The Creation of a Gendered Division of Labour in Mule Spinning: Evidence from Samuel Oldknow, 1788-92

Introduction

Spinning yarn for textile production is an activity that can be traced back as far as the ancient civilisations of Egypt, India, China, and Rome, among other major centres of historical innovation. Prior to the great technological advances of the Industrial Revolution, spinning was carried out entirely by hand and primarily by women and children. Craig Muldrew has shown that in England, hand spinning was undoubtedly the most important paid female occupation.[1] In the eighteenth century, spinning by hand was superseded incrementally by a series of inventions, including James Hargreaves' (1720-1778) spinning jenny, Richard Arkwright's (1732-1792) water frame, and Samuel Crompton's (1753-1827) spinning mule. These new machines enabled unprecedented increases in productivity and stimulated complex changes in labour requirements.

Of the three inventions, Crompton's mule, conceived in the 1770s and first made publicly available in 1780, was arguably the most important technological breakthrough.[2] The mule was a hybrid machine which combined design elements from Hargreaves' jenny and Arkwright's water frame. The jenny was an improvement on the traditional spinning wheel.[3] It allowed one worker to spin yarn on multiple spindles simultaneously. The process of spinning yarn by jenny was intermittent, as the sliding carriage that drew out, twisted, and wound the rovings (long and narrow bundles of cotton fibres) into yarn had to be moved back and forth entirely by hand. The jenny could only spin cotton weft yarns.[4] The water frame employed a patented roller system to spin cotton yarns which was an improvement on the original roller-spinning invention of Lewis Paul and John Wyatt. Paul and Wyatt's 1738 patent established the important roller-spinning principle, which allowed rovings to be

stretched out mechanically by passing them through sets of rollers moving at different speeds.[5] In contrast to the jenny's intermittent spinning, the water frame's spinning process was continuous, with drawing, twisting, and winding occurring in a non-stop motion. It was operated by waterpower and could not produce cotton weft yarns but rather only the stronger cotton warp yarns. Like the water frame, Crompton's mule used a roller-system to stretch out the rovings and multiple spindles on a moving carriage to further draw out and twist the yarn, like the jenny. With this mixed design, the mule could uniquely spin both cotton warps and wefts, as well as produce much finer cotton yarns than had been previously possible. Commercially, the mule's ability to produce finer, cheaper yarns of both types marked an industrial turning point. In the expanding global trade for textiles, Britain could finally produce all-cotton cloths like muslins that could compete with very fine imports from India.[6] The rapid adoption of this new technology would produce profound societal consequences by reversing the traditional division of labour in spinning from women to men. This article deepens understanding of this process by examining employment on the early, hand-powered mule in much greater quantitative detail than has hitherto been attempted. It uncovers why men ultimately came to dominate the technology which would become the mainstay of the British cotton industry.

To do so, the article examines the business records of Samuel Oldknow, an early adopter of the spinning mule who pioneered fine cotton cloth manufacturing in Britain in the 1780s. The article aims to better understand the early, understudied period of the mule's diffusion in the late 1780s and early 1790s, when the machine was still entirely hand-powered, though on the cusp of being made steam-assisted and incorporated into the factory system. By analysing piece-rates, yarn production, yarn counts, and payments made to Oldknow's spinners sorted by gender, this article adds quantitative nuance to the literature on the relative numbers of men and women employed on the mule prior to the factory system. It shows that men and

women were often paid the same piece-rates for the same work, but men's earnings were higher. This was because of the physical effort required to operate the larger mules that produced the finer yarns that secured higher piece-rates. Crucially, and qualifying recent findings in the literature, this reordering of the gender division of labour in spinning predated the activity's concentration in factories.

The data from the Samuel Oldknow archives includes 845 observations of individual spinners when the firm's production was organised based on the putting-out system between 1788 and 1792 in Anderton, Lancashire. While the type of technology is not explicitly stated in the wage records, based on the listed yarn counts produced, this article argues the technology being used was clearly the hand-powered spinning mule.

