the making of the all-cotton cloth. The mule enabled the making of fine cotton warp and weft, leading to the first manufacture of British muslins. Secondly, there is clear path dependence upon the old technological paradigm of the jersey wheel's mechanism. Although the waterframe and its successors followed the old technology of the saxony wheel, the mule, despite combining the methods of the waterframe and the jenny was predominantly a refinement in the mechanism of the jenny, which was based on the jersey wheel. Thirdly, each subsequent machine distanced further the old skill component of the technology-plus-skill combination of the old technological paradigm. This did not imply a break from the old paradigm. Instead, it involved a new skill-related engagement with the modified technology to produce the same product but in a new environment. The evolution in machines enabled the making of pre-existing Indian cottons mechanically.

A re-assessment of Table 5 in light of the above discussion also shows that 'technological change' in the British cotton industry is more aptly described as mechanisation of the old technology of the spinning wheel, whether the Jersey wheel or the Saxon. The survey of the history of technological evolution has demonstrated that path dependence was fundamental to the evolution of spinning machinery. The jenny was based entirely on the mechanism of the jersey wheel of Indian origin, the waterframe applied initially animate and later inanimate power to a device that was based on the mechanism of the Saxony wheel from Europe. Although there were some remarkable new additions, such as rollers for drafting the rovings,

[350] Ibid. p. 334
[351] Ibid. p. 335

these ideas had Continental origins too and had also been explored and applied previously with mixed results.

The mule, the key spinning machinery that enabled competitive fine spinning in Britain, was based on the jenny and the waterframe's working mechanisms. Indeed, except for the adoption of the rollers for the first drafting of the rovings, the mule was entirely a refined and improved jenny, based upon the Indian jersey wheel. From the second stretch of the fibres to the spinning and winding on, the mule adopted the full operative procedure of the jenny. If the jenny was, as Ure described, a multi-spindled application of the 'ancient spinning mechanism of Hindostan,' then all of the machinery that was developed based on this mechanism was technologically based upon the old Indian spinning technique. The difference lay in the mechanisation of the technology with modifications made to replace the old Indian technological paradigm's skill component.

As Table 5 has shown, each new spinning machinery in the British cotton industry had a clear technical ancestor. Technical ancestry of all but the waterframe, which is based on the Saxony wheel, may be traced to the Jersey wheel. The table also shows that each successive machinery enabled finer spinning of cotton through mechanisation of a previously known technology. Since the technology was largely that of the jersey wheel, the main distinction conveyed by mechanisation of the known technique was skilled-labour replacement.

5.8 Mechanisation and the Skill Gap

The Oxford English Dictionary defines the term 'skill' as 'capability of accomplishing something with precision and certainty; practical knowledge in combination with ability; an ability to perform a function, acquired or learnt, with practice.'[352] It implies the existence, or lack of, knowledge and expertise for performing a set task. In the making of cotton cloth, the fundamental primary task is the successful manufacture of adequate cotton yarn. The 'skill' to make the adequate yarn is, therefore, crucial to the success of the manufacture.

Skill, as has also been mentioned earlier, may be viewed as a form of capital, present or absent from a particular technological paradigm and capable of being expanded and contracted

[352] https://www.oed.com Oxford English Dictionary, accessed 10 May 2021

through investment of time and effort.[353] Given this background, it is worthwhile to set out and examine the different technological and skill combination options available in the 18th century for the imitation of Indian cotton textiles. In order to be able to match the quality of India cottons, and hence in order to be able to spin cotton yarn to the desired specifications, the options available to anyone seeking to replicate the Indian cotton goods were as follows:

a. Adopt Indian technique = jersey wheel + skilled spinner
b. Adopt European technique = saxony wheel + skilled spinner
c. Modify Indian technique = modify jersey wheel or skill of the spinner
d. Modify European technique = modify saxony wheel or skill of spinner
e. Invent an entirely new technique = a new way of spinning cotton yarn
f. Invest in the skill development of the local labour force, through training, possibly by inviting expert Indian spinners to lead said training, ultimately resulting in option a

Historiography of technology shows that option e did not materialise as we can trace clear ancestry of all machines. Further, there is no historical evidence of option f; indeed, the focus on finding a mechanical solution to spinning cotton yarn indicates a trend in opposition to option f. Therefore, the only realistic options were a-d.

British entrepreneurs, merchants, spinners, and other stakeholders explored options a and b during the early phase of import substitution of Indian cottons. Textual evidence has shown that this early phase of imitation demonstrated the inability of the local workforce to spin adequate quality of cotton yarn using either the jersey wheel or the saxony wheel.[354]

Since the quality of the yarn spun through these techniques was not competitive,
British entrepreneurs next tried options c and d, moving away from skilled labour towards mechanisation of existing spinning technology. Option c is the jenny through the modification of the jersey wheel and the reduction in the skill required by the spinner, and subsequently the mule. Option d is the waterframe and its successor, the throstle, through the modification of the Saxony wheel and the skill required by its spinner. However, if Indian yarn quality had to be matched, any technique based on option d would be unfeasible because it was technically

[353] Roy, *The Crafts and Capitalism*, p. 16
[354] Previous p. 44-45

impossible to spin fine yarn using the mechanism of the saxony wheel, later deployed in the waterframe.[355] Therefore, the only viable options were either a or c. The British entrepreneurs adopted option c because option a was unadoptable owing to lack of labour skill and technically, option c was the only one that would enable successful imitation of the quality of Indian cloth. The key combination of factors, therefore, that determined mechanisation were the pursuit of yarn quality and the absence of skilled labour that could spin fine yarn using the old technology of Jersey wheel spinning.

As discussed earlier, tracing the evolution of mechanisation from the jenny to the mule, Hills' observations regarding the transfer of skill from the spinner to the machine are crucial to the phenomenon of mechanisation of a labour-intensive craft such as spinning cotton.
The pertinent question, then, is - which skills were the machines intended to replicate?

In the case of the British cotton industry, historical documentary and material empirical evidence has demonstrated that the British spinners could not spin cotton warp adequately.[356] Machines were, hence, a means of bridging this skill-gap in the workforce. This skill gap, as evidence shows, is a technical problem related to cotton spinning. There is some evidence suggesting that fine spinning was achieved by a handful of women spinners in England. These references pertain mainly to the spinning of wool and demonstrate the extraordinary talent of individual British spinners who had perfected the skill of fine wool spinning over time.[357] In the context of cotton, the only way in which an all-cotton cloth could be made with locally hand spun cotton warp in Britain was if the warp was doubled to offer the requisite tensile strength. Technically, while such a scenario fulfilled the criteria of an all-cotton cloth, it cost more and was heavier than the lightweight Indian cottons, and hence incapable of competing against them in the market.[358]

The skill-gap argument is not a cultural but a technical argument. Historical unfamiliarity with the cotton fibre meant that British spinners struggled to spin it to the required specifications of fineness and strength. The characteristics of cotton as a fibre are distinct from wool, flax or

[355] Previous p. 112
[356] Baines, *The History of the Cotton Manufacture*, p. 52; Ure, *The Cotton Manufacture*, p. 189-193; Unwin, *Samuel Oldknow and the Arkwrights*, p. 7, 69-72
[357] Ivy Pinchbeck, *Women Workers and the Industrial Revolution 1750-1850*, Virago Press Limited, London, 1930, p. 130
[358] Lemire, *Fashion's Favourite*, p. 80

silk. Local labour skill is shaped fundamentally by the materials in which a population has traditionally developed its skills over time. Indian spinners had honed the skill to spin fine yet strong cotton yarn over centuries within a very specific family and caste-centred vertically integrated system of cloth production.[359] British spinners, faced with an alien fibre, were unable to master the skills required to spin by hand fine cotton yarns to match those produced by Indian spinners. Arguments related to the opportunity cost of training become less significant in the face of traditional skills developed over time and within entirely distinct socio-economic contexts. Equally, relative British and Indian wages are less relevant when the skill to make a product to the required specifications is non-existent in one setting.[360]

Explaining the mechanism of Indian fine cotton spinning, Baines contended that using simple tools alongside an 'acute and delicate' sense of touch, Indian spinners produced yarn that was much 'finer and much more tenacious than any machine spun yarn in Europe.'[361] On the other hand, explaining the delay in the development of European and British cotton manufacture Baines notes 'Owing to the rudeness of the spinning machinery, fine yarn could not be spun, and of course fine goods could not be woven.'[362] An inherent contradiction is evident in his two statements – simple tools sufficed for Indian spinners to spin fine cotton yarn but not for the British or European spinners. This contradiction brings into sharp focus the issue of skill.

The replacement of Indian spinner's 'acute and delicate' sense of touch through machinery provides a crucial connection between Indian spinning technology and the motivation for mechanisation in the nascent British cotton industry. The early machines were intended to replace not the skill of the English spinner but that of the Indian spinner, whose manual dexterity and generational experience with cotton was broken down into parts and emulated by means of the multiple movements and successive phases of operation in each spinning machine.

Mechanisation of wheel spinning itself is a step towards elimination of human input on the spectrum towards automation. The early spinning machines, the jenny and the waterframe,

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[359] Tirthankar Roy, Knowledge and divergence from the perspective of early modern India, *Journal of Global History*, Vol. 3, 2008, p. 361-387
[360] Prasannan Parthasarathi, Rethinking Wages and Competitiveness in the Eighteenth Century: Britain and South India, *Past & Present*, February 1998, No. 158, p. 79-109
[361] Baines, *The History of Cotton Manufacture*, p. 68
[362] Ibid. p. 102

could spin lower counts of cotton yarn with minimal human inputs. For higher counts, the mule continued to need human 'skill' inputs in handling and using the machinery 'skilfully' to produce yarn of desired specifications.

As the machines evolved, the mechanisms also became more complex in order to be able to replicate the fine spinning of the Indian spinner, as evident in the two-staged drawing and twisting action of the mule. Re-skilling of the English labour force – of those previously skilled in spinning of non-cotton fibres, those skilled in other crafts but choosing or compelled to move to machine spinning in the factories, as well as the unskilled - in the operation of spinning machines cannot be equated to de-skilling of the workforce. 'Skill' as a concept itself must be defined within the technological context in which it is situated. In the Indian model, the skill was that of spinning the yarn using the spinning wheel or drop spindle. In the British model, the skill shifted to that of operating the machinery. Mechanisation was simultaneously de-skilling for Indian spinners but re-skilling for the British workforce embarking upon mechanised cotton spinning.

The issue of skill is further brought into focus when seen in the light of motivations for the development of the self-acting mule. Richard Roberts' self-acting mule was the first example of industry leaders commissioning a mechanical invention with the specific and stated aim of labour replacement. Roberts was authorised in 1824 by a consortium of mill owners who, following a series of widespread and determined strikes by unionised male mule spinners, persuaded him to develop a fully automated mule.[363] Roberts applied for the first patent for a self-acting mule in 1825, with a second patent acquired for an improved machine in 1830. His design for the machine was widely accepted and provided the foundation on which self-actors continued to be built for well over a century.

Prior to the development of Robert's self-actor in 1825, spinning on Crompton's mule has been described as requiring great 'skill and care.'[364] This is because while the mule was a mechanised process of spinning yarn, it still required significant input from the operator in terms of attention, oversight and good mechanical judgement. Specifically, with regards to building up the cop of spun yarn upon the spindle in the process of backing-off, the operator

[363] Catling, *The Spinning Mule*, 1986, p. 63
[364] Ibid

had to bring a combination of skills into effect – physical strength, calibrating the speed of the retreat of the shaft in line with the speed of the yarn being accumulated on to the spindles, effectively building a good, strong and stable cop of yarn. As the size of the cop increased with increasing revolutions of yarn around it, the operator's judgement of the speed of the two processes – backing of the shaft while simultaneously collecting spun yarn on the spindles – was critical for the development of a good cop.[365]

The above discussion related to the mechanical skill required to spin fine cotton on the mule is reminiscent of David's concept of 'learning by doing' and the experiential learning acquired over time through engagement with new techniques of production.[366] It suggests a trade-off between quantity efficiency and quality efficiency. The waterframe sufficed to make lower quality cottons but the higher labour investment of the mule was critical for higher quality cotton manufacture. More time, and significantly more skill acquired experientially through working on the machinery, were required in the making of fine yarns, both in the Indian and British systems. Fine yarn, therefore, remained labour intensive in both systems, commanding high salaries alongside low investments in cotton and capital over time. This is indicative of a production equilibrium distinct from the spinning of low-medium quality cotton yarn.[367]

5.9 Mechanisation and Differentiation of Spinning Skill

An analytical comparison of 'skill' required to spin fine yarn in the old Indian technology and the new British modified technology is singularly insightful. In this assessment, the function of the 'hand-mind connection' is crucial.[368] The feedback loop between the construction mechanism of the hand and the constant response from the mind for each movement of the hand related to the construction of yarn is central to the concept of skill required for spinning. Addressing the working mechanisms of this feedback loop allows for the identification of differentiated skills amongst spinners using basic spinning tools or those using complex machinery.

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365 Richard Marsden, *Cotton Spinning*, p. 224-225; William Lazonick, Industrial relations and technical change: the case of the self-acting mule, *Cambridge Journal of Economics*, September 1979, Vol., 3, No. 3, p. 231-262
366 David, Learning by Doing, p. 523, 530, 592
367 Roses, The Choice of Technology, p. 29-30
368 Lissa Roberts, Workshops of the Hand and Mind: Introduction, in Lissa Roberts, Simon Schaffer and Peter Dear (eds) *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialization,* Amsterdam: Royal Netherlands Academy of Arts and Science, 2007, p. 6

Both Indian and British fine yarn 'spinners' have been described as artisans, but for entirely distinct reasons and for the deployment of very different skill-sets. The Indian spinner was a skilled artisan and a maker of the cotton yarn, using basic tools including her hands and mind as integral components of the working mechanism of the yarn production process. The manipulation of the yarn was accomplished through the fingers registering an instant feedback signal in the brain pertaining to the nature and quality of the twist. This feedback allowed the spinner to calibrate every successive draft and twist action in line with the feedback being constantly received by the brain. This method of intelligent spinning could produce any count of yarn commissioned, as long as the spinner, through training and experience comprising investment in countless woman hours, had developed sufficient skill to manipulate the yarn in the tightly controlled environment created by the spinning wheel, one hand moving the wheel, the other drafting and twisting and winding on, and the brain engaged in a constant feedback loop throughout the process. The higher the yarn count desired, the greater would have to be the attention to the details of each portion of the process. Arguably, the skilled spinner could allow her attention to wander when required to spin coarser counts, or a less skilled spinner could suffice for the lower counts, but both attention and skill needed to be at their highest levels for the finest yarns. The higher the yarn count, therefore, the more intelligent the spinning.

In the British system, the 'artisan' was a mule operator, a mechanic, as well as an assessor of the quality of yarn being spun by the machine. He operated the machine, which was invested with the ability to spin yarn to desired specifications. The machine required periodic calibration in order to be able to spin different counts. The skill of the spinner in setting up the machine to accomplish this calibration was indispensable. In addition, the mule spinner required great skill in the operation of the machine to successfully accomplish the backing-off process and winding the yarn into a cop. Further, just like in the Indian setting, spinning of finer yarn required greater operational as well as assessment skill from the spinner. Because the spinner was not spinning the yarn with her/his hands, the constant feedback loop with the mind had to operate differently. The spinner had to watch and assess the quality of the yarn being spun, look out for irregularities or broken parts, and be simultaneously aware of the mechanical aspects of the working of the machine. The large mule may have replaced the small spinning wheel but the attention to the details of the process of spinning was still required from the mule spinner. This attention had not yet moved into the 'overseer' category, which materialised with the arrival of the self-acting mule.

Fine spinning continued to require 'skill' from the workforce in its new setting, just like it did in the old paradigm. This is another significant continuity with the old paradigm, dependent on the fact that the high-quality Indian goods could only be replicated using the technological option that included the Jersey wheel's operational mechanisms. Effectively, the British cotton industry produced Indian cottons using base-line Indian technology by adapting the technology to suits its labour's skill-gap by instilling the skill of spinning into the machine. Coarser counts were easily spun this way by both the jenny and the waterframe. But in competing against Indian fine yarns, British entrepreneurs could not eliminate the higher labour inputs required by the mule, until the successful commissioning of the self-acting mule.

5.10 Mechanisation, Cloth Quality and the Cotton Staple

There exists a consensus within the vast literature on the history of cotton manufacturing pertaining to the relationship between the staple of raw cotton and the final cloth quality. Long-staple Sea Island cotton, from the Caribbean and The Americas, is deemed of higher quality, resulting in higher quality yarn and subsequently, higher quality cotton cloth. In contrast, the short-stapled Indian cotton, of the kind known as Surat or Smyrna cottons, are seen as lower quality cottons resulting in lower grades of cotton yarn as well as final cloth.[369] There are two inter-related problems with this narrative. The first relates directly to the technology used for spinning, and the second to the skill of the spinner.

The literature ascribing qualitative superiority to long-staple cotton over short-staple cotton is mainly referring to the staples in the context of mechanised spinning of cotton. Mechanised spinning used long-stapled cotton, indeed could not be achieved with short-staple cotton fibres. According to Ure, 'When they are short, and consist of rather broad and flimsy ribands, they will be ill adapted to machine spinning, though still susceptible of being spun by the tact of delicate fingers. We can thus understand how the Hindoo women manage to spin fine yarn from the Dacca cotton, which is the growth of an unequable wool consisting of flimsy ribands, like most of the Indian cottons.'[370] Quoting Roxburgh, Ure further notes, 'The most intelligent

[369] Baines, *The History of the Cotton Manufacture*, p. 293-299; Ure, *The Cotton Manufacture*, Vol 1, p. 93; Styles, The Rise and Fall of the Spinning Jenny: Domestic Mechanisation in Eighteenth Century Cotton Spinning, *Textile History*, 2021, p. 195-263
[370] Ure, *The Cotton Manufacture*, Vol1, p. 83

manufacturers at Dacca think that the great difference between the Dacca muslin and that of other places, lies in the spinning, and allow little for the influence of the soil, or the variety of the Gossypium herbaceum, which is cultivated in Dacca.'[371]

Looking back at the evolution of the waterframe, the Saxony wheel was used for the spinning of long fibre wool and flax.[372] The waterframe, based on the technology of the Saxony wheel, required long-staple cotton for successful spinning operation.[373] Just as the Saxony wheel complemented the Jersey wheel for coarse to medium grade spinning of long fibres of wool and flax, the waterframe complemented first the jenny, based on the Jersey wheel mechanism, for the spinning of medium quality warp from long-staple cotton and subsequently the mule for the same.

Secondly, the final quality of cloth, while reflective of the staple of the fibre, is largely a result of the combination of both the technology and the skill of the spinner. As John Forbes Watson's meticulous scientific and empirical comparative experimentations of 1866 showed, out of the highest quality Indian, British and French muslins, Indian muslins were the finest as well as the strongest. Destructive experiments demonstrated that this combination of strength and fineness of the Indian muslins was a product of the more robust short-staple cotton filament and the highly refined skill of the Indian spinner who was able to spin the finest cotton from the short-staple cotton fibres by imparting it the greatest number of twists.[374]

Therefore, the final cloth quality is a product of the combined inputs of the staple as well as the skill of the spinner using a given technology. Indeed, the skill of the weaver is equally critical for the weaving of diaphanous muslins using the finest of cotton yarns, though not a focus of this study. As Forbes-Watson showed back in 1866, the finest British and French mule spun yarn made from long-staple cottons into the finest British and French muslins could not compete with the fineness and simultaneous robustness of the highest quality Indian muslins spun using rudimentary tools alongside short-staple cotton fibres. Evidently, it is not the staple

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371 Ibid.
372 Previous p. 108
373 C. Aspin and S.D. Chapman, *James Hargreaves and the Spinning Jenny*, p. 56; Morton and Wray, *Introduction to Cotton Spinning*, p. 151-152; Hills, Why three inventors? p. 116
374 Previous p. 94-95

of the fibre that is fine or otherwise, it is the skill of the spinner, in tandem with a specific technique of spinning, that renders the yarn coarse or fine.