Crompton's first mule of the early 1780s was a wooden, hand-powered machine, that could spin cotton yarns up to counts in the Ne 80s.[7] In the standard English cotton system, a yarn's count (unit symbol Ne) was defined as the number of hanks (coils of cotton) of length 840 yards per pound. For example, a yarn of count Ne 28 means that there are 28 hanks per pound of that yarn, with each hank consisting of 840 yards. In this system, the higher the number, the finer the yarn. The earliest mules were operated in the home and contained 20 to 30 spindles. The machine improved rapidly, however, and the 1780s saw the rise of hand-powered mules with up to 130 spindles. Operating the first mules required upper body strength to drive the rotary power necessary for the "…exhausting business of driving spindles at high speed during the draw and during twisting at the head."[8] Henry Stones, "an ingenious mechanic" from the village of Horwich, Lancashire, is credited with converting the wooden rollers to metal and improving the machine's gearing, which made operating mules of more than 100 spindles feasible for a single individual.[9]

Hand-powered mules grew larger in size during the 1780s and they were soon adapted to be assisted in their operation by inanimate motive power. The first water-assisted mule was

erected in 1790 and the first steam-assisted mule was introduced in Manchester in 1795.[10] These mules were assisted in the sense that they were not wholly powered by an external motive power source – the movement of the carriage and winding still required manual labour. Arguably the most important technical improvement to the mule came when the Welsh engineer Richard Roberts (1789-1864) made it "self-acting" in 1825.[11] This meant that the carriage moved backwards and forwards automatically, instead of having to be pushed using human muscle, leading to continuous action.[12] These later mules of 300 spindles or more were operated wholly by steam power and were housed exclusively in cotton factories.[13]

The traditional narrative is that the upper-body strength required to operate hand-powered mules increased as the number of spindles increased during the 1780s and 1790s. Consequently, only adult men could operate the larger machines. The introduction of the self-acting mule from the 1830s was meant to eliminate strength requirements and dispense with the need for the labour of expensive and often refractory adult men in the spinning process and replace them with cheaper women and children. Scholars like William Lazonick, Mary Freifeld, and Michael Huberman have debated the reasons why this substitution did not happen at length – including the exclusionary power of male unions, the greater effectiveness of male mule spinners as supervisors, and the prohibitive costs of changing an engrained system of industrial organization.[14]

However, the earliest period in the mule's history remains relatively obscure because of a lack of surviving primary evidence, and the traditional male-strength narrative has largely been left unquestioned. Joyce Burnette has argued that while women worked the earliest hand-powered mules, they began to leave the occupation as mules grew larger and strength became an important factor in a spinner's productivity.[15] However, Burnette never analysed any primary source data from the 1780s to demonstrate that men became more productive at

operating the mule than women, which led to higher earnings. It has also not been conclusively shown that men and women in mule spinning earned the same piece-rate wages for producing yarns of the same quality (count), and that any pay gap between them would be the result of productivity differences alone.

One scholar who has questioned the strength narrative is Paul Minoletti, who argued that it was mainly gender ideology associated with the rise of the factory system rather than strength that cemented the gender division of labour in mule spinning and excluded women from the highest paying jobs.[16] Minoletti argued that scholars like Burnette have placed too much emphasis on the strength narrative; while strength was a factor, it was the rise of the hierarchical and formal factory system which more convincingly explains women's exclusion.[17] While Minoletti's helpful work is important in understanding divisions of labour, more primary source data from spinners using the mule in the putting-out system is needed to examine the extent to which gender ideology associated with centralised factory work was culpable for excluding women, rather than the earlier development of the technology toward larger machines beyond the physical limits of most women.

This article's key finding is that strength was indeed the most important factor in shaping the gendered division of labour in mule spinning during the initial phase of technological adoption when the machine was hand-powered, prior to the factory system. The primary evidence presented here suggests that men and women were paid the same piece-rates for spinning the same quality yarns on the hand-powered mule, meaning direct gender discrimination was not occurring. However, the data shows a clear shift in that men came to monopolise the production of the finest yarns, which received the highest piece-rates because of their greater length per pound spun, and the longer time required to spin them. Furthermore, the article highlights a previously unstudied relationship that the finest, most valuable yarns were best spun on longer mules, which required greater upper body strength to

operate. This relationship between fine yarns, larger mules, and higher piece-rates helps explain why men began to take over mule spinning prior to the factory system and has been neglected in the traditional strength narrative.