5.11 Conclusion

Technological change in spinning in the British cotton industry, leading up to industrialisation in the British cotton industry, symbolises much less of a break from the past than a continuity with significant adaptations. Evidence reveals rootedness not only in the technology of the past but also in the ways in which these techniques functioned alongside human skill within different socio-economic contexts. The motivations for mechanisation were determined by the labour skill levels related to cotton spinning within which British entrepreneurs attempted to imitate the Indian cotton goods. Early recognition of the lack of adequate spinning skill of the British spinners motivated the move towards mechanisation and the instilling of the skill to spin low-medium quality yarn into the machine. Yet, as evidence related to fine spinning shows, labour skill and attention continued to be required for fine spinning, until a decided drive by entrepreneurs to eliminate human skill and mechanise the entire process of cotton yarn spinning.

Quality-led mechanisation of cotton spinning had its roots in the pursuit of the replication of a range of cotton products created and perfected by centuries of anonymous Indian artisans, and the transfer of the generational knowledge and techniques of India, which were adapted, mechanised and expanded in Europe. While culturally, geographically and organisationally mechanisation of cotton spinning in Britain appears to be distinct from the Indian process of yarn production, it followed the same pathways of techniques and intensity of labour investment. It remained a process innovation, which, far from being a radical break from the past, was a continuation and adaptation of the old techniques, modified to be in line with British socio-economic conditions.

Chapter 6: Evolution of Printing and Dyeing: The Impact of the Imitation of Indian Printed and Painted Calicoes

Abstract

This chapter examines the growth of textile printing and dyeing in the early British cotton industry and the influence of handmade Indian cottons on the evolution of this industry. Textual evidence suggests that there was an early stimulus delivered by Indian printed cottons to the growth and technological development of the British calico printing industry in the form of direct transfer of knowledge. Material evidence demonstrates that there was a sustained influence of Indian cotton goods upon the emerging calico printing industry in Britain. This influence is demonstrated through the shift from monochrome to polychrome prints from the early 18^{th} century well into the second half of the 19^{th} century in Britain. The chapter also highlights that the current historiography pertaining to direct painting with indigo on to cloth needs further investigations and possibly revision.

6.1 Introduction

Machine made printed cotton goods from the north of England began making inroads into global markets from the middle of the 18^{th} century and went on to successfully serve the growing world-wide demand for cotton textiles at the onset of industrialisation. Literature on early British calico printing refers to early imitations of Indian cotton textiles by British printers and dyers. Is there a connection between Indian printed cottons and the early British cotton printing industry's growth and technological evolution in the long term?

There exist few systematic investigations into whether pre-existing benchmark Indian textiles - and indeed direct knowledge transfer through them, if any - offered any long-term impact upon the growth of printing and dyeing in Britain. Riello has pointed out that while useful knowledge transfer related to calico printing from India sparked the development of calico printing in Europe through early imitative endeavours, European experimentation, artisanal mobility and mercantilist pursuit of expertise in calico printing ultimately led to the growth of the industry in Europe and Britain.[375] Thomson has highlighted the early connections with

[375] Giorgio Riello, Asian Knowledge and Calico Printing in Europe, *Journal of Global History*, Vol 5, 2010, p. 1-28

Armenian textile printers and dyers for the diffusion of printing knowledge into Europe, and shown that entrepreneurs viewed the development of calico printing, in imitation of Indian calicos, as in line with the institutional framework of the time which promoted import substitution.[376]

If a product is imitated, then its key characteristics must be translated and transferred into the new product developed in its place. Indian printed cotton goods were readily imitated in Britain and Europe – do we see their key distinguishing characteristics replicated in the British printed goods of this period? While several characteristics of 'benchmark' can be deployed for printed textiles, such as quality of print registration, fastness of dyes to washing and light, and use of dyes to achieve high colour 'quality,' not all of them lend themselves to straightforward measurements, especially given the limitations related to the use of historic textiles. Therefore, this research uses colour count as the comparative variable between British and Indian printed calicoes. Some colours may be lost to us owing to time and the fugitive nature of dyes. However, such a limitation is likely to impact Indian and British historic textiles equally. Therefore, this chapter assesses the impact of pre-industrial printed and painted Indian textiles on British cotton goods from two perspectives – transfer of codified knowledge from India, and the evolution of colours in textile printing in Britain and India.

6.2 Historical background

Textile printing, using pigments - and not dyes - was practised in Europe since the Middle Ages. The Rhenish printed linens of the 14th century show pigments and colours attached to the surface of the cloth with resin or gum-like substances.[377] Cloth ornamented or stained in such a manner was unsuitable for washing, and therefore, everyday consumption on the body. Typically, such printing was carried out on linen or coarse canvas using blocks and was meant for ornamentation of walls and other fixtures.[378]

Historians tell us that the textile printing industry in Britain owes its origins to Protestant French Huguenots who brought with them the art of fustian manufacture, via Holland, towards

[376] J.K.J. Thomson, *A Distinctive Industrialisation: Cotton in Barcelona, 1728-1832*, Cambridge University Press, Cambridge, 1992, p. 51, 64, 75
[377] Geoffrey Turnbull, *A History of Calico Printing in Great Britain*, St Ann's Press, Altrincham, 1951, p. 17; Joyce Storey, *Textile Printing*, p. 27
[378] Turnbull, *A History of Calico Printing*, p. 17-18

the end of the 17th century.[379] Attempts have been made to stress upon the European character and origins of this industry. However, evidence suggests that the Dutch printers, from whom the Huguenots learnt the art of printing on textiles, were themselves imitating the printed and painted Indian cotton goods of the time, aiming to print chintz 'according to the East Indian manner.'[380] Once again, the naming of products after their places of origin - like 'Patnas' and 'Surats' - is a clear give-away of the embedded sources of inspiration and imitation.[381]

It is against this backdrop of an existing domestic fustian manufacture, which itself found its print inspiration in Indian printed cottons, that printing and dyeing was first established in Britain. The direct introduction of Indian printed and painted textile goods provided the stimulus for the growth and expansion of the industry.[382] According to Brunello, the influx of new products as well as exotic natural materials in the form of dyestuffs rejuvenated the European printing and dyeing techniques.[383]

6.2.1 Origins of Calico Printing

Literature on the origins of calico printing in Britain is almost entirely reliant on the works of P.C. Floud, Keeper of the Circulation Department at the Victoria and Albert Museum in London (1947-1960), with subsequent authors having based their assessments on his pioneering writings on the topic. According to Floud, the industry was established in 1676, in all likelihood, by William Sherwin at West Ham. In the same year, Sherwin took out a patent for 'the only true way of East India printing and stayneing … never till now performed in our kingdom.'[384] The explanation Floud offers is that Sherwin appears to have somehow discovered 'the secret of the Indian chintz with their brilliant fast colours.'[385] Evidence suggests that Sherwin's enterprise was flourishing, as, in a petition against a bill to prohibit printed calicoes he declared that he and his neighbour employed 400 people.[386] In the absence of any

[379] Wadsworth and Mann, *The Cotton Trade*, p. 130
[380] Ibid. p. 130-131
[381] Ibid
[382] G.P. Baker, East Indian Hand-Painted Calicoes of the Seventeenth and Eighteenth Centuries and their Influence on the Tinctorial Arts of Europe, *Journal of the Royal Society of Arts*, Vol. LXIV, No. 3313, 1916, p. 482-492
[383] Franco Brunello, *The Art of Dyeing in the history of mankind,* Neri Pozza Editore, Vicenza, 1973, p. 196
[384] P.C. Floud, The Origins of English Calico Printing, in *The Journal of the Society of Dyers and Colourists*, Vol 7. No. 5, p. 275-281
[385] Ibid
[386] Wadsworth and Mann, *The Cotton Trade*, p. 132

evidence to the contrary, if Sherwin's printing establishment is to be taken as the first English textile-printing workshop, then the influence of Indian printed products, as well as techniques, is fundamental.

The first half of the 18th century saw rapid dispersion of printing houses along the Thames and the Lea at Richmond, Bromley, Crayford, Waltham Abbey, Merton Abbey and others even as prohibition of printed cotton goods was first introduced in 1701.[387] From the middle to the second half of the century, printworks emerged in the north of England, Scotland and Ireland, some prominent ones being John Collins of Bromley Hall in 1765 and William Kilburn in 1780. In 1764, Robert 'Parsley' Peel established printworks in Brookside.[388] Calico printing was a prominent industry well into the 19th century with iconic design and printing houses associated with it, such as William Morris and Liberty.[389]

6.2.2 Evolution of Dyeing Techniques

The history of dyestuffs and techniques of printing and painting with dyes also relies heavily upon the works of P.C. Floud. According to Floud, the reason why printing with fast colours using the mordant technique was so delayed in Europe as compared to India was because of the lack of suitable thickening agents for the application of colour using block prints.[390] He also asserts that as far as knowledge of thickeners goes, Europe did not learn anything from India because Indians themselves did not possess the knowledge of thickening agents for block printing.[391] He further states that the English were the first to paint directly on to cloth with indigo by introducing the 'pencil blue' technique with the addition of orpiment or arsenic trisulphide as an agent for delaying re-oxidation of the leuco-indigo.[392] In introducing the technique of 'China blue' where indigo is mixed with ferrous sulphate, lime and thickeners, the English first set out the use of thickening agents in block and copper-plate printing.[393] Both these assertions, pertaining to thickening agents and direct painting of indigo on cloth will be re-assessed in this chapter.

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387 Storey, *Textile printing*, p. 29; Wadsworth and Mann, *The Cotton Trade*, p. 132
388 Brunello, *The Art of Dyeing*, p. 250
389 Brenda King, *The Wardle Family and its Circle: Textile Production in the Arts and Crafts Era*, The Boydell Press, Woodbridge, 2019, p. 7-10
390 Floud, Origins of English Calico Printing, p. 278
391 Ibid.
392 Floud, English Contribution to the Early History of Indigo Printing in England, *Journal of the Society of Dyers and Colourists,* Vol 76, No 6, p. 344-349
393 Ibid. p. 347

Further contributions were made to the history of dyestuff and techniques of calico printing by John Irwin, Keeper of the India Section of the V&A and P.R. Schwartz, from the Museum of Printed Fabrics, Mulhouse, France. Irwin and Schwartz use material evidence as well as two French manuscript sources detailing Indian practices of printing and painting of calicos along the Coromandel Coast.[394] The discovery of a third manuscript in 1964, detailing processes of printing in Ahmedabad, contributed further to our understanding of the global history of dyestuffs.[395] They establish the significance of the connection between India and Britain, and certainly Europe, via the trade of Indian printed and painted textiles. The existence of these manuscripts in France throws light on the French emphasis upon understanding the Indian techniques and methods of cotton printing and dyeing. It is also a reflection upon the diametrically opposing perspectives adopted by the British and French colonial empires in India. The French East India Company, unlike the English East India Company, was a government backed venture.[396] The three manuscripts pertaining to printing and dyeing techniques in India were commissioned by French Company officials.

According to Irwin and Schwartz, different regions in India developed their own distinct techniques and styles of printed and painted goods exported to Europe. These goods, however, shared a distinctive Indian likeness that allowed them to be identified as such.[397] Therefore, Indian chintz were 'quintessentially Indian' yet, their attraction was their cheapness and technique and not their designs.[398] 'Hindu craftsman was a willing and imaginative copyist, ready to adapt his decorative style in any way required.'[399] This view has filtered through in the historiography which asserts that the patterns and motifs employed on Indian calicoes had more to do with 'European constructions of the exotic than with Indian visual culture.'[400]

[394] The Beaulieu Manuscript, c. 1734, Translated from French by P.R Schwartz in French Documents on Indian Cotton Painting and Coeurdoux manuscripts, *Journal of Indian Textile History*, No II, 1956, p. 5-19; The Roques Manuscript of 1678, Translated from French by P. R. Schwartz, in, P.R. Schwartz, *Printing of Cotton at Ahmedabad, India in 1678*, Calico Museum of Textiles, Ahmedabad, Museum Monograph No. 1, 1996, p. 4-9

[395] The Roques Manuscript in Schwartz, *Printing of Cotton in Ahmedabad*, p. 4-9

[396] Felicia Gottmann, French-Asian Connections: The Compagnies des Indes, France's Eastern Trade, and New Directions in Historical Scholarship, *The Historical Journal*, Vol. 56, No. 2, June 2013, p. 527-552; Elizabeth Cross, The Last French East India Company in the Revolutionary Atlantic, *The William and Mary Quarterly*, Vol 77, No. 4, October 2020

[397] John Irwin and Paul R. Schwartz, *Studies in Indo-European Textile History*, The Calico Museum of Textiles, Ahmedabad, India, 1966, p. 8

[398] Ibid p. 51

[399] Ibid p. 52

[400] John Styles, Product innovation in Early Modern London, *Past and Present*, Aug 2000, No. 168, p. 124-169

However, the customisation of products for different markets and their various preferences was the key to the longevity of the manufactures of pre-industrial Indian printers and dyers. British cotton manufacturers, later, also deployed a variety of marketing and intelligence gathering techniques to attain the same ability of customisation for specific markets.[401]

According to Irwin and Brett, Europeans disliked authentic Indian designs and patterns and therefore European designs were sent to India for copying and translation into printed and painted textiles. The attempt is to emphasize the European origins of these patterns. Yet these floral designs were altered and 'parodied' by the Indian craftsmen for whom these patterns were alien. Therefore, what they painted and printed was their interpretation of the European designs, the outcome being much Indianized patterns, exotic to European eyes. These 'parodied' forms fed a new and growing 'appetite for exoticism.' [402]

What precisely fuelled this growing appetite for Indian printed goods – the European patterns or the Indian interpretation of the patterns and their Indianizing/exoticizing – is unclear from the existing literature. Brett and Irwin themselves appear to answer the question, stating that more and more of these exotic fanciful goods were demanded in the West. There is evidence to suggest that after initial attempts to influence the Indian artisans' design and colour choices, from the second half of the 17th century English East India Company officials preferred Indian patterns rather than European ones. As has been mentioned earlier, Thomas quotes a 1731 directive by the English East India Company's Board of Directors in London to Bombay, which says, 'Let the Indians work their own fancies, which is always preferable before any patterns we can send you from Europe.'[403]

Designs and patterns have fluid, amorphous histories with inspirations originating from unlikely streams and sources. The Chinese origins of some of the European designs sent to India are clear indications of the global network of influences that operated, and continue to operate, in the artistic realm.[404] Equally, English and European imitations of Indian patterns on cotton goods are clear references to the appeal of the Indianized designs and their novelty by

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[401] Previous p. 37-39
[402] John Irwin and Katherine Brett, *Origins of Chintz*, Victoria and Albert Museum, London, 1970, p. 4-5
[403] Thomas, *Mercantilism and the East India Trade*, p. 40
[404] John Irwin and Margaret Hall, *Indian Painted and Printed Fabrics,* Calico Museum of Textiles, Ahmedabad, 1971, p. 36

virtue of being a hybrid of European, Chinese, Indian and Persian imaginations. Brett and Irwin's assessment of the dislike/non-acceptance in the European markets of Indian prints and patterns contrasts with the historical evidence they themselves present as well as the trajectory of the growth of the printed cotton industry in Britain.

Philip Sykas, writing about the significance of pattern books in the growth of the British cotton industry towards the end of the 18th and early 19th century, refers to the 'visual and artefactual evidence' that they supply to manufacturers.[405] Using six textile pattern books in the NW, Sykas has shown that these are books of samples of textiles showing examples of prints, colours and patterns used extensively by manufacturers as sources of inspiration. He quotes a manufacturer who notes that such condensed and compiled examples of textile products offer at a glance the 'minute particulars relative to certain methods of manufacture… how an article is started in the loom, the size of warp and weft used, and the method of dyeing and finishing'.[406]

In the 18th century, however, pattern books of the kind that Sykas refers to were not present – if any exist then they are yet to be discovered. The products that acted as prototypes for replication in place of the pattern books were the actual Indian printed and painted cloth. If pattern books were expected to provide this invaluable information and knowledge for repeating the process of manufacture of a printed textile, it may be inferred that pre-industrial Indian cottons acted similarly as the examples for emulation for both their colours as well as prints.

6.3 Indian Cottons and Calico Printing in Britain

From the analysis of existing literature, three aspects of printing and dyeing are of significance – the materiality and distinctiveness of colours, the techniques of their application on the cloth, and patterns that makes them appealing for consumption. This chapter examines the influence of Indian cottons along the first two parameters – dye colours and their application techniques. What was the role played by Indian printed and painted cottons on these two strands of calico printing in Britain? It challenges received literature on the theme and offers evidence showing that familiarity with Indian printed cotton goods as well as written transfer of Indian printing

[405] Sykas, *Secret Life of Textiles,* p. 11
[406] Ibid.

and painting techniques exposed the European and British manufacturers to tropical dyestuffs and to the techniques related to their application on to cloth. Further, the existing historiography of dyestuffs holds that the technique of directly painting with indigo on to cotton cloth was first discovered by the English around 1738. This contention does not square with the material evidence which suggests that in several museums around the world there exist Indian cotton textiles from as early as the 12th Century where curators have deemed parts of the blue to have been painted on.

6.3.1 Materiality of Colours and Dyeing Techniques

As mentioned earlier, before the advent of Indian cloth into European markets, European and British printed textiles used pigments for surface imprinting of cloth and deployed gum-like substances for adherence of colouring material to the cloth. Since mordants were not used in printing, these prints were not washable. With the advent of bright, multi-coloured, colourfast Indian printed goods, immediate efforts were made to obtain the knowledge required to be able to replicate these printed outcomes on cloth.

There are several historical examples of codified transfer of knowledge pertaining to printing and dyeing from the sub-continent to Europe. Both Dutch and French enthusiasts and East India Company officials from this period sought to acquire direct knowledge of printing and finishing techniques from India.[407] In this process, local production techniques were observed and compiled with a view to enabling their replication in Europe. These manuscripts contain detailed descriptions of the complex and time-consuming processes involved in the manufacture of multi-coloured, colourfast Indian printed and painted cottons.

This study examines the contents of three such French manuscripts to assess their impact on British printing techniques. These are the Roques manuscript compiled by Georges Roques between 1678-1680, the Beaulieu manuscript compiled by Antoine Georges Nicolas de Beaulieu sometime between 1726-1739, and the Coeurdoux manuscript, a series of letters by Pere Coeurdoux, a Jesuit living in India between 1742-1747. These will be assessed against the writings of Edward Bancroft, who published one of the earliest and widely read works on textile

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[407] Olivier Raveux, Spaces and Technologies in the Cotton Industry in the Seventeenth and Eighteenth Centuries: The example of printed calicoes in Marseilles, *Textile History*, Vol. 36, No. 2, p. 131-145; Joseph Brennig, Textile Producers and Production in Seventeenth Century Coromandel, *The Indian Economic and Social Review*, 23, 4, 1986, p. 333-355; Riello, *Cotton*, p. 167

printing and dyeing in Britain, titled *Experimental Researches Concerning the Philosophy of Permanent Colour* in 1794. Translations of the French manuscripts were published by the Calico Museum of Textiles, Ahmedabad in its Journal of Indian Textile History series from 1955-1967 under the aegis of John Irwin, the Keeper of the Indian Section of the Victoria and Albert Museum.

The Roques manuscript's pages pertaining to textile printing explain the processes involved in printing of cotton cloth in Ahmedabad, Gujarat. The printed cloth that Roques refers to is the 'chittes' or the 'chintz' involving white background with evenly distributed patterns throughout. The process of printing he describes uses blocks, mordants as well as soluble thickening agents enabling attachment of both mordant and colouring agent to cloth. In a roughly 10-step process, multiple colours are printed on to the cloth using blocks designed to fill specific part of the desired patterns. [408]

Of all the manuscripts under consideration here, the Roques manuscript is the oldest but also the one that was discovered last. Its discovery in 1965 not only caused unprecedented excitement amongst historians but also enabled revision of till-date knowledge with the establishment of some key facts. Firstly, Indian artisans used thickening agents alongside mordants for block printing well before the practise gained currency in Europe.[409] Secondly, Roques' advice to his fellow commissioners of printed textiles in India regarding the quality of the base cloth is unequivocal – fine base cloth makes for fine printing.[410] Thirdly, Indian artisans were 'overburdened' by the demands for their skills and products, often resulting in rushed and unsatisfactory jobs.[411]

The Beaulieu manuscript relates to the method of producing painted cottons in Pondicherry on the Coromandel Coast in the early part of the 18th century, around 1726-39.[412] The manuscript contains 11 pieces of fabric in various stages of imprinting, cut out by Antoine Georges Nicolas Henri de Beaulieu to illustrate visually alongside his handwritten instructions. Detailed step-by-step descriptions of the processes involved in painting the multiple colours are set out,

[408] The Roques Manuscript, p.4-9
[409] Ibid p. 1
[410] Ibid p. 2
[411] Ibid p. 5
[412] According to Schwartz, Beaulieu was in Pondicherry 5 times between between 1726 and 1739, Dufay died in 1739 but before his death he gave a detailed account to Querrelles

together with local colouring agents and mordants used. The manuscript is a product of a request made by chemist M. Dufay to Beaulieu to record the printing and painting of cotton textiles in India. The manuscript is not in Beaulieu's handwriting - he narrated the processes to Du Fay upon his return to France. Neither is it in Du Fay's hand, leading Irwin and Schwartz to conclude that it may have been copied, perhaps more than once. Indeed, there are two identical versions of the manuscript at the Museum National d'Histoire Naturelle in Paris.[413] The manuscript served as the basis of an influential work on textile printing techniques by Querelles in 1760.

Like the Beaulieu manuscript, the Coeurdoux letters detail the methods of printing, dyeing and painting of cottons in the south of India but more specifically along what Coeurdoux calls the 'Malleialam, a mountainous country, extending considerably along the Malabar Coast.'[414] Unlike Beaulieu's manuscript which is a personally witnessed and narrated/recorded account of the processes involved in printing and painting cloth in Pondicherry, Coeurdoux's work consists of two letters written by him in 1742 and 1747 after obtaining the account of printing/painting processes by local craftsmen. Therefore, Coeurdoux did not witness the processes he set out in the letters, although he did offer a crucial hint in the use of Cadou or myrobalan as a tannin during the preparation process as well as the finishing of the cloth. He also informs the recipients of his letters about the brilliance of Chay root or Chaiaver for the colour red. The significance of hard water and calcium for the brightness of the resultant reds is also highlighted in the text of the letters.[415]

Irwin and Schwartz went to great lengths to highlight the differences between the accounts narrated by Beaulieu and Coeurdoux. However, such differences are to be expected in pre-industrial manufacturing as techniques were determined by customary practices, traditions, and locally available, suitable organic and inorganic materials rather than scientifically established phases of production. Indeed, the two accounts themselves differ substantially in the styles of narration and explanations of very similar processes. The differences in the processes between the Beaulieu and the Coeurdoux manuscripts attest to the fact that different processes were

[413] Schwartz, French Documents On Indian Cotton Painting, p. 79

[414] The term bears strong phonetic resemblance to 'Malayalam,' the language spoken in the region presently known as Kerala along the Malabar coast.

[415] Letters from Father Coeurdoux, 1742 and 1747, translated from French by P. R. Schwartz in, Schwartz and Irwin, *Studies in Indo-European Textile History*, Calico Museum of Textiles, Ahmedabad, 1966, p. 105-118

followed even within different regions, often even between different printing and painting households within one region, depending upon locally available materials as well as customary practices.

Did these manuscripts, and the techniques illustrated within them, have any impact on the growth of printing and dyeing in Britain? What was the impact of knowledge diffusion from these codified sources and how was the knowledge contained in them assimilated within a new cultural and ecological context? The following section argues that attempts to imitate the Indian coloured cotton goods revealed the lack of technical expertise of the European and British dyers and colourists to imprint on cotton with colourfast natural dyes, stimulating the development of the printing and dyeing industry in Britain.

6.3.2 Codified Knowledge Transfer from India

Printed and painted Indian calicos stimulated the growth of an industry which all of existing literature calls 'calico' printing. Its very nomenclature contains the crux of its identity – it was not an all-textile printing industry or a woollen/silk/linen printing industry. Its connection to calico is fundamental both to its germination as well as evolution. It is upon this new cloth 'calico,' introduced from the East Indies, that printing was attempted to replicate the Indian printed cloth. Therefore, in its essence, it is a continuation or transfer of calico printing from India, not a new industry established in Britain or Europe.

The very existence of these manuscripts containing the methods of printing, painting and dyeing of cloth deployed by Indian artisans signifies the European pursuit of the knowledge of colourfast printing in a variety of colours and attempts to acquire this knowledge from the Indian sub-continent. Both the Beaulieu and Coeurdeux manuscripts received significant attention from emerging printers and dyers in Europe. The Beaulieu manuscript was known to the famous Basle textile printer and manufacturer Jean Ryhiner. His work, '*Traite sur la fabrication et la commerce des toiles peintes*', written in 1766, was based upon the works of both Coeurdoux and Beaulieu.[416]

[416] Schwartz, French Documents, p. 95

In 1760, six years before the Ryhiner treatise, Chevalier de Querelles wrote '*Traites sure les toiles peintes*' in Paris. In this work, Querelles not only mentioned the Beaulieu manuscript and Dufay's connection to it, but also used it as the basis of his first chapter, 'On the method of producing painted cotton in India.'[417]

According to P.R. Schwartz, the Coeurdoux letters were carefully scrutinised by the well-known English scientist and chemist Edward Bancroft, who used it extensively in his book '*Experimental Researches Concerning the Philosophy of Permanent Colour*,' published in London in 1794.[418] Dutch and German translations of Coeurdoux's letter detailing the process of textile painting in South India were widely circulated often as anonymous copies. Indeed, P.R. Schwartz conducts an interesting comparison between one such anonymous manual published in the Journal Oeconomique in Paris in July 1752, showing stark similarities in processes explained and terminologies used.[419] This evidence suggests that the knowledge contained in the Beaulieu and Coeurdoux manuscripts was available to those who needed it via the many works based on them that circulated amongst stakeholders during the period.

6.3.3 Edward Bancroft and his Experiments with Dyestuffs

Edward Bancroft (1745-1821) was a physician, chemist, spy and entrepreneur with varied interests and a scientific bent of mind. He travelled extensively around the world, particularly North and South America, during his youth, and experimented with vegetable dyes from various natural sources.[420] He wrote extensively about the chemistry of dyes, having conducted experiments himself on most aspects of printing and dyeing of fabrics. He was widely recognised as the authoritative expert on dyes and techniques of textile printing in Britain. In 1794, Bancroft wrote two volumes of his much publicised and widely circulated '*Experimental Researches Concerning the Philosophy of Permanent Colours*'. This is also one of the earliest authoritative works on dyestuffs published in Britain.

According to Schwartz, Bancroft had carefully scrutinized Coeurdoux's letters.[421] Indeed, upon examination, it is clear that both the Beaulieu and Coeurdoux manuscripts had been studied in

[417] Ibid. p. 77
[418] Ibid. p. 95
[419] Irwin and Schwartz, *Studies in Indo European Textile History*, p. 99-100
[420] Thomas Schaeper, *Edward Bancroft: Scientist, author, spy*, Yale University Press, 2011, p. 30
[421] Irwin and Schwartz, *Studies in Indo-European History*, p. 95

great detail by Bancroft, who analysed the processes described in the manuscripts and meticulously offered his scientific and empirical assessments.[422] Bancroft was not only familiar with Indian printing processes but he was also able to verify them and conduct his own experiments using Indian raw materials with the help of his connections with both Indians residing in India as well as English East India Company officials in India. His relationship with William Roxburgh is well documented within his two volumes. Roxburgh not only provided useful assistance in obtaining samples of organic and inorganic Indian products for Bancroft's experiments but also performed the priceless service of another willing and interested scientifically inclined mind with whom Bancroft could discuss his ideas and findings.[423]

In addition to his Indian connections, Bancroft also had useful French connections with scientists and chemists who were themselves experimenting with the knowledge of Indian processes received through the above-mentioned manuscripts, and were interested in colouring agents, dyestuffs and their processes, including Jean Hellot and Claude Louis Berthollet. MacNalty, writing about Bancroft at the Proceedings of the Royal Society of Medicine in the context of the history of medicine notes, 'Bancroft corresponded with French savants, especially Berthollet, the eminent French chemist, and was accepted by the scientists of both London and Paris as one of themselves and an authority in his own subject – dyeing. He was regarded by the East India Company as the chief expert of the day on dyes, and they submitted samples of Indian products to him for information concerning their dyeing properties.'[424] All of this accumulated knowledge, from India and Europe, fused within a scientific and empirical experimentations-based approach, Bancroft deployed in making a success of his commercial venture in sourcing dyes for calico printing, especially logwood and quercitron from the Americas.[425]

Bancroft is also one of the first authors to document the evolution of mordant-based printing in Europe, especially with iron oxide and aluminium. For the technique deployed to print black and red on to cloth using iron oxide and alum as mordants, he explains that the processes came

[422] Edward Bancroft, *Experimental Researches on the Philosophy of Permanent Colours*, Vol I, p. 259-266
[423] Bancroft, *Experimental Researche*s, Vol 1, p. 356-357
[424] Arthur S. MacNalty, Section of the History of Medicine: Edward Bancroft, M.D., F.R.S., and the War of American Independence, in *Proceedings of the Royal Society of Medicine*, Vol. XXXVIII, 1944, p. 7-15
[425] Bancroft, *Experimental Researches*, p. 356, 359, 403-405

to Europe from India.[426] For the use of aluminium as a mordant, he holds that the process came to Europe via the Turkey red route and was refined through trial and error with the aim of imitating the reds produced in Indian printed goods. According to Bancroft, the Turkey red process of dyeing using alum as a mordant is itself one developed as a means of replicating the Indian process of dyeing red using Chay root.[427] Bancroft refers to indiscriminate trial and error amongst textile printers in Britain in order to be able to produce bright and wash-proof dyes for calico printing in imitation of Indian printed calicoes.[428]

6.4 Application of Indigo directly on to Cloth

The interest in Indian printed cottons and the resultant experiments to imitate the many colours produced by Indian craftspeople on cotton cloth resulted in innovative new techniques. One such technique was that of pencilling the indigo directly on to cloth, with a brush, to apply blue using indigo to small parts of the cloth. Another was that of the China blue technique, which involved mixing the reduced indigo with gum in order to thicken its consistency with a view to enabling block printing with it. Existing literature credits English printers as being the first to be able to do both – print directly on to cloth with blue and thicken dyestuff using resinous substance for block printing. New historical textual evidence in the form of the Roques manuscript refutes the old narrative and shows that Indian printers were using resinous additives to thicken the consistency of dyes for easier block printing.[429] Analysis of material evidence challenges the old view related to the first direct painting with indigo on to cloth. Surviving material evidence suggests that Indian printers were painting with indigo straight on to cloth from as early as the 12th century.

According to all historical accounts, detailing Indian printing and painting processes, indigo is a difficult dye to work with and even in India there were specialist Indigo dyers in charge of transcribing this colour to cloth.[430] This is because in its normal form, indigo is insoluble in water. It must be 'reduced' to its 'white' state or de-oxidised state, for it to be able to attach to cloth. 'Reduction' of indigo is a process that can be started with the introduction of an alkaline medium which converts the indigo into 'leuco-indigo,' an acid form that attaches itself to the

[426] Ibid. p. 348-367
[427] Ibid. p. 245-303
[428] Ibid. p. 376
[429] Previous p. 154
[430] The Coeurdoux letters, in Irwin and Schwartz, *Studies in Indo-European Textile History*, p. 108

cloth. As a result, the easiest method to dye a cloth blue with indigo historically has been to dip-dye it in a vat where indigo has been reduced. As the cloth is removed from the vat, the indigo quickly re-oxidises in contact with the oxygen in the air and turns from 'leuco-indigo' to the blue indigotin.[431]

This particular quality of indigo made it hard for it to be painted directly on to cloth in small areas as the dye would re-oxidise on the paintbrush before its application on the cloth. This feature is also the reason why historical textiles are mostly white-on-blue, the white areas having been resisted and the cloth dip-dyed with indigo reduced in a vat. In the absence of direct references to indigo having been painted on to cloth in India, historians have assumed that in the large *palampores* and other printed chintz exported from India to Europe from the 16th century onwards, the achievement of small areas of blue, such as in tiny leaves and other small motifs, is a result of resisting over 90% of the textile and dip-dyeing the cloth.[432]

According to Floud, English calico printers were the first to successfully paint with indigo directly on to cloth by mixing it with orpiment (arsenic trisulphide), which delayed its re-oxidation on coming in contact with the oxygen in the air while still on the painter's brush.[433] As a result, it has been mentioned that Indian artisans possibly learnt the technique of painting directly on to cloth from England as a reverse transfer of knowledge after 1738 when the arsenic technique was first used in England.[434]

The problem with the above narrative, as set by Floud and then carried into the historiography of dyestuffs and textile/economic history, is that it does not square with surviving material evidence. Extant Indian printed and painted cloth from as early at the 12th century show evidence of indigo having been painted directly on to the cloth.[435].

431 Dominique Cardon*, Natural Dyes: Sources, Tradition, Technology and Science*, p. 339-340
432 Floud, Early history of indigo painting in England, p. 345
433 Ibid
434 Susan Greene, *Wearable Prints, 1760-1860*, p. 31
435 Gittinger, *Master dyers*, p. 33, 56; Susan Greene, *Wearable Prints*, p. 183; Barnes, Cohen and Crill, *Trade, Temple and Court*, p. 64; Gittinger 'Indigenous Techniques in Early Indian Dyed Cotton, *Marg*, 40: 3, Bombay 1989; Barnes, *Indian block-printed cotton fragments in the Kelsey Museum,* p. 29, 85

6.4.1 Testing for Directly Applied Indigo

To test this assessment of the current historiography pertaining to the direct application of indigo on to cotton cloth, I examine select historic material evidence in a sequential four-step process using visual analysis, Raman spectroscopy, X-Ray Fluorescence (XRF) and Gas Chromatography – Mass Spectroscopy (GC-MS).[436]

If the Indian cloth had been overwhelmingly resisted for the purpose of achieving blue colour in small parts of larger patterns, then we should find evidence of resist-dying upon conducting visual examination. Firstly, if a substantial portion of the cloth is resisted, then as is the nature of resist dyeing, we should see faint blue lines as a result of wax cracks on textiles where the assumption is that a large part of it has been resisted. Secondly, we should see other signs of resisting, like globular shapes for small motifs like leaves on the patterns. Thirdly, we should not see brushstrokes of the kind produced by the use of brush/kalam for direct painting. Fourthly, we should not find any residual evidence of direct painting like spillage in the form of small dots or stray brushstrokes.[437]

In order to test this assessment of over 90% of the cloth being resisted by Indian dyers to apply blue to small areas of the cloth, I study select samples of Indian painted palampores where curators and conservators have concluded that areas of the cloth appear painted, rather than printed in blue. All the samples are from the textiles collections at the Winterthur Museum in Delaware, USA and the elemental and dye analysis is undertaken at the laboratory in Winterthur Museum with Dr Rosie Grayburn and Dr Chris Petersen. Four painted Indian *palampores*[438] are identified for initial examination via Raman spectroscopy using the Renishaw Invia Raman spectrometer (785nm diode laser) in conjunction with WiRE 3.4 software with extended scan from 200-2200cm-1, 50X objective lens, exposure time of 60 seconds/scan for 1 accumulation, and 0.5% laser power. In this initial examination, we aimed to test for the presence of indigo in the areas identified by curators as painted blue.

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436 All tests, including visual analysis, conducted at Winterthur Museum, Delaware with the help of curatorial and laboratory professionals at the museum. This part of the research was generously supported by a 4-month Dissertation Fellowship awarded by the Winterthur Museum.
437 I am most grateful to Head of Collections Linda Eaton and conservators Laura Mina and Kate Sahmel at Winterthur Museum for their help in assessing historic textiles. I am also very grateful to Dr Rosie Grayburn and Dr Chris Petersen for conducting the scientific tests required for this study.
438 Object ids 1960.0786, 1957.129, 1952.0163, 1960.0781, Winterthur Museum Textile Collections

Figure 79: Object 1952.0163 inside Raman Spectrometer

Table 6: *Dye analysis for presence of indigo using Raman Spectrometry*

Object number	*Place of origin*	*Date*	*Test*	*Method*	*Result*
1960.0786	India (made into a quilt in England)	1827-1830	Dye analysis	Raman	A very strong peak at 1577cm-1 was measured from blue areas of the textile, indicating the presence of Indigofera tinctora[439]
1957.129	India (palampore)	1730-1760	Dye analysis	Raman	A very strong peak at 1576cm-1 was measured from blue areas of the textile, indicating the presence of Indigofera tinctora[440]
1952.0163	India (textile, painted)	1725-1775	Dye analysis	Raman	A very strong peak at 1576cm-1 was measured from blue areas of the textile, indicating the presence of Indigofera tinctora[441]
1960.0781	India (palampore)	Unknown	Dye analysis	Raman	A very strong peak at 1577cm-1 was measured from blue areas of the textile, indicating the presence of Indigofera tinctora[442]

Source: Dye analysis through Raman spectroscopy using the Renishaw Invia Raman spectrometer (785nm diode laser) WiRE 3.4 software, extended scan from 200-2200cm-1, 50X objective lens, exposure time 60 seconds/scan for 1 accumulation, 0.5% laser power (Winterthur Museum Library and Laboratories, Delaware, USA). Tests conducted by Dr Rosie Grayburn.

[439] A. Baran, A. Fiedler, H. Schulz, M. Baranska, In situ Raman and IR spectroscopic analysis of indigo dye, *Analytical Methods*, 2(9), 2010, p.1372-1376

[440] Ibid

[441] Ibid

[442] Ibid

The results of the Raman spectroscopy tests show that the areas identified as painted amongst the samples all contain indigo. This indicates that the blue areas deemed painted are indeed indigo. But this does not show what other agents were used by the Indian artisans to delay the re-oxidisation of indigo to allow for it to be painted directly on to cloth. For this purpose, we conducted further elemental analysis, firstly to determine if we find traces of arsenic within the painted parts with a view to testing the reverse transfer of knowledge hypothesis or to determine whether the Indian printer-dyers had used any arsenic compound to delay re-oxidation of indigo. For this purpose, X-Ray Fluorescence analysis of select Indian textiles was undertaken to test for the presence of arsenic.[443]

XRF maps were collected using a Bruker M6 Jetstream Instrument from Bruker. The data was collected and examined with the Bruker M6 Jetstream software package. The chemical elements detected by the instrument were identified in each scan by examining the overall spectral summation and the maximum pixel intensity spectra. [444]

443 The selection of textiles for this process is cumbersome as the XRF analysis requires samples to be mounted on top of an aisle for long durations. As a result, limited options were available of mountable Indian textiles for this analysis. Object ids 1960.0781, 1958.0610.003, 1969.904, INV2012-2-52 Winterthur Museum Textile Collections

444 This instrument consists of a measuring head that moves in front of the surface of the textile at a 1–2 cm distance by means of an XY-motorized stage (10 μm minimum step size and 800 × 600 mm maximum travel range). The measuring head consists of a Rh-target microfocus X-ray tube (30 W, 50 kV maximum voltage, 0.6 mA maximum current), and a 30 mm2 X-Flash silicon drift detector (energy resolution <145 eV at Mn-K∝). The beam size is defined by poly-capillary optics and is determined by the distance between the painting and the measuring head. Area dimensions are shown in the multimedia attachment. The X-ray tube settings were 35 kV and 0.8 mA; 0.54 mm step size, 500 ms/step dwell time and 0.54 mm diameter estimated beam size. I am grateful to Dr. Rosie Greyburn at the Winterthur Museum for discussing and explaining the working mechanisms of the investigative techniques.