The first section of this article introduces Samuel Oldknow and his business. The second section discusses the primary source data and argues that the hand-powered mule was being used. The third section presents the data on gendered employment, piece-rates, and individual spinner pay. The fourth section presents evidence that larger mules were more effective for spinning finer yarns.

Samuel Oldknow and his Business

Samuel Oldknow was one of the pioneers of fine muslin production in Britain during the 1780s and 1790s. He helped to revolutionise the cotton industry by producing not only mixed cotton-linen cloths, but also fine, pure cotton muslins, which could compete with cloths imported from India during his time.[18] Oldknow's business started out organised on a "putting-out" basis. Under this form of business organisation, Oldknow coordinated the entire production process from the preparation and processing of raw cotton (picking and carding), to spinning, winding, warping, and finally, weaving and finishing. Although Oldknow managed the "value-chain" of cloth production, the division of labour was such that different individuals working at home or in workshops at different locations undertook each step of the production process and were paid piece-rate wages. That is, production was not centralised in a single location or under one roof, and each process required different skills and machinery. The realities of how the system functioned were of course complex. For example, some production processes did take place within Oldknow's warehouses as well, such as winding, warping, and finishing.[19] In terms of spinning, Oldknow also purchased yarns outright from some of the largest cotton spinning mills of the day, including those from Richard Arkwright's spinning factories.

Oldknow was born in 1756 in Anderton, Lancashire. Oldknow's grandfather, Thomas Oldknow, worked as a draper in Nottingham until his death in 1787. His father, also called Samuel, had moved from Nottingham to Anderton to become a textile manufacturer. So, a legacy of textile work in the family already existed when the young Samuel Oldknow was apprenticed to his uncle, also a draper named Thomas in Nottingham. In 1781, they entered a business partnership and decided that Samuel would return to Anderton to become an entrepreneurial manufacturer of cotton and cotton-linen goods, while retaining his stake in the Nottingham business.[20]

Within 18 months of returning to Anderton, Samuel Oldknow had begun producing fine cotton muslins, which at the time were considered the highest achievement of British cotton manufacturing. The key technological breakthrough that allowed this new product to be manufactured was the introduction of Crompton's spinning mule from 1780. However, in the early days of the mule's diffusion, between about 1780 and 1782, a supply shortage of "rovings" – long, narrow bundles of drawn-out cotton which needed be "fed" into the mule to spin fine yarns – limited the machine's diffusion.[21] Rovings were produced by slow spinning wheels, the jenny, or Arkwright's carding and roving machinery, of which the use of the latter was restricted by patent. Collectively, the output of rovings from these machines could not keep up to meet the input demands of those using the mule. The annulment of Arkwright's patent for carding, drawing, and roving machines in 1781, meant that all machinery required to prepare cotton for mule spinning became more widely available to entrepreneurs wanting to enter the trade. In 1782, the "slubbing billy", another hand-powered machine whose inventor remains unknown, also helped to improve the supply of rovings.[22] These developments allowed Oldknow to produce the yarns required for muslins, though in small quantities.

Though experimentation with muslin-making had probably been undertaken as early as the late seventeenth century and continued until the invention of Crompton's mule, the absence of a consistent supply of fine yarns ultimately rendered the experiments unsuccessful.[23] All that can be said with certainty is that with the emergence of the spinning mule in 1780, Samuel Oldknow became the first manufacturer to gain eminence in muslin making in Britain.

Between 1782 and 1784, Oldknow operated a warehouse in Anderton that produced muslins, calicoes, and mixed cotton-linen cloths based on the "putting-out" system of production, as well as a salesroom in Manchester, less than 20 miles to the southeast, a town with a rapidly expanding population of around 60,000, where he displayed his goods for show.[24] Once Oldknow's weavers had been trained to produce more finely woven cotton cloths, he shifted the centre of his sales to London, where the demand for his new fine muslins from the wealthy and fashionable was nearly insatiable.[25] The only obstacle limiting the sale of muslins was Oldknow's ability to produce them.