Figure 80: Object INV2012-2-52 mounted for mapping XRF on Bruker M6 Jetstream Instrument

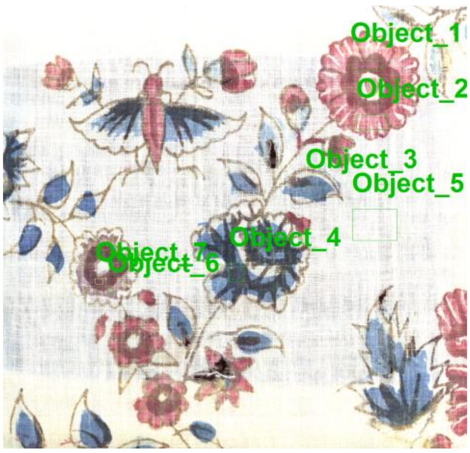
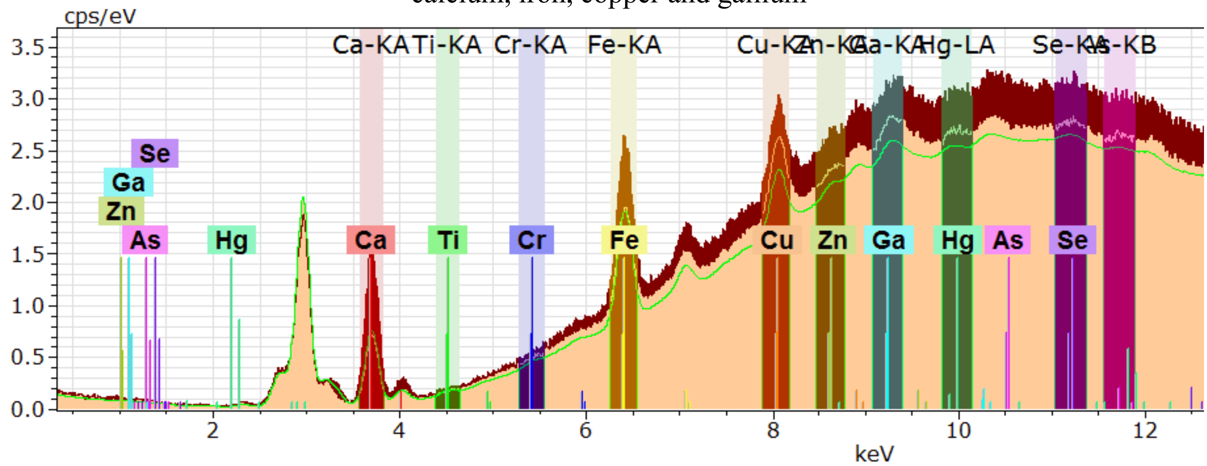


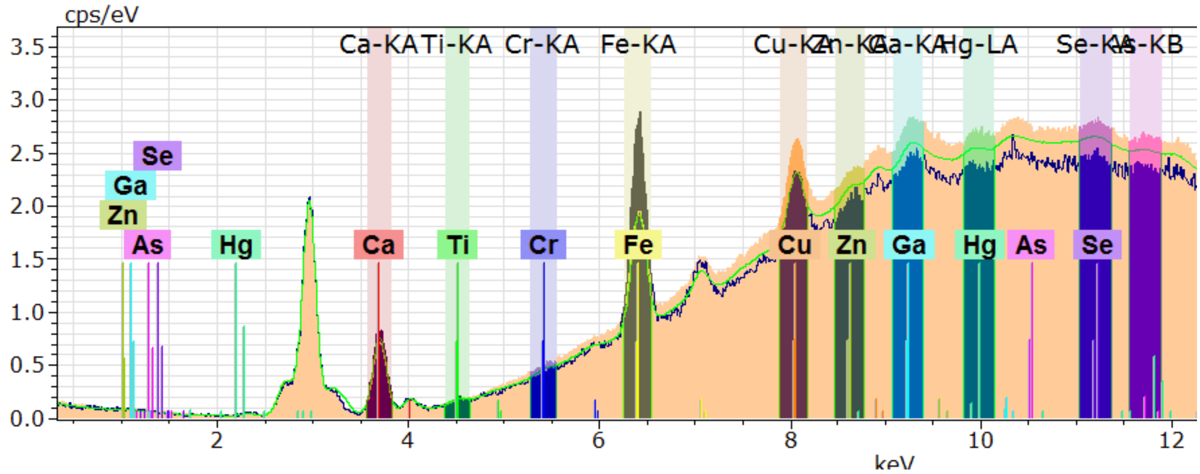
Figure 81-82: X-Ray Fluorescence image of object showing placements of mordants – calcium maps to red and black, iron to black only (INV2012-2-52)

Figure 83: INV2012-2-52 XRF Spectra for dark red parts vs background – shows presence of calcium, iron, copper and gallium



Source: INV2012-2-52, Winterthur Textile Collections

Figure 84: INV2012-2-52 XRF Spectra for dark blue parts vs background – shows presence of predominantly iron, no arsenic



Source: INV2012-2-52, Winterthur Textile Collections

Table 7: *Elemental analysis of select Indian cottons using XRF*

Object Id	*Place of origin*	*Date*	*Test*	*Method*	*Result*
1952.0163	India	Unknown	Elemental analysis	Mapping XRF	Iron and calcium detected in both blue and red areas. Peak height for calcium is higher in one red area; iron peak is higher in both blue areas. Further pigment analysis is necessary to elucidate elemental trends. No traces of arsenic.
1958.0610.003	India	1750-1775	Elemental analysis	Mapping XRF	Calcium maps to red colorant and black line; iron maps to black line only. No traces of arsenic
1969.904	India	Unknown	Elemental analysis	Mapping XRF	Calcium maps to red colorant and black line; iron maps to black line only. No traces of arsenic
INV2012-2-52	India	Unknown	Elemental analysis	Mapping XRF	Calcium maps to red colorant and black line; iron maps to black line only. No traces of arsenic

Table 7: Results of elemental analysis using a Bruker M6 Jetstream Instrument from Bruker. Tests conducted by Dr Rosie Grayburn.

The XRF elemental analysis shows clear use of mordants in Indian printed goods, with iron, calcium and aluminium showing strongly in areas where expected. Further, no traces of arsenic are found suggesting that it is unlikely that the orpiment technique travelled from Europe to India. Our knowledge of the existence of other pieces of painted Indian textiles around the world from as early as 12th century further negates this reverse transfer of knowledge hypothesis.

Having established that areas upon Indian cloth that were determined by curators as having been painted contained indigo but not arsenic, the next logical step is to determine what manner of re-oxidation reducing agent was used by Indian dyers to enable direct painting with indigo. For this purpose, destructive Gas Chromatography-Mass Spectrometry (GC-MS) analysis was conducted upon select areas of Indian painted blue cottons to test for presence of lime and/or honey as agents for delaying re-oxidisation.[445] Pre-existing frays and tears in the historic textiles were exploited to obtain samples for GC-MS investigations – no new tears or incisions were made.

Selected samples were tested through GC-MS instrumentation using the Hewlett-Packard 7820A gas chromatograph equipped with 5975 mass selective detector (MSD) and G4513A automatic liquid injector by Dr. Chris Petersen. The procedure looked for carbohydrates such as gums, starch, sugar and cellulose, and proteins such as hide glue, fish glue, egg-white and other comparable animal products.

Figure 85: Area of sample extraction (from natural fray in fabric) for GC-MS testing

Figure 86: Samples in vials for GC-MS

445 I am very grateful to Linda Eaton, Head of Collections at Winterthur Museum, Delaware, for putting me in touch with Michel Garcia, leading expert in historical natural dyeing techniques. Michel suggested we look for traces of honey and lime in areas of painted blue. The sugar in honey would be expected to reduce the indigo and lime would be expected to act as the alkali facilitating the action of the reducing agent.

Figure 87: GC-MS preparation for Object 1960.0781

Table 8: *Residue identification via Gas Chromatography – Mass Spectroscopy (GC-MS)*

Object id	*Place of origin*	*Date*	*Test*	*Method*	*Result*
1960.0786	India	1750	Residue identification	GC-MS	Inconclusive. Suspected not enough sample analysed; retest with more.
1960.0781	India	1827-1830	Residue identification	GC-MS	Inconclusive. Suspected not enough sample analysed; retest with more.
1952.0163	India	1725-1775	Residue identification	GC-MS	Inconclusive. Suspected not enough sample analysed; retest with more.

Table 8: Results of residue identification via Gas Chromatography – Mass Spectroscopy (GCMS) technique using Hewlett-Packard 7820A gas chromatograph equipped with 5975 mass selective detector (MSD) and G4513A automatic liquid injector. Test conducted by Dr Chris Petersen.

As Table 8 shows, the GC-MS tests were inconclusive owing to lack of adequate size of samples. Post-experiment discussions also focussed on the repeated washing of cloth involved in Indian printing and dyeing processes – it is likely that residues of any organic matter that may have been used have simply washed away leaving no discernible traces. Further tests and innovative methodologies of deciphering the dyestuffs related information hidden in these textiles are needed to prove conclusively the methods used by Indian artisans for painting directly with indigo on to cloth. It will help not only to resolve the existing incompatibility between the historiography of painting with indigo on cloth versus extant material evidence from Indian sources but also facilitate a better understanding of historical dyeing methods and the possibilities as well as limitations of knowledge transfer via the material route.

6.5 Colours and the Evolution of Calico Printing in Britain

The history of calico printing in Britain, as charted by historians focussing on the theme, includes the history of the evolution of dyestuffs and chemical textile colours as well as the changes in mechanical techniques for the application of these colours on to cloth.[446] This part of the study focuses on the evolution of colours using dyestuffs for use in the English calico industry. Did the introduction of Indian printed cottons stimulate the pursuit of colourfast dyes applicable to cottons? Does the material evidence show a trend from monochrome to polychrome?

One of the earliest attempts to systematically categorise different types of printed cotton textiles used the number of colours as the differentiating factor. Godfrey Smith, writing in his ambitious compilation of practical methods for the crafts, titled *The Laboratory or School of Arts*, published in 1799, notes that 5 different types of chintz or printed calicos were manufactured in England at the time. The first category is what Smith calls 'whole chintz', which incorporate three shades of red, two purples, blues, greens and yellows. On blending, these colours also offer crimson, orange, olive, buff, chocolate and other shades. As a combination of printing and painting (pencilling) was deployed to achieve this range of colours, according to Smith they 'appear upon the cloth like a curious painting.'[447] Alluding to the high quality of both cloth and printing of these 'whole chintz' Smith notes that '… chintz printed in England has, for art and beauty, surpassed any that has been brought from East Indies.'[448]

The second type of chintz or printed cotton fabric, according to Smith, was the 'half chintz', which was different from the 'whole chintz' in having only two shades of red and no purples.

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[446] Linda Eaton, *Printed Textiles*, p. 17, 127
[447] Godfrey Smith, *The Laboratory of School of Arts*, 1799, p. 52
[448] Ibid. p. 52

The third type of chintz was the ‘five colour chintz’ with one red, and a black outline for the remaining colours like blue, green and yellow. The fourth type was the ‘three coloured chintz’ patterned using only red, blue and black, or two purples and a blue. The last category of chintz, according to Smith, were the single purples, commonly depicting small flowers or sprigs.[449]

Smith’s categorisation based on increasing colours in printed cottons in England is indicative of the pursuit of an increasing variety of colours on cloth. His comparison to the quality and aesthetic of Indian chintz is suggestive of comparative learning from Indian printed and painted cottons.

Table 9: *Categorisation of printed chintz based on number of colours*

Type of Chintz	*Reds*	*Purples*	*Blues*	*Greens*	*Yellows*	*Black*	*Combinations (crimson, orange, olive, buff, chocolate, etc)*	*Total colours*
Whole Chintz	3	2	1-2	1-2	1-2		2	10-13
Half Chintz	2	0	1-2	1-2	1-2		1	6-9
Five Colour Chintz	1	0	1	1	1	1		5
Three colour Chintz 1	1	0	1	0	0	1	0	3
Three colour Chintz 2	0	2	1	0	0	0	0	3
Single Purples	0	1	0	0	0	0	0	1

Source: Godfrey Smith, *The Laboratory or School of Arts*, 1799

Textual evidence suggests that the imitations of Indian printed cottons in Britain and Europe spurred the growth of the empirical knowledge of natural textile dyes.[450] This enabled British manufacturers to print their goods in multiple colours and successfully create polychrome cotton products that could withstand repeated washing. In order to test this assessment, I construct a database of British cotton textiles from 1720-1860, tracking the number of colours used on cotton textiles over the time period.

[449] Ibid. p. 53
[450] Previous p. 156-158

6.5.1 Data and Methodology

The material evidence for tracking the colours used in British printed cottons from 1720-1860 was obtained by studying English printed cottons in the textile collections at Winterthur Museum, Delaware, USA. These comprise individual samples of printed cotton textiles manufactured in England or Scotland, acquired by Henry Francis DuPont for his personal use and as collectibles by the museum over time.[451] In all, 489 textiles currently form part of the database.

Any museum collection as a source suffers from inherent selection as well as survival bias. Textiles collected for personal consumption in his family home by Henry Francis DuPont are undoubtedly influenced by his taste, preferences and affordability. They are not representative of the cheaper textiles consumed by the general populations in England or overseas. In addition, those textiles that have not withstood well the handling of human hands and passage of time are lost to us permanently, and hence, are also missing from this database.

Despite these limitations, the data provided by these collections offers worthwhile insights for the purpose of this research. Selection bias is uniform for both English and Indian textiles. Survival bias is likely to be a problem with Indian textiles more than the English, merely by virtue of vintage, and is therefore, unlikely to bias the results in favour of Indian textiles. Some colours, such as a yellow obtained by safflower, are expected to have faded equally from any pattern that deployed them, whether English or Indian.

For such an exercise to be meaningful and representative, two parameters must be decisively ascertained – the original place of manufacture and the date of manufacture. As mentioned above, only textiles made in England or Scotland have been included in this database. This includes textiles where curators have placed England as the first potential place of manufacture. Further, only textiles with a date or a date range, pre-determined by museum curators, have been included in the database with a view to charting colours used over time.

Some textiles in the database come with information related to the printing houses they were printed in and exact dates. Not all textiles supply this information. In places where the year of manufacture is not available, it is common practise for curators and conservationists to supply

[451] Eaton, *Printed Textiles*, p. 13

an indicative date range. This date range can vary, from two to five years to a few decades. In cases with date ranges, the mid-point has been determined and applied. Where the mid-point is a decimal, the previous whole has been applied. For instance, for a textile with the date range of 1780-1820, 1800 is the applied date. For one with a supplied date range of 1835-1840, 1837 is used as the applied date.

In order to determine the colour count as clearly as possible, different shades of colours have been individually recorded, such as light pink, pink and red. Textiles where two shades of blue have been obtained via two separate phases of resist application are recorded as two distinct shades. Black outlines have been recorded as a separate colour. Combination shades like orange and olive are recorded as such.

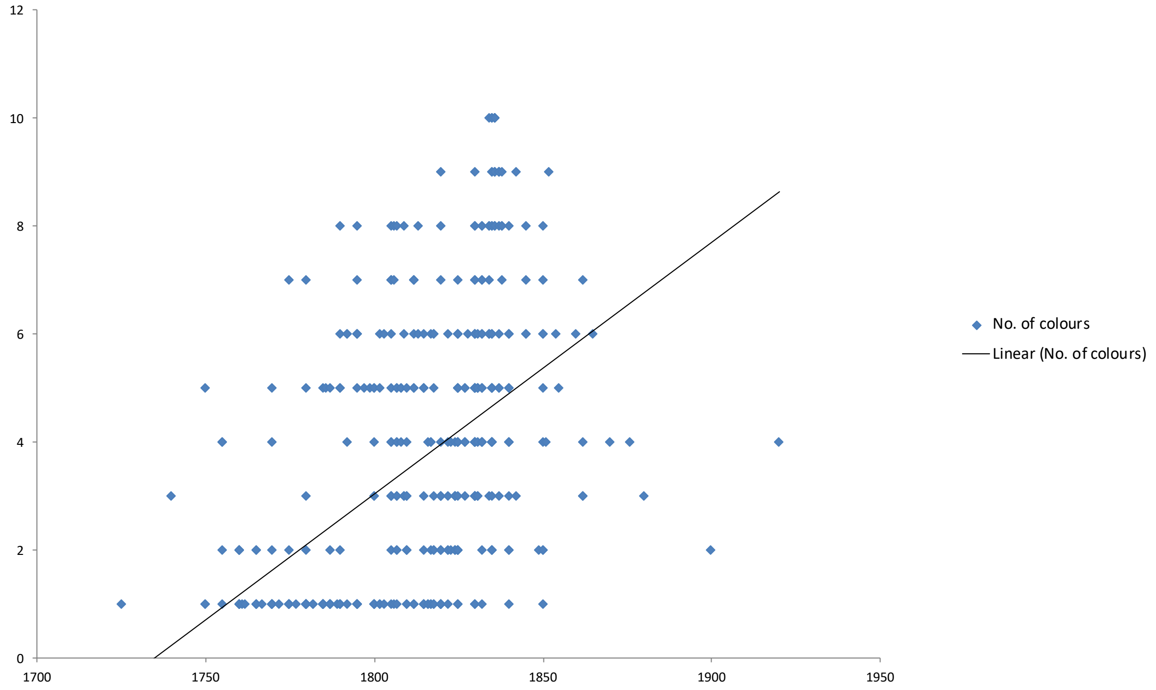
Godfrey's categorisation of chintz is used as the guiding format for the task of charting chintz colours over time. Going by his classification, the database should reveal printed textiles of a variety of colour combinations over time, allowing us to see at what time in history a new set of colours, underpinned by advances in technical knowledge, are first visible. The expectation is that by the end of the 18th century, we should see 'whole chintzes', with ten or more colours, in the collection of English textiles.

6.5.2 Evolution of Colours in English Printed Cottons

An analysis of data obtained from the English printed textiles database shows a decided growth in the number of colours used to print cotton textiles from 1720-1860. Findings show a clear evolution from monochrome to polychrome, even as calicos made of single and fewer colours continued to be manufactured, and popularly consumed, alongside multi-coloured 'whole chintz'.[452] This effectively means a wider range of printed textiles was manufactured over the time period.

[452] Smith, *The Laboratory*, p. 52; Eaton, *Printed Textiles*, p. 127

Figure 88: Evolution of number of colours in English printed cottons 1725-1860



Source: Textile Collections, Winterthur Museum, Delaware, USA

This data does not show any 'whole chintz', as described by Smith, manufactured in England in the 18th century; the earliest is from 1834. This could be a result of selection bias in the way the textiles have been collected or/and a case of exaggeration of the variety of colours displayed together on English printed textiles on Smith's part. Further, one key criterion for a 'whole chintz' according to Smith is the use of the colour purple.[453] Purple first appears in the data in 1824 in a three-coloured roller printed fabric alongside brown and yellow.[454]

The earliest English textile in the database is a printed fabric with uniform blue chevrons, with a date range of 1720-1730. The simple monochrome repeat is achieved though block printing. From 1740 onwards, tricolour calicos began to be printed in England, going up to five colours by 1750, seven by 1775 and eight by 1790. The highest numbers of colours on English textiles in this database are nine and ten, from 1820 and 1834 respectively. These are, effectively, the material manifestations of sequential technological advancements that enabled simultaneous printing with an increasing number of multiple colours on cloth. These newest products of their

[453] Smith, *The Laboratory*, p. 52
[454] Winterthur Textiles Collections Object Id W/1959.0084.002

times not only represented novelty and choice for the consumers but also extensions of the limits of technical and mechanical possibilities for designers and entrepreneurs.

Figure 89: W/1960.0248, 1 colour

A closer look at the data reveals useful details of each of the printed products that were innovative for their time, each representing a new technological frontier. The first tricolour from 1740 is a unique piece of textile history comprising a double pocket made from coarse cotton woven of unevenly spun yarn, with a thread count of 107 threads per inch. The fabric is block printed with red and brown as the main colours; black is used for outlining the motifs.

Figure 90: W/1969.3102, 3 colours

The first five-coloured printed textile in this database is from 1750. It is spun with coarse yarn with a linen warp and cotton weft; the fabric's thread count is 115. Pink, red, blue, pale brown and dark brown are block printed alongside blue, which has been applied using the pencilling technique.[455]

Figure 91: W/1969.3254, 5 colours

Seven colours for printed cottons are first witnessed towards the end of the third quarter of the 19th century. This is an arborescent design, block printed in around 1775 on an all-cotton fabric, with a thread count of 149 threads per inch. Light pink, dark pink, red, light brown, dark brown, blue and black are used to create a floral pattern with bold, meandering branches and exotic fruits and flowers. This particular pattern, with peonies and pomegranates, is strongly reminiscent of hand-painted tree of life designs on Indian cottons. According to Eaton, arborescent designs were created in imitation of flowering tree patterns from India.[456]

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[455] Eaton, *Printed Textiles*, p. 158

[456] Ibid. p. 206

Figure 92: W/1969.3248.002, 7 colours

A dark-based dress fabric from 1790 is the first to display eight colours. Light pink, dark pink, red, yellow, light brown, green and blue are used to create a small floral pattern on a dark brown base. According to Eaton, such a base and pattern would have been fashionable in the 1790s, as it required less washing.[457]

Figure 93: W/2009.0015.001, 8 colours

The data shows that from about the middle of the first quarter of the 19th century, nine-coloured chintz begin to be manufactured in England. The piece from this database is a block-printed design from about 1820, created using pink, red, yellow, orange, pale brown, brown, black,

[457] Eaton, *Printed Textiles*, p. 221

green and blue. The design is produced on a fine all-cotton cloth with a thread count of 192. According to Eaton, a piece such as this would probably have been created for use as the centre of a patchwork quilt.[458]

Figure 94: W/1961.0025, 9 colours

The first 'whole chintz' of ten colours, to use Smith's terminology, is a roller printed polychrome fabric from 1834. A complex design with flowers and lace is created on an all-cotton fabric with a thread count of 179, using acid green, olive green, yellow, orange, red, pink, brown, blue, purple and black. This is not the first appearance of the colour purple in the database.[459] According to Eaton, the intricate shading and colours of this design are achieved by using at least three cylinders, in addition to blocks or surface rollers.[460]

[458] Eaton, *Printed Textiles*, p. 249
[459] The first piece with purple as part of the print is from 1824, where purple is deployed alongside brown and yellow using rollers. Object id 1959.0084.002, Winterthur Collections
[460] Eaton, *Printed Textiles*, p. 313

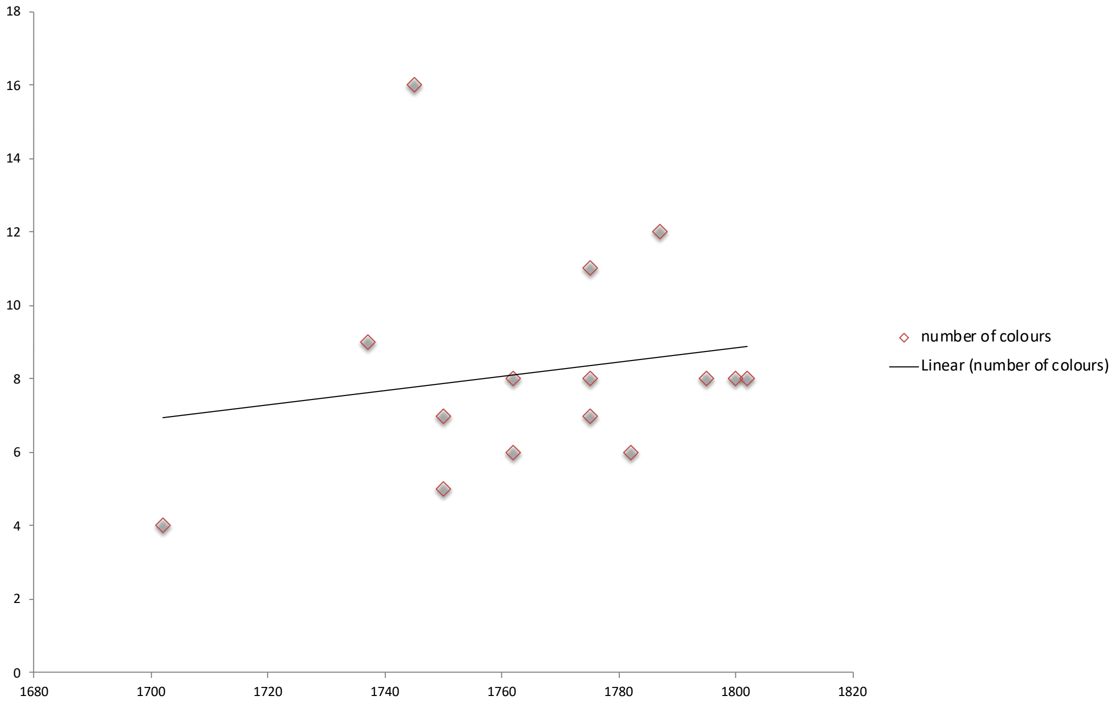
Figure 95: W/1959.0084.037, 10 colours

6.5.3 Colours in Indian Printed and Painted Textiles

In order to be able to comparatively assess the English and Indian use of colours in printed cottons, I conduct a similar exercise for Indian printed and painted textiles in the Winterthur Collections. Since the number of colours has been identified as a measure of printed cotton quality in this research, this exercise is expected to show a comparable measure of colours in Indian textiles for the same time period.

The numbers of Indian printed textiles that have survived in museum collections are far fewer than their English and European counterparts. Out of a total of 55 Indian textile objects in the Winterthur textile collections, 19 are identified as printed and/or painted cotton textiles, and therefore suitable for this project. The date ranges for these textiles are vast, primarily because of the difficulty in establishing dates owing to the lack of knowledge/evidence of key local techniques used by Indian artisans for achieving distinct colours.

Figure 96: Number of colours on Indian printed and painted textiles, 1700-1820



Source: Textile Collections, Winterthur Museum, Delaware, USA

Data on the use of colours in Indian textiles shows that Indian artisans were printing in a variety of colour combinations since at least the early 18th century. Bearing in mind again that the number of observations is fewer than the English numbers and also that these textiles were likely, in part, selected for their colourful appeal, the surviving evidence, nevertheless, strongly suggests a flatter evolution, if any, in the number of colours used over time. When read in conjunction with textual evidence, it is clear that the design imperatives - and not the ability, or otherwise, related to the technicality of applying a colour on to cloth - determined the palette of an Indian printed/painted cotton. There does not appear to be any sequential increase of colours used for printing and/or painting – it is possible that such an evolutionary increase in the printer/painter's palette did take place earlier in Indian textile history but the evidence under investigation is insufficient to throw any light upon such a potential evolution.

The lowest colour count of an Indian printed textile is from a popular Mughal poppy motif-based print, with a supplied date range of 1675-1750 and an applied date of 1702. Evidence suggests that this textile might be from an even earlier date. Similar textiles at the Metropolitan Museum in New York and the Victoria and Albert Museum in London are dated as having been made in the 17th century.[461] Upon closer examination, the four-coloured design is achieved via mordant-based block printing and painting using pink, red, light blue and dark blue. The cloth is all-cotton with a thread count of 152.

Figure 97: W/1969.3186A, 4 colours

A painted palampore[462] from 1737 (date range 1700-1775) is created using nine colours. Pink, red, light blue, dark blue, yellow, pale brown, light brown, dark brown and black are used on a fine cotton with a thread count of 171 yarns per inch to create a floral, tree-of-life style design.

Figure 98: W/1960.0785.001, 9 colours

[461] https://www.metmuseum.org/blogs/ruminations/2015/from-the-ground-up, http://collections.vam.ac.uk/item/O1191442/floorspread-unknown/ both assessed 19 July 2021

[462] The word 'palampore' originates from the Hindustani word 'palang-posh' meaning bed cover. Mattiebelle Gittinger, *Master Dyers to the World*, p. 198

Out of the 16 Indian textiles with a supplied date range, three are ‘whole chintz’ made with ten colours or more. From 1775, this hand-painted design on a fine cotton cloth with a thread count of 235 threads per inch uses 11 colours to create the intricate design. Pink, red, light brown, dark brown, green, olive, purple, dark purple, blue and black are used to create this ‘whole chintz’.

Figure 99: W/1960.0018.002, 11 colours

Another ‘whole chintz’ from 1787 uses 12 different colours. Light blue, grey-blue, blue, pale pink, pink, light red, red, purple, brown, olive, deep purple and black are used on a fine cotton cloth with a thread count of 213.

Figure 100: W/1958.0072.011, 12 colours

The ‘whole chintz’ with the largest number of colours displays a staggering 16 shades. Pale pink, pink, dark pink, red, yellow, light blue, dark blue, light green, dark green, orange, light brown, dark brown, light purple, dark purple, maroon and black are used to create the design on a fine cotton cloth with a thread count of 205. The date range ascribed to this chintz is 1730-

1760, yet there is no consensus on this range. The lack of consensus stems from the blue used in the design. The blue is ostensibly painted on to the cloth, yet according to the literature on the history of dyestuffs, Indian artisans could not paint with blue directly on to the cloth during this period.[463] This textile brings into sharp focus how our present historiography of the evolution of dyestuffs does not quite square with the material evidence. The problem of dating this textile is fundamentally connected to our understanding of the global history of dyestuffs. This textile was not studied via the X-Ray Fluorescence technique due to its large size and risks involved in safely mounting it for XRF analysis. As the textile is in pristine condition exhibiting no pre-existing tears or frays, GC-MS analysis was also not undertaken on this sample.

Figure 101: W/1957.1290, 16 colours

Upon closer examination, in the process of counting the colours on this textile, I identified three tiny, easily missed stray brushstrokes in blue. Stray brushstrokes may be 'read' as spillage, as part of the process of painting. One step of the four-step checklist for visual examination of a textile to determine whether it is painted or not is the existence, or otherwise, of brushstrokes of the kind produced by the use of brush/kalam for direct painting. The existence of intended as well as unintended brushstrokes, especially in blue, lends weight to the curators' assessment that this is a painted textile with the blue also painted directly on to the cloth.

[463] I am extremely grateful to Linda Eaton at Winterthur Museum for discussing the issue of dating this textile with me. If this textile is to be dated as pre-1740 then it would mean that Indian artisans could paint blue directly on to the cloth, something that is contrary to current historiography. If the textile is dated as post-1740 then there is the possibility of reverse transfer of knowledge from England to India pertaining to the arsenic technique of pencil blue. In that scenario, we should find arsenic on the cloth. XRF was not conducted on this textile but evidence from other Indian textiles studied under XRF shows no presence of arsenic.

Figure 102: W/1957.1290, arrow pointing at stray blue brushstroke

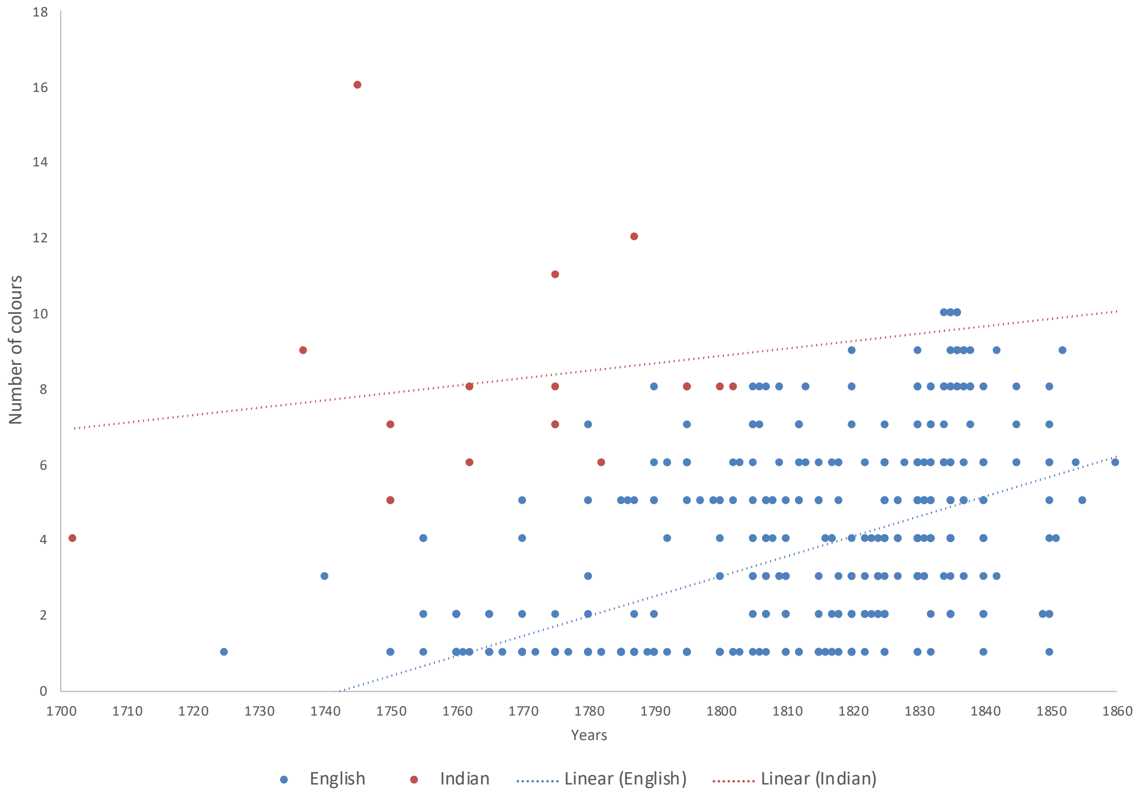
Figure 103: W/1957.1290, arrows pointing at stray blue brushstrokes

This particular textile is also interesting because it displays not only an extraordinary range of colours but also, more specifically, the colour purple. The earliest purple in the English set of printed textiles is from 1824. Purple was a much sought-after but expensive colour, obtained in the pre-industrial period through two main sources in Europe – Tyrian purple from a mollusc and Orchil, a species of lichen. The discovery of a synthetic colour purple in 1856 was a significant instance of scientific and technical advancement in the chemical science of dyestuffs, aimed at increasing the repertoire of dye colours for the calico industry as well as comprising a major breakthrough in the systematization and scientification of the study of dyestuffs.

6.5.4 Comparative Analysis

In order to undertake a comparative analysis of English and Indian printed calicos, I chart the colours of the two sets of printed textiles together to observe their chromatic evolution.

Figure 104: Comparison of Colours - British Vs Indian Calicos, 1700 to 1860



Source: Winterthur textile collections, Indian and British printed and painted cotton textiles, 1700-1860

Comparing the colours used in English and Indian printed and painted cottons from 1700-1860 reveals a significant increase in the number of colours used to make English calicos versus the many colours visible on Indian calicos from much earlier. The chart clearly demonstrates that Indian artisans were able to use more colours in order to create their designs. Since the measure of colours on the cloth is a measure of the print quality of the cloth, it may be concluded that Indian calicos were made of a higher print quality. The evolution of the colour palettes of the British calico printers may be seen as an imitative response to match the quality of the benchmark printed cottons of the period. The data shows that, over time, the British calico colours tended to converge with Indian polychrome textiles.

The total number of 'whole chintz' in the database, with ten or more colours, is 11. Out of these, 8 are English, made between 1834 and 1836, using 10 colours each. The three Indian 'whole chintz', as discussed earlier, are from 1745, 1775 and 1787 with 16, 11 and 12 colours respectively. The material evidence suggests that Indian printed and painted cottons were made using several different dyes with the printers able to achieve a variety of shades using local techniques involving mordants. The English calico industry, which began by imitating the Indian printed goods, evolved from fewer colours to several in a matter of just over a century, via the process of imitating the Indian products and learning from this imitation.

6.6 Conclusion

This chapter has used textual sources to demonstrate that Indian printed and painted cottons were imitated soon after introduction in England. Direct knowledge transfer of Indian techniques used for printing and dyeing were readily disseminated amongst the English population. The process of imitation led to the development of the dyestuffs industry with technical and scientific knowledge pertaining to it, effectively allowing the print quality of English calicos to improve over time. The material evidence supports the findings from the textual sources to show that Indian artisans were printing/painting 'whole chintz' at the latest by the first half of the 18th century and that English calico printing evolved from monochrome to polychrome, to match the print quality of the benchmark products from India.

This evolutionary analysis of colours in English and Indian calico history has also raised a significant question regarding our understanding of the global history of dyestuffs. It is based upon a handful of often-cited sources, which are themselves based on a mix of unstable evidence and conjecture. More scientific investigations are required to establish the robustness of current historiographical claims as well as challenges to them if we are to have a reliable understanding of the history of dyestuffs for calico printing.

Chapter 7: Evolution of Calico Printing in Britain: Impact of Indian Printing Techniques

Abstract

This chapter demonstrates that the imitation of Indian printed cottons was made possible through the imitation of the Indian printing and dyeing techniques and their adaptations to suit local conditions and resources in Britain. It shows that the Turkey red process of dyeing red was developed in imitation of the Indian Chay root process of dyeing red and adapted to the use of locally available dyeing materials. It shows the knowledge related to Indian printing and dyeing techniques was diffused through the increasing supply of dye manuals from 1760 onwards. Further, it highlights an intersection and overlap between the artisanal dyeing techniques transferred from India and the growth of the science of chemical dyes.

7.1 Introduction

The material evolution of colours in the British calico printing industry suggests that it evolved from monochrome to polychrome to converge with the number of colours on Indian printed and painted calicoes. This chapter asks two further questions. First, did the diffusion of textile printing and dyeing knowledge from India among British printers and dyers lead to the growth of calico printing and dyeing knowledge in Britain through enhanced learning and knowledge accumulation? Second, were British calico printing and dyeing techniques and practical methods of dyeing cotton textiles influenced by the Indian textile printing traditions? This chapter connects the nascent development of knowledge of dyestuffs within the British calico industry in the 18th and 19th centuries to the codified transfer of knowledge from India via Europe. It charts the diffusion of knowledge of printing and dyeing skills by tracing the evolution of dye manuals in Britain in the 18th and 19th centuries. Further, it shows path dependence upon Indian dyeing techniques in the development of empirical dyeing techniques in Britain through the example of the Turkey red dyeing process. It also highlights an overlap of inspirational stimulus from Indian dyes and empirical techniques on the separately and parallelly evolving branch of the chemical science of dyestuffs.

This chapter argues that the technology of printing on cotton fabrics was substantially influenced by the benchmark product, Indian cottons. New dyestuffs were introduced into Europe directly from India or via Turkey or through the Mediterranean trade routes. These dyestuffs were introduced both in the form of raw materials as well as finished products, as printed, painted and dyed ornamentations on cotton cloth. The process of turning the raw dyestuff into wash-proof patterns on cloth involved the knowledge, skill and experience of the Indian printer artisan. I argue that the imitation of Indian printed and painted textiles enabled the transfer of this skill to European and British printers via learning by doing. The trial-and-error method of learning, aided by codified knowledge transfer from India and facilitated by the existence of the comparator benchmark product, allowed for the development of the empirical techniques of textile dyeing. I further argue, that unlike the relatively 'quick' adaptation of cotton spinning via mechanisation, techniques related to the development and application of dyes remained mainly in line with the Indian techniques until the late 19th century, owing largely to the widespread adaptation of Indian techniques of printing and dyeing as well as because of the late development of the science of chemistry in Europe. Empirical knowledge and expertise related to cotton printing and dyeing intersected and overlapped with the science of chemistry and within it the science of chemical dyes.