In his classic account of Oldknow's business history, published in 1924, Unwin noted the challenges Oldknow faced in obtaining regular supplies of fine yarn – in particular, warps – to produce muslins.[26] These challenges were related to the supply of skilled labour, as well as access to technology, capital, and credit. On the technology front, although the spinning mule had become available in 1780, it remained an invention in the early stages of its development. Before 1790, the mule was a hand-driven device that was still more expensive than the spinning jenny.[27] At Anderton, between 1782 and 1784, Oldknow was likely procuring cotton weft from spinners working on jennies, while obtaining warps principally from Arkwright's water frame factories, and to a far lesser extent from putting-out work to some using early versions of the mule.[28]

In 1784, Oldknow expanded his business by setting up a second warehouse in the Hillgate in Stockport, south of Manchester. Oldknow subsequently made Stockport his principal headquarters. In 1790, he would construct his factory at the Hillgate site, which housed spinning mules and an 8-horsepower Boulton & Watt steam engine (installed in 1791), which was used to power the winding machines.[29] It is unclear if steam was ever used to assist the mules at Stockport. It is probable that they remained hand-powered even in the factory setting, as the first concrete reference to steam-assisted mules in England is in Manchester in 1795.[30] Despite the shift in headquarters, Oldknow continued operations at Anderton, employing a manager there to oversee the putting-out system.

In 1784, following the Stockport warehouse's establishment, Oldknow reduced his production of cotton-linen mixes and focused production more on higher value, pure-cotton cloths. In 1784, the business was divided almost equally between calicoes and muslins, but Oldknow was keen to produce more of the higher-value muslins at lower cost. By the end of the 1780s, Oldknow's cloth output mix had changed, with the shift in production toward the finer muslins fully established.[31]

This shift in product mix had not been achieved without difficulty. At Stockport, as in Anderton, Oldknow continued to rely on the putting-out system of production between 1784 and the construction of his first spinning mill in 1790. There were significant disadvantages in using the putting-out system for spinning to produce fine muslins. The dual need for increasing production while retaining quality control was not conducive with a system of fragmented, manually produced goods that was geographically dispersed, difficult-to-supervise, and in which thievery and embezzlement posed constant problems.[32] In addition, to secure a steady supply of finely spun warps, Oldknow had been relying on supplies provided by Arkwright water-frame mills. However, while Arkwright-style mills were able to supply Oldknow with a consistent supply of cotton warps of counts around Ne 60, by the late

1780s the demand for finer cloths required cotton warps of higher counts.[33] To that end, surviving letters between Oldknow and Richard Arkwright Jr. suggest the latter's cotton warps were not fine enough and suffered from quality defects, and that Oldknow needed to procure finer yarns to meet the rising demand for producing finer muslins.[34] This indicates that the issue of quality control that plagued the putting-out system had not been fully solved by relying on factory suppliers, and that the warps Oldknow received from Arkwright Jr.'s mill could be unreliable and lacking in fineness for muslin production.

Mule-spinning technology was required to obtain consistent supplies of good-quality, fine cotton yarns. While Oldknow had been putting out cotton to some spinners using early versions of the mule since 1782, there were probably simply not enough spinners using the mule around until the later 1780s for Oldknow to rely on to produce the quantity of fine yarns his business required. The initially slower rate of adoption of the mule between 1782 and 1785 was likely because Arkwright held the patent on roller spinning. Since Crompton's mule also operated on a system of rollers, it could conceivably have been in violation of Arkwright's patent, which perhaps constrained its diffusion between 1780 and 1785. Arkwright eventually lost a series of court cases over the originality of his inventions, and his roller-spinning patent was cancelled in the summer of 1785, meaning others could freely copy his design.[35] As a result, mules began to proliferate generally after 1785, and quickly became larger machines with up to 100 spindles by around 1790.[36] So, recognising the deficiencies with relying on Arkwright's water frame for muslin production, Oldknow increased his reliance on putting out yarns to spinners using the mule.[37] He also developed the idea of setting up a centralised factory in Stockport where he would produce greater quantities of finer count yarns by mules assisted by steam power.[38] This way, Oldknow could more easily supervise fine yarn production than he could relying on the putting-out system.