Ornamentation of textiles using printing and dyeing techniques have historically been activities that have required great skill and expertise. They are also complex, multi-phased activities, with each phase calling for a distinct set of knowledge and appropriate expertise. As discussed earlier in Chapter 6, technology related to calico printing may be broadly divided into two distinct sub-sets. The first relates to the chemistry of dyestuffs and their combinations with various metallic mordants, to enable the application of viable dyes in various colours on to fabric. It comprises the knowledge required - empirical or scientific – related to the dye material and its successful attachment to the cloth, often with the help of other additional substances. The second relates to the actual process of application, using tools that are specifically designed to enable efficient and appropriate application of the dyes. These comprise the blocks or rollers or *kalam* (paint brush), i.e., the tools for application of the dye to the cloth. This chapter addresses the first sub-set of calico printing, pertaining to the evolution of dyestuffs in the calico printing industry in Britain in the 18th century.

Unlike cotton spinning, cotton printing and dyeing have received relatively scant attention from economic historians. Literature on the growth of dyestuffs within the British calico industry has, however, evolved significantly from a predominantly British perspective to a more

European perspective.[464] As discussed in Chapter 3, new dye products and printing processes from India, both through codified knowledge transfer and via the products that contained the dyes as decorative ornamentation acting as prototypes, stimulated the printing and dyeing industries in European and Britain. The example of French manuscripts detailing the transfer of knowledge related to cotton printing, dyeing and painting shows a clear pathway to the accumulation and use of this knowledge in Europe and Britain. According to Clow, 'During the industrial revolution much of the expansion of the chemical industry was indeed conditioned by the prodigious growth of the textile industry.'[465] How may we discern the evidence of this codified and material knowledge transfer related to calico printing and dyeing? Comparing the Turkey red technique to the Indian Chay root technique of obtaining the colour red, I show path dependence upon Indian dyeing techniques through their imitation and adaptations. Using a database of printed and published dye manuals, I trace the dissemination of codified knowledge related to printing and dyeing techniques. Finally, using digital text analysis, I show the evolution of the dyer from printer-artisan to chemist.

The rest of the chapter shows the impact of the spontaneous imitative response by the European and British printers to the introduction of Indian printed and painted cottons within their domestic settings. Part two offers a brief overview of the history of dyestuffs. Part three assesses the impact of Indian dyeing techniques by comparing the Turkey red method of dyeing red against the Indian Chay root technique of obtaining red on cotton to test for similarities and differences. Part four undertakes a chronological tracking of dye manuals and digital text analysis to trace the diffusion of knowledge hypothesis and to track the shift from artisanal to chemical-scientific mode of dyeing practices. Part four undertakes digital text analysis of Berthollet's *Elements de L'Art de la Teinture* as well as re-assessment of Perkin's discovery of aniline purple to discern the evolution of the printer dyer from artist to chemist. Part six concludes.

[464] For a British perspective, see P.C. Floud, Origins of English Calico Printing; For a European perspective, see Irwin and Schwartz, *Studies in Indo-European Textile History*; Chapman and Chassange, *European Textile Printers in the Eighteenth Century*; Riello, *Cotton*

[465] A. and N.L. Clow, The Chemical Industry: Interactions with the Industrial Revolution, in Singer, Holmyard, Hall and Williams (eds) *A History of Technology*, Vol IV, p. 256

7.2 A Brief History of Dyestuffs and Textile Dyeing

The history of dyestuffs resides within the history of chemistry as a subset of the main discipline. Decoration of fabrics using natural colouring agents has been practised since antiquity. The methods of application of these natural dyes were the same in Europe as those developed in the East and which passed westwards through Egypt and Greece.[466]

Textile colouring agents fall in two broad categories – pigments and dyes. Pigments are colouring agents that stay on the surface of the textile. These are applied usually with the help of a binding agent, often resinous, and not wash resistant. Dyes, on the other hand, are colouring agents that penetrate the textile material that they are applied to.[467] This adhesion happens largely through a process known as mordanting, where a metallic salt is applied during the process of printing or dyeing, enabling the dye to attach to or 'bite' into the cloth – the word mordant comes from the French word 'mordre' meaning 'to bite'.[468]

The dyer's craft in the pre-industrial period in Europe, has been variously described as highly technical, involving valuable expertise, such that it was common for the processes involved to be kept trade-secrets.[469] Yet, the colours were largely not fast despite the use of some mordants, mostly of alum.[470] Printed ornamentation was undertaken for textiles used for wall decorations, such as hangings, which did not require repeated washing.[471] Blacks were derived from gall extracts combined with iron sulphate, blues from indigo from India or woad from Europe through a vat-dip method of whole cloth/resist dyeing, yellows through weld mordanted with alum, and greens with a combination of weld and woad/indigo.[472]

Two other significant colours, red and purple, continued to elude successful application on to cotton until the end of the 18th century and the middle of the 19th century respectively. Both

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[466] Peter Morris and Anthony Travis, A History of the International Dyestuffs industry, *American Dyestuff Reporter*, November 1992, p. 59-60
[467] Taylor and Singer, Pre-Scientific Industrial Chemistry, in *History of Technology*, Vol II, p. 359
[468] A. and N.L. Clow, The Chemical Industry: Interaction with the Industrial Revolution, in, *History of Technology*, Vol. IV, p. 256
[469] Taylor and Singer, Pre-Scientific Industrial Chemistry, p. 364
[470] Ibid
[471] P.J. Thomas, The Beginnings of Calico Printing in England, *The English Historical Review*, Vol. 39, No. 154, April 1924, p. 206-216
[472] Ibid. 364-366; Derry and Williams 266-267

were important colours that appeared on Indian chintz in a variety of shades and hues. Both were critical for the creation of a 'whole chintz' as categorised by Godfrey Smith.[473]

Several natural sources of red for textile dyeing existed in pre-industrial Europe. A species of 'coccus' insects like kermes, cochineal or lac were variously used for textile.[474] Redwoods such as Brazilwood and Sappanwood were added to the repertoire of red dyes from the Middle Ages.[475] However, the main source of the colour red, in its various shades from rose to crimson, was madder. Madder is obtained from Rubia peregrina, Rubia tinctorum or Rubia cordifolia of the Rubia species of plants. The Rubia species are native to many regions of the Old World, from Japan and China on one end to France and the Netherlands on the other, stretching to the east and west coasts of Africa, South America and the Northern parts of Australia.[476] In the Asian subcontinent, it was cultivated extensively in the northern parts, especially Sindh and Kashmir, alongside other varieties such as munjeet and Naga madder.[477] The main chemical colouring matters in madder are alizarin and purpurin. Alongside alizarin and purpurin, xanthopurpurin, pseudopurpurin, rubiadin and munjistin are also present in madder.[478]

Indigenous to parts of coastal South India was an entirely different dyestuff known as Chay. This is Oldenlandia umbellate in Latin or Chayaver in Malayalam, Chirval in Hindi, Surbuli in Bengali and Chiruver in Tamil. The French called it Chay or Chay root and that became its popular name in the West. The only significant colouring matter in Chay root is alizarin; it does not contain any of the other additional components like madder.[479] This is a key distinction between madder and Chay which allows scientific examination of the dyestuff on historic textiles today to ascertain which dye was used. Indian artisans used Chay effectively to achieve the deepest true reds on cotton cloth, prized for the tone and uniformity of colour dispersion. These reds were colourfast and withstood weathering through time remarkably well – some of them still exist in their vivid red hues in museum collections around the world despite having undergone repeated washing and exposure to the elements. While madder provides various

[473] Previous p. 168-169
[474] Taylor and Singer, pre-scientific, p. 366-367; Judith H. Hofenk de Graaf, *The Colourful Past: Origins, Chemistry and Identification of Natural Dyes*, Abegg-Stiftung and Archetype Publications, Switzerland and London, 2004, p. 52-85
[475] Cardon, *Natural Dyes*, p. 274-283; de Graaf, *The Colourful Past,* 140-158
[476] Cardon, *Natural Dyes,* p. 122-129
[477] Ibid. p. 129-134
[478] De Graaf, *The Colourful Past*, p. 90-91
[479] Cardon, *Natural Dyes*, p. 138-139

shades of deep reds, the intensity and deep tones of Chay reds made them exceptionally prized and may be seen as the highest 'quality' of reds.

Indian processes of dyeing with Chay involved complex phases of treatments of cloth with a variety of substances, such as oleaginous buffalo's milk, extracts of myrobalan galls and other organic substances, including a diverse combination of mordants for different shades of red.[480] Further, the use of hard water or addition of chalk to the dye mix by Indian dyers has been corroborated by recent scientific research which points out that alizarin, aluminium and calcium form complexes with cellulose, effectively allowing the dye to attach firmly to the cloth.[481]

Such an empirical understanding of the relationship between dyestuffs, mordants, other organic additives and the cotton cloth was only beginning to develop in Europe with the introduction of Indian printed cottons in the 17th century. Madder, despite being indigenous to Europe, including Turkey and the Middle East, was a complex dyestuff to work with. Pre-industrial European dyers had substantial experience of working with madder for wool, silk and linen dyeing, but not with cotton. Mordanting was practised, especially alongside alum and tin salts, to enable fixing of the dye to the cloth. Despite the skill and expertise involved in dyeing, the colours were not fast. Evidence suggests that early imitations of Indian cottons were made using pigments which could not withstand washing.[482]

The brilliance of the red resulting from Chay was well-noticed in Europe and Britain upon the introduction of Indian printed and painted chintz.[483] However, Chay was a novel dye for the European dyers, who had no previous experience in working with it. Evidence suggests that early attempts to understand the use of Chay by Indian dyers was done in the language of madder – Chay was seen as a superior version of madder. Jean Ryhiner, who has been mentioned before in connection with the codified transfer of knowledge of printing techniques from India through the three French manuscripts, noted in 1766 that the difference in the quality

[480] Coeurdoux Letters, in Irwin and Schwartz, *Studies in Indo-European Textile History*, p. 109-111
[481] Cardon, *Natural Dyes*, p. 139
[482] G.P. Baker, East Indian Hand-Painted Calicoes of the Seventeenth and Eighteenth Centuries and their Influence on the Tinctorial Arts of Europe, *Journal of the Royal Society of Arts,* Vol. LXIV, No. 3313, 1916, p. 482-492
[483] Bancroft, *Experimental Researches*, p. 284

of Indian red and European red was a result of the superiority of ‘this species of madder’ over the European madder.[484]

Early attempts were made to replicate the use of Chay for the achievement of brilliant reds on cotton, but with little success. Bancroft refers to the importation of Chay from India into France by the French East India Company in 1774.[485] Attempts were also made to grow the plant in France in the 1760s.[486] There is at least one piece of evidence of a high profile, high quality print by Oberkampf of Jouy as having been completed using Chay, indicating successful trials of Chay in Europe. According to Taylor, a 1789 print in the Whitworth Art Gallery called ‘Louis XVI, Restaurateur de la Liberté’ was tested in 1991 using thin-layer chromatography (TLC). It revealed that the dye contained only alizarin. For the dye to be madder, purpurin or pseudopurpurin must also be present. Since synthetic alizarin was not developed until the second half of the 19th century, it was concluded that the Jouy print was made of Chay. According to Cardon, ‘By experimenting with this exotic red dyestuff composed of concentrated natural alizarin, he [Oberkampf] was already on the track which chemists were to follow during much of the 19th century, when they worked, first at isolating alizarin from dyer’s madder roots and then at synthesising it, thus attempting to reproduce what nature had accomplished in the Chay root.’[487]

Bancroft himself experimented with Chay obtained by him through his acquaintance William Roxburgh, who was in India at that time.[488] Successive experimentations were only partially successful and he held the deteriorating quality of the dyestuff during transportation to be responsible for the mixed success of the experiments.[489] It is interesting, however, that Oberkampf was successful in his experiments with Chay in France, unlike Bancroft in England, despite both having obtained the dyestuff from India. However, despite his success with the dye, Oberkampf did not use it in his subsequent re-prints of the pattern; he resorted to the more common madder in later repeats of the print.[490]

484 Jean Ryhiner, 1766 quoted in Cardon, *Natural Dyes*, p. 139
485 Bancroft, *Experimental Researches*, Vol 1, p. 264-5; Vol II, p. 184, 211, 223-225
486 Cardon, *Natural Dyes*, p. 142
487 Cardon, *Natural Dyes*, p. 143
488 Bancroft, *Experimental Researches*, p. 298-303
489 Ibid
490 George W. Taylor, A Jouy Calico Print using Chay Root, *Dyes in History and Archaeology*, No. 9, 1990, p. 33

As discussed previously, Bancroft highlighted two aspects related to Turkey red dyeing. First, he clarified that the Turkey Red process of dyeing came from India via Turkey. Second, he emphasised that the Turkey Red method was an attempt to imitate the Chay reds of India.[491] Therefore, within the Turkey red process of dyeing reside the twin connections of imitation of a colour from an Indian dye material (Chay) and the adaptation of the processes involved in Indian dyeing methods.

7.3 Indian Dyeing Techniques and British Calico Printing

Were British calico printing techniques of the 18th and 19th centuries related to the old Indian cotton printing and dyeing techniques? Did imitations of Indian textile printing techniques lead to the adaptation of Indian printing methods within British calico printing? Evidence suggests that imitations of Indian cotton printing methods were responsible for the development of the Turkey Red method of dyeing and printing cloth red. There appears to be widespread acceptance within recent writings in textile history and the history of dyes that the Turkey Red process had its origins in India. According to Cardon, the knowledge of dyeing cotton spread westwards from India up to the Ottoman Empire. From there, it reached Europe, known as 'Turkey red (originally India red) or Edirne red after the Turkish town Edirne (Adrianopolis of the ancient world).'[492]

The early-modern timing of the Turkey red technique's adoption in Europe and Britain also strongly hints at connections to the Indian Chay red process as the two were roughly contemporaneous. According to Cardon, the knowledge of the process of Turkey red dyeing was brought into France from Smyrna in 1746 by Greek dyers, resulting in the setting up of Turkey red dyeworks at Darnetal near Rouen, Aubenas in Languedoc, Nimes and Saint-Chamond near Lyons. Before long, dyeworks spread across Germany, Switzerland, France and Sweden. The technique was brought to Britain in 1784 by Louis and Abraham Henri Borelle. In 1785, Frenchman Pierre-Jaques Papillon introduced Turkey dyeing methods in Scotland at the dyeworks of George Mackintosh and David Dale at Dalmarnock near Glasgow.[493] The enterprise gained fame for making bandanas or pulllicates, named after a town on the

[491] Previous p. 158
[492] Cardon, *Natural Dyes*, p. 116
[493] Ibid, 117

Coromandel Coast of Southern India.[494] High quality red on cottons was only possible with this labour-intensive and multi-phased Turkey red technique.[495]

As discussed earlier, the Turkey red method of dying a true red was brought by Greek dyers from the Ottoman, where the technique was developed to imitate the true red of Indian Chay root but by using madder. Was the Turkey red method of dyeing and printing of cotton substantially different from the Indian Chay red method set out in the French texts compiled in the 18th century? What did this widely noted 'spread' of knowledge from India to Britain, via Turkey, look like? If Bancroft and others are correct in saying that the Turkey red method was developed in imitation of the Indian Chay red method, then we should see similarities in the processes. If it is substantially different then clear distinctions must be visible.

I conducted a comparative analysis of the Turkey red dyeing technique versus the Indian Chay root dyeing technique. As sources, the following analysis uses the method deployed in Scotland as enunciated by Stana Nenadic and Sally Tuckett's *Colouring the Nation: The Turkey Red Printed Cotton Industry in Scotland* (2013), and Dominique Cardon in *Natural Dyes: Sources, Tradition, Technology and Science* (2007). Beaulieu's 1734 account of Indian Chay red process, translated and published by P.R. Schwartz for the Calico Museum of Textiles in 1956, is used as the comparator to assess for similarities or distinctions.

7.3.1 Turkey Red Dyeing

The Turkey red technique used madder as the main colouring agent. It required about a month to colour skeins of yarn red. The phase of preparation of cotton for taking on the dye was critical. It involved cleaning and bleaching (in the sun initially before the development of chlorine as a beaching agent) of the yarn to remove all impurities that might impede the uptake of the dye. Once the yarn was prepared, it was taken for mordanting, which involved soaking and saturating it with oils or fats. These fatty substances depended upon local availability and ranged from suet, lard, olive oil, fish oil to whale oil. The oil had to be rancid and to it were added sheep dung and other organic waste matters such as cow dung, wood ash etc. The yarn was allowed to ferment in this preparatory bath and then dried in the sun. This process was

[494] Clow, The Chemical Industry, in *History of Technology*, vol IV, p. 249
[495] Alexander Engel, Colouring Markets: The industrial transformation of the dyestuffs business revisited, *Business History*, Feb 2012, Vol. 54 Issue 1, p. 10-29

repeated several times to allow thorough penetration of the fibres by the oxidised fatty acids. Once this preparation was deemed adequate, usually after a couple of weeks, the skeins of yarn were washed and treated with gall or sumac tannins, sometimes both. They were then mordanted with alum. Following this, the yarns were dyed in vats containing the madder extract and ox or sheep's blood. The albumin in the blood removed the resinous brown substances in madder that darkened the red and gave it the brown patches, something that Charles O'Brien pointed out.[496] Finally, the skeins were cleaned and brightened by boiling in a solution of tin chloride.[497]

Important improvements in the process were introduced by Daniel Koechlin in 1810, whereby in addition to cotton skeins, now cotton cloth could be dyed using the Turkey red process. It was also possible to obtain prints via the discharge method where a whole cloth dyed red could be made to reveal repeats of white or blue or yellow patterns by the block or roller application of specific discharge materials that would leave desired colour in the pattern.[498]

7.3.2 Indian Chay Root Dyeing

The Indian process of dyeing using Chay was conducted alongside other processes required for different colours on a cotton fabric. For the purpose of this comparison, the stages necessary for Chay red, enlisted by Beaulieu, are described. The cloth was first cleaned and bleached using rice-water and lime. It was then dried. It was then soaked overnight in a myrobalan solution. Next morning, the solution with the cloth in it was boiled, cooled, rubbed, beaten, washed in fresh water and left to dry. The cloth was next steeped in a mixture of myrobalans and buffalo milk, then washed thrice, beaten and dried. Once dried, the cloth was again beaten on hard polished wood, then spread on a table and the design etched on it with charcoal. A pot of water and sapanwood was then boiled to which alum was added. Using this liquor, the parts of the pattern that were meant to be red were drawn and shaded. The cloth was then washed and dried. Chay root was added to a pot of boiling water. To this was added the prepared, mordanted cloth and allowed to boil for 2 hours over moderate heat. Upon removal from heat the cloth was left to cool in the pot, removed, washed in fresh water and dried. A second round of 'maddering' was undertaken after any other colours like blue, green or yellow may have

[496] Charles O'Brien's *The Callicoe Printer's Assistant*, 1795, unpaginated
[497] Cardon, Natural Dyes, p. 117; Nenadic and Tuckett, *Colouring the Nation: The Turkey Red Printed Cotton Industry in Scotland c. 1840-1940*, National Museums Scotland, Edinburgh, 2013, p. 26-27
[498] Nenadic and Tuckett, *Colouring the Nation*, p. 28-29

been added to the pattern. In the second round, cloth was again seeped and boiled in a concentrated pot of water and Chay, on low heat for 4 hours, left to cool in the pot, removed, squeezed, and dried. It was followed by a soak in kid-dung mixed with water for 3 days after which it was washed in soapy water.[499]

A comparative assessment between the Turkey red process and Indian Chay red process enables a process analysis of the Indian and English techniques to investigate if there are any similarities. In case of similarities, it allows us to understand their characteristics and position within the technical process of dyeing. Process imitation may be seen as the artisanal way of recreating a colour or dye. In case of any differences, it allows the investigation of any fundamental distinctions, diverse sources of origins and/or plausible deviations from one technique towards another. For instance, once the chemical knowledge of materials improved, other ways were derived to obtain textile colours, using compounds based on the properties of organic materials like alizarin and indigotin.

The comparative assessment reveals both similarities and differences. The main difference is that the Turkey red process used madder, and the Indian process used Chay. Madder was the locally available and known substitute for Chay in Europe and Britain. Indeed, in his account for the French government, Beaulieu writes, 'Note: Chay-root is known to me, but madder, kermes or cochineal can be used instead,' implying that the Chay-root technique of dyeing could be adapted to other dye materials used for the colour red.[500] Experiments were conducted with Chay in Europe and Britain with some limited success, as discussed earlier. However, madder continued to be the red dye of choice, signalling path-dependence and connectivity to local traditions.

[499] Translation of the Beaulieu manuscript, P.R. Schwartz, *Studies in Indo-European textile history*, p. 80-88
[500] Ibid. p. 82

The two processes may be broken down into key parts and looked at side by side as follows:

Table 10: *Comparative assessment of Turkey red and Indian Chay red dyeing processes*

Sequence	*Process*	*Turkey Madder red*	*Indian Chay red*
1.	Cleaning, bleaching	Sunlight	Rice-water, lime, sunlight
2.	Pre-mordanting preparation by soaking in oily substance	Soaking in rancid olive oil or other fatty substances with sheep dung	Soaked in solution of myrobalans and buffalo milk
3.	Mordanting with alum	Treatment with gall or sumac, then mordanted with alum	Sapanwood and alum solution used on parts to be red
4.	Dyeing 1	Dyed in solution of madder extract and ox blood	Cloth boiled in solution of water and Chay for 2 hours
5.	Dyeing 2	None	Cloth boiled in concentrated Chay solution with water for 4 hours
6.	Cleaning and brightening	Boiling in solution of tin chloride	Cloth soaked in kid-dung solution for 3 days

Source: Dominique Cardon in *Natural Dyes: Sources, Tradition, Technology and Science* (2007); Stana Nenadic and Sally Tuckett's *Colouring the Nation: The Turkey Red Printed Cotton Industry in Scotland* (2013); The Beaulieu Manuscript (1734) in P.R. Schwartz, *Journal of Indian Textile History*, Number II, Calico Museum of Textiles, 1956

Comparative assessment based on the different broad stages of the two processes reveals remarkable similarities in the overall principles. The use of oily substances, animal waste, soaking in galls and deploying alum as mordant are common amongst the two processes, although the timings vary slightly. Two other key differences are the use of ox blood and tin chloride in the Turkey red process. Both are missing from the Indian Chay process. Their absence may be explained by way of the fact that Chay root contained concentrated alizarin, unlike madder where the alizarin component is diluted by the presence of purpurin, pseudopurpurin and other compounds. Chay's concentrated alizarin resulted in bright reds without the need for additives to brighten the colour, unlike madder, which needed tin to brighten the 'saddened' madder prone to dull brown patches. The addition of ox blood and tin may be viewed as means of overcoming the limitations of madder to produce a bright red such as the one produced by Indian dyers using Chay.

Further, it took European and British dyers until 1810 to be able to use the Turkey red technique directly on to cotton cloth and to print resist patterns on to the Turkey red dyed cloth, signifying the evolutionary development of printing and dyeing knowledge. It was not possible, using this method, to achieve red in small parts of larger, polychrome prints. While mordant dyeing with madder had become widespread with the introduction of Indian calicoes, the use of the Turkey red process remained confined to large dyeworks specialising in resist-printed reds owing to the highly labour-intensive, high cost and highly skilled nature of the process. Further, Chay was used by Indian artisans to dye different shades of red as well as violets and purples within a single piece of cloth, with the use of different mordants, alongside several other colours. The versatility and adaptability of the Indian Chay red technique was missing from the industrial vats of Turkey red which could produce one shade of red and one shade of purple, at any given time.

It may be concluded, hence, that the Turkey red method of dyeing was based upon the Indian Chay red method of dyeing, with modifications dependent largely upon the local availability of raw materials as well as the crucial difference, the use of madder instead of Chay. The labour and capital intensive and multi-phased Turkey red technique was developed to compete with the high quality and non-fugitive Chay red on Indian chintzes.

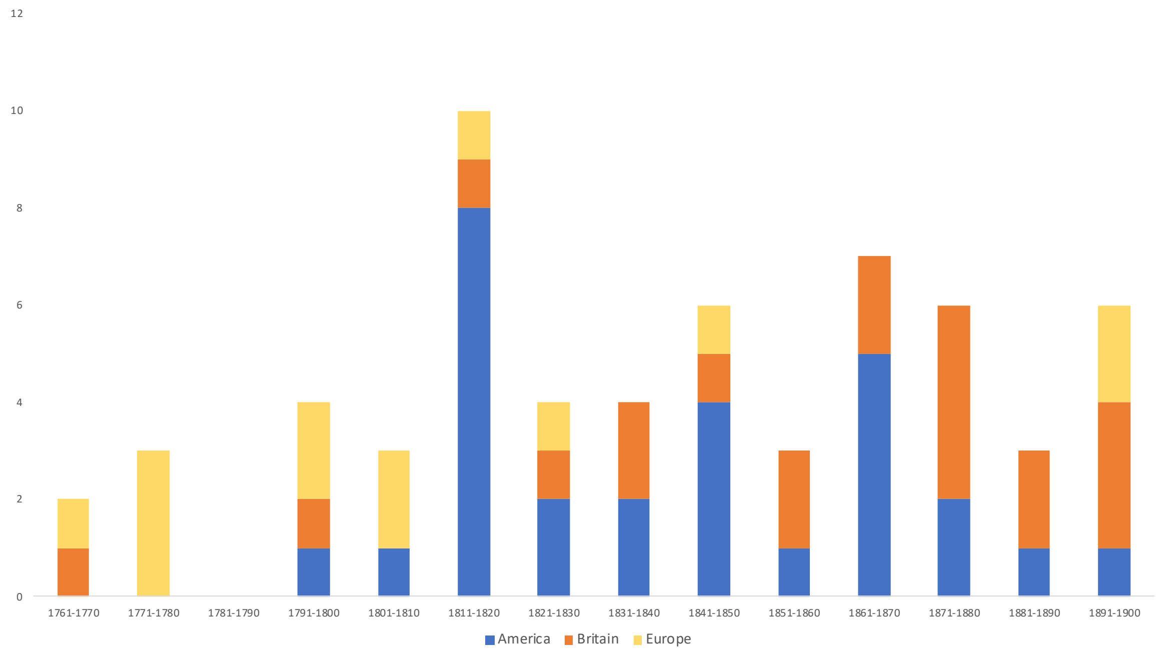
7.4 Knowledge Transfer and Diffusion

Codified knowledge, once transferred, should necessarily have been diffused for it to have had an impact on calico printing in Britain. Edward Bancroft's example, discussed in the previous chapter, demonstrates that his work definitively aided in the adaptation and diffusion of Indian printing and dyeing techniques. Are there other examples of similar diffusion of knowledge? If the knowledge of mordant based printing and dyeing was scant in Britain and Europe during the period under consideration then arguably, there should be a demonstrable demand for guidance and expertise related to it. Is there an identifiable trend for the dissemination of printing and dyeing knowledge and expertise during the period under consideration?

I test this question by tracing all published dye manuals in the Winterthur Museum's Library collection from 1750-1900. Winterthur Museum is a leading research museum for textile analysis with a comprehensive collection of books and manuscripts related to textile history. While there exist several dated manuscripts at the library related to textile printing and dyeing techniques, these have not been included in the database of dye manuals as they may or may not have been widely circulated. Therefore, only published dye manuals from Britain, Europe and America have been included in this database. Only manuals where a definitive date and place of publication are present are included. Manuals published in America are included alongside British and mostly French but also some Italian and German ones because, as indicated by Edward Bancroft's case, American publications were widely distributed and consumed in Britain.

One key limitation of this database is that it is not an exhaustive compilation of all dye manuals published during the period in the three regions. There may certainly be others that could justifiably be included in the list. This database is, therefore, a conservative estimate of the dye manuals published during the period. However, most of the well-known dye manuals of the period find themselves in the database, which suggests that it is unlikely to be missing any significant, and hence widely consumed, volumes. Nevertheless, it is important to read this data as indicative and not definitive. In all, the database comprises 61 British, European and American dye manuals from the period 1760-1900. Of the 61, 28 dye manuals are printed in America, 20 in Britain, 11 in France, 1 in Germany and 1 in Italy.

Figure 105: Textile dye manuals published in Britain, Europe and America, 1761-1900



Source: Winterthur Museum Library Collections

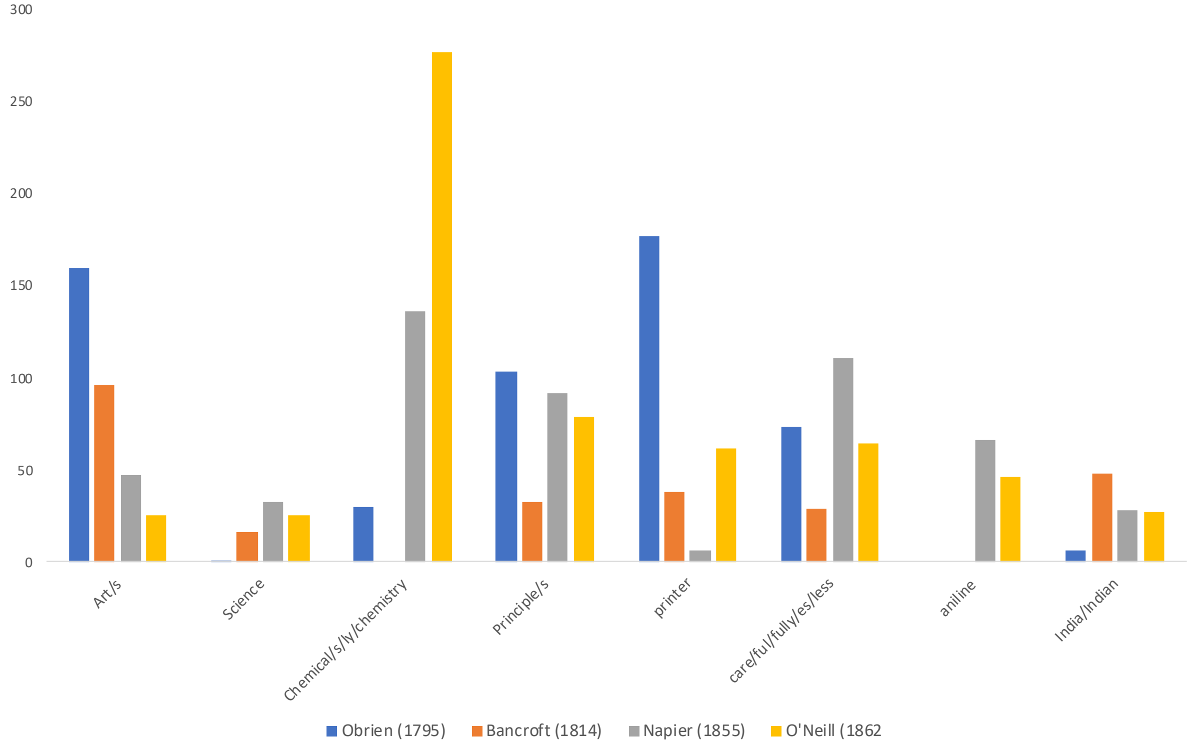
Geographical breakdown of dye manuals in Figure 105 shows a westward evolution of the dyestuffs industry from Europe to Britain and America from the 18th century to the end of the 19th. This finding is in line with previous assessment which shows the Continental route that calico printing techniques took on their way from India to Britain. The inclusion of America in this analysis indicates a further westward diffusion of knowledge and expertise related to dyes and dyeing.

Figure 105 shows an increase in the publication of dye manuals reaching its peak in 1820. This is in line with the findings in Chapter 5 which show an increase in the number of colours in British calico printing industry, viewed as an increase in the measure of print quality. The evolution of dye manuals, in addition, shows a demand for the knowledge pertaining to dyestuffs and dyeing techniques. To that end, it is noteworthy that the highest number of dye manuals were printed in 1811-1820 indicating a higher demand for dyeing expertise until then. Mass production of cotton textiles may be partly responsible for the upsurge in demand for dye manuals - itself an outcome of the popularity of Indian printed cottons – in tandem with the demand for technical knowledge pertaining to printing and dyeing. This is also in line with the findings related to the Turkey red process from the previous section which shows that by the 1820s, the knowledge from Indian techniques had been successfully adapted within the British cotton industry.

The numbers of dye manuals decline somewhat after 1820, picking up again towards 1850. This is a curious phenomenon as, if the techniques to print and dye cottons according to Indian techniques had already been mastered, then what explains this resurgence in the supply (presumably based upon resurged demand) of dye manuals? Mass production of cotton goods in the British cotton industry may again offer an explanation for the resurgence in demand for dye manuals. However, was this the same knowledge and expertise as the previous cohort of dye manuals contained?

In 1856, William Perkin discovered aniline purple, laying the foundations of the chemical science of dyestuffs. Interestingly, between 1855 and 1861 there are no dye manuals in the database. Is there a visible shift in the methods of textile printing from artisanal to scientific evident in a comparative analysis between dye manuals from 1795 versus those from the early 1850 onwards?

Figure 106: Reference word count in select dye manuals, 1795-1862



Source: Charles O'Brien *The Callicoe Printer's Assistant* (1795), Edward Bancroft *Experimental Researches concerning the Philosophy of Permanent Colours* (1814), James Napier *A Manual of Dyeing and Dyeing Receipts* (1855), Charles O'Neill *A Dictionary of Calico Printing and Dyeing* (1862) using Voyant Tools https://voyant-tools.org

To discern if there is a shift in emphasis from artistic to chemical-scientific orientation in dye manuals, digital text analysis of 4 dye manuals from 1795, 1814, 1855 and 1862 is conducted using a web-based digital text analysis software, Voyant Tools. The four manuals are Charles O'Brien's *The Callicoe Printer's Assistant* from 1795, Edward Bancroft's *Experimental Researches* from 1814, James Napier's *A Manual of Dyeing and Dyeing Receipts* from 1855 and Charles O'Neill's *A Dictionary of Calico Printing and Dyeing* from 1862. Reference word analysis is conducted to determine frequency usage of key words pertaining to artistic versus scientific orientation. Key words used include art/s, science, chemical/s/ly/chemistry, principle/s, printer, care/ful/fully/less/s, aniline and India/Indian.

Digital text analysis reveals a distinct swing from language rooted in the artisanal mode of textile printing to more scientific chemical analysis terminologies. The shift is discernible in the emphasis by O'Brien and Bancroft on calico printing as an art and the role of the printer as a craftsperson, including the care/skill required from him/her, versus the emphasis visible in Napier and O'Neill's work on a more scientific and chemical knowledge-based approach to dyes and dyeing techniques. This shift in terminology post-1850 indicates the development of a distinct and original science of chemical dyestuffs. In line with the material evidence, the digital textual evidence suggests that the artisanal mode of textile printing and dyeing, influenced by Indian techniques, continued until the onset of the coal-tar based dyes.

All four dye manuals make references to India. Bancroft makes the most references to India with a count of 48, while O'Brien makes only 6 Indian references, mostly related to the quality of water in India. Bancroft's high number of references to India are expected as his work is an experiments-based compilation of processes of dyeing with natural dyes, which includes in-depth comparative analysis of Indian dyeing techniques. Interestingly, Napier and O'Neill make 28 and 27 references to India, respectively. For Napier, the main specific collocates alongside India are 'galls' and 'vat.' For O'Neill, the top specific collocates with India are 'yellow,' 'rubber' and 'cotton.' A closer reading of both the texts reveals references to traditional Indian natural materials and methods of textile dyeing alongside chemical dyes and their application processes.

7.5 Transition from Artist to Chemist: Overlap between Natural and Synthetic dyeing

Did Indian printing and dyeing techniques have any influence on the development of the synthetic, coal-tar based dyes in Britain and Europe? I assess this question using the examples of two chemists, C.L. Berthollet and William Perkin, to show that while there does not appear to be a direct influence of Indian dyes and textiles on the emerging science of chemical dyes, based on evidence currently available, an overlap is identifiable through common interests, focus and personal connections.

The transition from empiricism to science, within the discipline we now understand as chemistry, was a gradual process that began in the mystical, religious and superstitious birth waters of alchemy. Historians of science and technology tell us that alchemistic orientations, motivated by the pursuit of gold, remained dominant until the 16th century.[501] Towards the second half of the 18th century an 'international character of science' began to develop.[502]

[501] John Read, *From Alchemy to Chemistry*, G. Bell and Sons Ltd., London, first published 1951, then 1995, p. 95
[502] Ibid. p. 126

Joseph Black from Scotland, Wilhelm Scheele from Sweden, Joseph Priestly and Henry Cavendish from England, M.H. Klaproth from Germany, Joseph-Louis Guy-Lussac, C.L. Berthollet and Antoine Laurent Lavoisier from France, to name a handful, contributed to the re-shaping and growth of the discipline along scientific principles. Scheele discovered chlorine in 1774 and Berthollet applied it in 1785 to textile bleaching. Lavoisier's famous *Traité Élementaire de Chimié* was published in 1789. Within this branch of organic chemistry, the chemical science of dyestuffs reached its commercial success in the 1850s.[503] Prominent chemists such as Berthollet and Lavoisier display an overlap of interests and focus between the study of chemistry and that of the nature and properties of dyestuffs, laying the foundations of the chemical science of textile dyes.

Three trends become visible from this brief overview of the history of dyestuffs. First, there appears to be a diffusion of knowledge pertaining to dyes and dyeing techniques from East towards the West. Second, the process of learning from Indian dyes and their techniques fuelled investigations, adaptations and the development of new knowledge within British and European calico printing. Third, the changes that this process of empirical learning and adaptations in Britain and Europe overlapped with the distinctly developing science of chemistry, ultimately leading to the development of aniline textile dyes and a transformation in the nature of the printer from printer-artisan to chemist-consumer of chemical goods.

In the 18th and 19th centuries, the study of chemistry was not restricted to scientists. Industrialists, manufacturers and merchants related to the calico printing industry also participated in scientific investigations related to the dye materials in use in industry. Prior to the introduction of Indian cottons and the frenzy of imitations to replicate their prints and dye colours, the dyer was both the empirical researcher, the repository of knowledge related to dyes and their processes, as well as the person responsible for the colouring of the cloth. With the introduction of Indian cottons and the heightened interest in deciphering the colouring techniques of Indian chintz, a new set of early proto-scientists with roots in chemistry or empirical dyeing, and often both, emerged. This cohort reflected the diffused nature of knowledge creation in the early modern world as its ranks included not just dyers and scientists but also traders, intellectuals, and philosophers. This new class of early scientists overlapped

503 Ibid.

with the empirical dyers and proto-scientists interested in understanding the properties and compositions of natural dyes.

One prominent example of a proto-scientist is John Mercer, who was born in a hand-loom weavers' family in 1791 but began experimenting using popular chemistry pocket-books at a young age. His experiments led him to be appointed 'experimental chemist' at Oakenshaw Printworks in 1818, where he was later to become partner.[504] He pioneered the collaboration between chemists and printer-dyers by organising monthly meetings where scientific knowledge from Britain and Europe and practical knowledge of the printers came together. Mercer is credited with the development of several mineral dyes, including Prussian blue, chrome yellow and orange, manganese bronze and antimony orange. He also modified the Turkey red process to produce different shades of red and set out a new process of dyeing with catechu to create a new brown. His most famous contribution, however, was in a new chemical treatment of cotton with caustic soda which packed the cotton yarn tightly together, giving it greater strength and compactness. Cloth made with mercerised yarn was more uniform and able to take colour better during the printing and dyeing process.[505]

The rapid growth of the textile industry in Britain and Europe in the eighteenth century attracted widespread attention. One such group observing this rise was that of chemical scientists. Chlorine had already been discovered in 1774 by Wilhelm Scheele and was developed as a bleaching agent for textiles by C.L. Berthollet in 1785.[506] French scientists were particularly encouraged to devise new methods of dye extraction and application by the state as well as society-led incentive schemes, such as a prize announced by the Industrial Society of Mulhouse for the development of chemical knowledge about madder. This led to the first isolation, extraction and analysis of the key constituents of madder – alizarin and purpurin.[507] French, German and English scientist were in close communication and interaction with each other, often moving from one university, laboratory, city and country to another, taking their knowledge with them.[508] The scientific study of these dyes, including isolating their key

[504] Edward Parnell, *The Life and Labours of John Mercer*, London, 1886, p. 40
[505] Agust Nieto-Galan, Calico printing and chemical knowledge in Lancashire in the early nineteenth century: the life and colours of John Mercer, *Annals of Science*, 1997, 54:1, 1-28
[506] E.L. Holmyard, The Chemical Industry: Developments in Chemical Theory and Practice, in Singer, Holmyard, Hall and Williams, *A History of Technology*, Vol IV, p, 221
[507] Morris and Travis, International Dyestuff Industry, *American Dyestuff Reporter*, Nov 1992, p. 60-61
[508] Ibid.

components through a variety of techniques began the ‘scientification of the production process’ and its commercialization to make more uniform dyes.[509] The late eighteenth and early nineteenth century saw the appearance of several attempts to create new chemical dyes, mostly fugitive.[510]

Berthollet’s application of chlorine to textile bleaching in 1785 has already been mentioned. He was a pioneering chemist who is well-known for his conceptualisation of chemical reactions as well as for his contributions to modern chemical nomenclature.[511] In his translation of Berthollet’s most famous work, *The Elements of the Art of Dyeing and Bleaching*, Andrew Ure includes notes and details, including an obituary which informs us that Berthollet possessed a degree of ‘Doctor in Medicine’ and was a Professor of Chemistry.[512] His association and cooperation with Edward Bancroft in investigating dyestuffs from around the world has been noted earlier.[513] Was Berthollet’s work influenced by Indian cotton textiles and aimed at investigating the character of dyestuffs used for the printing and dyeing of cottons?

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[509] Alexander Engel, Colouring Markets: The industrial transformation of the dyestuff business revisited, *Business History*, Vol. 54 Issue 1, Feb 2012, p. 10-29
[510] Charles O’Brien, *A Callicoe Printer’s Assistant*, 1795 unpaginated
[511] Derry and Williams, *A Short History of Technology*, p. 537
[512] C.L. Berthollet, *The Elements of the Art of Dyeing and Bleaching, translated from the French with notes and engravings, illustrative and supplementary*, by Andrew Ure, 1841
[513] Previous p. 158

Figure 107: Word Cloud of Berthollet's '*Elements de L'Art de la Teinture: Avec une description du blanchîment par l'acide muriatique oxigéné*,' 1804

Source: Cirrus/Word Cloud generated using Voyant Tools https://voyant-tools.org

A word cloud of Berthollet's *Elements de L'Art de la Teinture: Avec une description du blanchîment par l'acide muriatique oxigéné*, second edition, published in 1804 in Paris (Figure 107) shows the frequency of key words used in the work. Being a dye manual, the appearance of key words pertaining to dyestuffs, mordants and dyeing techniques is not unexpected. Two things are noteworthy, however. First, the cloud is indicative of Berthollet's scientific background, particularly through the high frequency use of words like 'dissolution' 'sulfate' and 'l'acide'. These words suggest that Berthollet was investigating textile dyes as a trained chemist, not as a printer-artist.

Second, the fifth most frequently used word in Berthollet's 374-page dye manual is 'coton', following general printing related words such as 'couleur' 'bain' 'dissolution' and 'teinture'. 'Coton' is used 233 times, 'soie' 173 times, 'laine' 78 times and 'lin' 31 times. This is indicative of Berthollet's focus on cotton printing and dyeing over silk, wool, and linen. That Berthollet was predominantly concerned with cotton printing is also signified by his focus on the bleaching of cotton cloth using chlorine. Berthollet's contributions were critical to the development of chemistry's interests in dyestuffs and the 'scientification' of the process of production and use of dyestuffs.[514] His focus on cotton indicates a common interest amongst scientists and empirical investigators of dyes and an overlap between stimulus from Indian cottons and the emerging science of dyestuffs in Europe.

Another well-known chemist, William Perkin is credited for laying the foundations of the synthetic coal-tar based synthetic dyes industry with the discovery of mauveine in 1856. However, chemical dyes, even those based on coal-tar, had been developed and were in circulation by the first quarter of the 19th century. Three of them deserve special mention. Roberts, Dale and Co. in Manchester pioneered the use of a coal-tar derivative called carbolic acid or phenol, which is from the same family of organic compounds as benzene used by Perkin later, to produce a synthetic yellow called picric acid. This technique had been applied by Lyon silk dyers in as early as 1845. Picric acid was fugitive in sunlight.[515] A semi-synthetic dye, murexide, was developed in Europe using uric acid in around 1835. The main raw material here were the solidified bird droppings or Peruvian guano. It was found that uric acid treated with nitric acid produced alloxan, a substance that stained skin reddish purple and was therefore suitable for dyeing animal fibres like wool and silk. By 1856, it had been worked out in Paris that it could be attached to cotton using lead, mercury and zinc as mordants.[516] A second semi-synthetic dye was French purple, developed in the early 1850s from an extract obtained from various species of lichens found throughout Europe. Initially the dye was suitable only for silk and wool, but concerted efforts were made to ensure its attachment to cotton using oxalic acid, ammonia and lactarane (casein).[517]

As French chemists' investigations revealed that the colouring agents in madder were alizarin and purpurin, Justin Liebeg in Germany discovered in the 1830s that the main colouring constituent of natural indigo was a substance called aniline, from 'anil' which is Sanskrit for indigo. In 1837, Liebeg's assistant Wilhelm Hofmann, while extracting nitrogenous oils from coal tar, found that these were identical to aniline. He moved to the Royal College of Chemistry in 1845 and continued his work into coal tar derivatives. A young eighteen-year-old research student working in his team was William Henry Perkin. Hoffman tasked Perkin, over the Easter

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[514] Alexander Engel, Colouring Markets: The industrial transformation of the dyestuff business revisited, *Business History*, Vol. 54 Issue 1, Feb 2012, p. 10-29
[515] Travis, *Perkin's Mauve*, p. 63-64
[516] Ibid
[517] Ibid. p. 65

holidays of 1856, to make synthetic quinine from coal-tar naphthalene. Perkin decided, instead, to begin with another coal-tar product called allyl toluidine as he experimented in his home laboratory. The experiment was unsuccessful, but he decided to repeat the process using a simpler aniline. The residue of this experiment left a purple stain on a piece of silk he was apparently using to clean up. He found that the colour stayed despite washing.[518]

Perkin immediately recognized the commercial potential of the purple stain as a textile dye. He sent samples to a Scottish dyeworks, John Puller and Sons in Perth, who wrote back in June 1856 saying, 'If your discovery does not make the goods too expensive it is decidedly one of the most valuable that has come out for a very long time, this colour is one which has been much wanted in all classes of goods and could not be had fast on Silk, and only at great expense on cotton yarns.'[519] Perkin devoted himself to commercializing the aniline purple which he initially called 'Tyrian purple' after the fabled colour of the Phoenicians, but changed it to 'mauve' to be more in line with French fashion.

Perkin's accidental discovery of mauve has been consistently highlighted in the literature as heralding the birth of synthetic coal tar dyes with emphasis on the accidental nature of the discovery. However, evidence suggests that prior to the famous discovery of aniline purple, Perkin was already interested in chemical dyes and had been investigating for some time the viability of the use of dinitrobenzole or nitraniline to produce a deep shade of the colour red - crimson. On 5 February 1856, Perkin published alongside his partner Arthur Church an article in the Royal Society, titled 'On some new Colouring Matters.' In this article, the duo assert that they had been able to create a new substance which they called nitrosophenyline, which produced the colour crimson, by making hydrogen interact with an alcoholic solution of dinitrobenole or nitraniline.[520] Evidence also suggests that this attention towards synthetic dyes may not have been accidental – Perkin's prompt resignation from his position at the Royal College of Chemistry despite the disapproval of his mentor Hoffman indicates that Perkin has been considering commercializing his knowledge for at least some time prior to the accidental

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[518] Anthony Travis, Mauve and its Anniversaries, *Bulletin for the History of Chemistry*, 2007, Vol 32, Nov 1, p. 35-44

[519] Ibid. p. 36

[520] Arthur H. Church and William H. Perkin, On some new Colouring Matters, *Proceedings of the Royal Society of London,* Vol 8, 1856

discovery of mauve.[521] His focus upon chemical dyes may be read as a means of commercializing his pursuit of chemistry – something he was successfully able to do upon the discovery of mauveine.

The existence of the article published by Perkin in February 1856 complicates the narrative of the accidental discovery of aniline purple. The discovery comprised of two distinct events. First, the purple stain appeared upon the cloth. This was unintended and hence entirely accidental. This was also rooted in the scientific chemical investigations pertaining to coal tar, separate from the developments in the textile industry. Second, the stain was recognized as a potential textile dye. This was not accidental. As the existence of the above-mentioned article shows, Perkin had been actively looking for viable synthetic dyes suitable for colouring textiles through his research. At the very least, the prompt recognition of the commercial potential of a chance purple stain - on what has legendarily been described as a cleaning cloth - was a product of his connection to the emerging world of chemical dyes, buoyed in part by the growth of calico printing in Britain and Europe.

Synthetic dyes were new products created by chemical scientists following years of scientific investigations and based upon the accumulated knowledge of the science of chemistry. Evidence suggests that this scientific knowledge was, in part, stimulated by the pursuit of the colour repertoire of Indian printed and painted calicoes, as well as the impulse to understand the scientific principles underlying the empirical techniques. A distinctive overlap is, therefore, visible in this intersection between dyestuffs, both natural and synthetic, related to textile printing. While there was no direct Indian influence on the history of chemical science that led to the development of the chemical science of dyestuffs, evidence suggests that the evolving proto-scientific nature of the investigations and proto-scientist character of the dyer-chemist is connected through a commonality of interests initially stimulated by the pursuit to understand the nature and characteristics of the multi-coloured natural dyes that formed the basis of the printed ornamentations of Indian cotton textiles.

[521] Anthony Travis, Sir William Henry Perkin, Oxford Dictionary of National Biography https://doi.org/10.1093/ref:odnb/35477 accessed 10 June 2021

7.6 Conclusion

Technological evolution of printing and dyeing of cotton textiles in Britain in the 18th and 19th centuries was influenced by Indian printing and dyeing techniques, as a result of diffusion and adaptation of knowledge through codified means and via the Continent. Evidence shows a strong interest in Indian dyes and calico printing traditions and suggests path dependence upon Indian dyeing techniques and a demand for the knowledge of these techniques through the popularity of dye manuals. A change in the language of dye manuals also highlights a shift from Indian-artisanal techniques towards European-scientific techniques of cotton dyeing and printing. Evidence suggests that an overlap of inspirational stimulus from natural dyes and dyeing techniques aided the shaping of the distinctively evolving branch of the chemical science of dyestuffs

Chapter 8: Conclusion

The importance of cotton in global economic history and its role as a commodity prioritising the significance of demand through the medium of fashion-led consumer preference in the early modern world has recently gained greater acceptance. However, the role of cotton in stimulating technological change through mechanisation is a perspective mired in debates and controversies. The history of cotton is a condensed version of global history. Yet the perspective this history has adopted so far has remained largely Euro-centric and teleological, overlooking the crucial global connections and dynamics, as well as non-predetermined outcomes of these connections, that underpin the origins of industrialisation and modern economic growth.

This research hopes to expand the scope of perspectives on the phenomenon of industrialisation and economic growth trajectories by challenging mainstream views on the theme, which largely overlook the global character of the main materials in question – cotton as a fibre and cotton fabrics as finished goods. It has attempted to offer material and mechanical evidence to stress the dynamic web of interconnections upon which the mechanical production of cotton textiles was built. It joins the dots between the Indian artisanal mode of cotton manufacture and the British artisanal-moving-to-mechanical-and-scientific mode of cotton manufacture and demonstrates in material details how this transition evolved. In the process, it has attempted to highlight the importance of the physical product intended for imitation, and the availability, or lack thereof, of the skill within the local population to successfully replicate the product, over other traditional arguments based on British or European exceptionalism, relative wages, opportunity cost of training or the availability of local energy resources or abundant raw materials. It hopes to show that cotton as a fibre, and as a cloth, determined the trajectory of mechanisation and technological developments in Britain.

The study has attempted to highlight the global roots of industrialisation through the medium of cotton and how this global stimulus elicited a specific response within the British pre-modern economy. Situated within the discourse on industrialisation from a global, product-specific, demand-led perspective, it aims to expand our understanding of the role of global connections in shaping the character and timing of the onset of modern economic growth. Using a multi-disciplinary methodology and extracting information from the silent material sources at the heart of the industrialisation debate, it has underscored the significance of imitations and the pursuit of product quality for the onset of mechanisation. Analysis of the materials has demonstrated that the development of the cotton industry in Britain, or anywhere in the world, involved the growth of knowledge in cotton cloth making as well as cloth printing. This knowledge had existed for centuries in India. The Indian cloths – printed, plain, painted, fine, coarse - contained this knowledge and became mobile vessels transporting this embedded knowledge to the locations they were traded in around the world. The immediate response they elicited in the locations where they were introduced was that of imitation. The process and context of imitation determined the trajectory of each society's response to the stimulus provided by Indian cottons.

Imitation of these Indian textile products took a specific pathway in Britain. Labour-saving inventions were already beginning to be seen as the way forward within the economy with the introduction of silk throwing. Early imitations of Indian cottons showed significant impediments in their replication and machinery was deployed to overcome these obstacles. This thesis has attempted to show that in cloth-making, the machinery evolved to overcome sequential bottlenecks, and was initially developed for the making of the all-cotton cloth and then for the making of the fine all-cotton cloth. It has demonstrated that cloth and print quality in the British cotton industry evolved to converge with the Indian cotton cloth and print quality. Literature so far has focussed on the labour-saving motivations for mechanisation. This thesis suggests that there is a labour-replacing motivation also underpinning mechanisation in the British cotton industry, which was a primary means of bridging the skill-gap between Indian and British spinners and the lack of skill-capital related to cotton spinning in Britain.

A key aspect of this project has been the study of the materials that constituted the benchmarks for emulation, as well as those that were created in imitation of the benchmarks, as a means of understanding mechanical innovations. Material evidence, in this case surviving British and Indian cotton textiles of the period related to industrialisation in the British cotton industry, has offered insights that would not have been possible through more conventional sources. New sources have also led to the adoption of new methodologies resulting in this thesis drawing on knowledge and insights from supporting disciplines and technologies like textile history, history of science and technology, as well as scientific and digital analysis.

In so doing, the thesis attempts to expand the vast pool of knowledge associated with industrialisation and pathways to modern economic growth. It does so by emphasising that entrepreneurship, knowledge, raw materials, trade and markets are closely tied together in a densely packed web of interconnections. They come together in the making of specific products and their consumption in specific markets. While wages, raw materials, sources of energy and other variables contribute to the development of an industry in specific directions, the product is the chief output of the industry determining the combinations of other factors necessary for its production. In the case of cotton, the study shows the benchmark Indian cottons determined the trajectory of their imitations. In printing, this trajectory involved adaptations of Indian printing techniques. In spinning, the inability to imitate the product by the means of pre-existing techniques led to the mechanisation of the production process and re-training of the labour force in mechanical skill in Britain.

The emphasis on imitation does not imply a negation or devaluation of other variables crucial for technological change, such as labour productivity, factor endowments or access to natural resources. On the contrary, it is an attempt to retrieve a handful of nebulous concepts like quality, imitation and import substitution from a bundle of opaque variables and disentangle them for greater clarity so they can contribute meaningfully alongside other pathways for explaining industrialisation. Similarly, the emphasis on Indian influence does not constitute a diminishing of British economic and material achievement. Instead, it explains in thread by thread and colour by colour detail how this achievement materialised, the trajectory of its materialisation and the footprints of the process of imitation on industrialisation.

While it answers many questions, the thesis has also thrown up several others. The isolation of cloth quality through thread per inch measure and that of print quality through the colour count of textiles has meant that other variables, as well as pertinent questions, have had to be left unexplored. For instance, what was the impact of Indian designs and motifs on the growth of the calico printing industry? Despite the historiographical trend which states that Indian designs were unpopular in Britain, there is evidence to suggest that iconic and well-known textile designers in Britain such as Anna Maria Garthwaite and William Morris had their early design training in Indian calico prints. Did their early interactions with Indian textile patterns have any impact on their celebrated textile designs? Or what was the purpose and impact of the shift from block-printing to roller printing? Roller printing does not constitute an Indian influence, as per the historiography on calico printing – what motivated this process innovation, what were its implications for print quality and how did it impact the growth of calico printing?

While the research has provided an imitation and quality-led rationale for mechanisation of cotton manufacturing in Britain, it has also re-surfaced one obvious big question – if all European societies were imitating Indian textiles, then what contributed to the concentration of mechanisation in Britain? In focussing on this issue, the wider socio-economic contexts within which imitations took place in the different regions in Europe and Britain must be re-evaluated. While this study has zeroed-in on the lack of labour skill in Britain as a key determining factor for mechanisation, further research may usefully focus on other aspects of the problem, related not only to the socio-economic settings, but also to environmental and sociological factors. For instance, did different social groups and regions in Europe respond to Indian cottons differently resulting in different outcomes?

Significantly, the study has thrown open the issue pertaining to the direct painting of indigo on to cloth and our historiographical understanding of this method of imparting the colour blue using indigo on to cotton cloth. If the advanced scientific tools available for historical research are unable to offer satisfactory answers about historical processes, as in the case of the GC-MS destructive analysis of select Indian textiles, then where does it leave historians seeking to confirm or refute received historical knowledge? These limitations force historians to seek creative and unconventional new methodologies based on new collaborations which can provide us with insights that are currently unclear in the face of limitations associated with archival sources and current scientific investigative techniques.

Little is known about indigenous textile printing and dyeing processes in India. While there exists some useful work on the social structure of cloth weaving, greater depth of knowledge is needed about pre-industrial spinning and dyeing techniques. Further research would greatly help in understanding the factors that made the Indian subcontinent the hub of pre-industrial cotton manufacture. What, for instance, was the role of geography in the growth of cotton-specific knowledge that was accumulated in India? These are all meaningful avenues for future research that would add substantially to our understanding of the role played by cotton as a fibre, and cotton clothing as consumables, in shaping the world both pre-and-post industrialisation.

This study has aimed to show that an inter-disciplinary perspective has the potential to throw new light on old questions in economic history. The beginnings of this project were rooted in multidisciplinary study of one particular combination, involving economic history, textile history, history of science and technology, material culture and scientific empirical analysis. The conclusion signals that our understanding of the first industrial revolution, and indeed that of divergent paths to economic growth amongst different regions of the world, might be well served by further research that deploys other cross-disciplinary intersections, involving but not limited to, economic history, economic geography, sociology and behavioural psychology.

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