He also intended to build another factory in Mellor, Derbyshire, where he would produce the lower counts of yarn by waterpower based on the Arkwright system.[39]

Oldknow's mule factory at Stockport was producing yarn by around 1791, though, as mentioned, it is unclear whether he had succeeded in rendering the mules steam assisted (likely only the winding machinery).[40] His Mellor Mill in Derbyshire was completed in 1793.[41] However, by the early 1790s, Oldknow's dream had come too late and at too great a cost. Though Oldknow was a pioneer during the earliest days of fine muslin-making from 1782 to around 1790, his business empire ultimately collapsed in the depression triggered by the onset of the French Wars in 1792, and an unsustainable debt burden because of his rapid business expansion. Much of Oldknow's indebtedness was to the Arkwrights from their earlier business dealings. Oldknow was forced to lease his Stockport spinning mill and sell his Anderton warehouse in 1794. Following his financial misfortune, he concentrated his efforts on Mellor Mill, where he engaged in producing cheap, coarser cottons alongside his farming interests.

Oldknow was nonetheless an important pioneer adopter of the spinning mule. There are no other known business records that provide comparable detail from this crucial and understudied period of the pre-factory adoption of mule machinery. The data collected and analysed in this article are from the surviving putting-out accounts of Oldknow's Anderton warehouse from 18 September 1788 to 10 August 1792 (with breaks which are explained carefully in the following section). The accounts reveal an intimate view of those men and women who operated the early hand-powered mule technology, and their production and earnings.

The Anderton Accounts

Anderton is a village around 5 miles northwest of Bolton in Lancashire, and around 25 miles northwest of Stockport. Opened in 1782, Anderton was the location of Oldknow's first

warehouse but was later eclipsed in size and value by his Stockport warehouse described above.[42] By the late 1780s, Oldknow's operations at Anderton represented the more traditional putting-out system that the firm was increasingly intent on moving away from.

The Anderton accounts, covering periods between 1788 and 1792, offer detailed perspective on Oldknow's putting-out operations in spinning from his warehouse.[43] The accounts are held in the University of Manchester's John Rylands Library (JRL) and contain data on the yarn returned by 158 named individuals, with 845 account entries between them.

[FIGURE 1]

Looking in more detail, the JRL catalogued the Anderton accounts into twenty-two numbered "pieces". A piece refers to each set of physically connected account entries, ranging anywhere from a single loose page to multiple bound pages. For the analysis that follows, the first fifteen pieces were digitised in full. The first seven pieces, with listed entries for 116 unique spinners from 18 September to 12 December 1788, do not mention a specific location.

The next set of pieces, numbered 8 to 12, feature entries for 63 unique spinners from 9 September to 10 December 1790, and are specifically recorded as referring to Oldknow's Anderton warehouse. Since many of the names (33 per cent) recorded in pieces 1 to 7 are also found in the second set (8 to 12), it is highly probable that the 1788 set also relates to Oldknow's Anderton operations. The pieces numbered 13 to 15 are more puzzling. The JRL has described the documents as follows: "…pieces 13-15 are similar [to pieces 1-12] for 31 July to 23 December 1792."[44] While piece 13 is clearly dated with entries from 31 July to 10 August 1792, there are no specified years on pieces 14 and 15 to show that they also refer to the year 1792. In addition, the dates are not continuous throughout the series, with piece 14 listing dated entries between 27 March and 7 April, while piece 15 lists dates between 16

December to 23 December. Piece 14, which is not definitely marked as 1792, has been left out of the analysis because of the ambiguity relating to its date.

Upon closer examination of piece 15, it appears highly likely that it is a portion of the accounts from 1788. There is a large gap in dates between pieces 6 and 7, skipping from 18 November 1788 to 23 December 1788 – over a month. It seems likely that piece 15, dated between 16 and 23 December, is a portion of the missing month's entries, fitting between pieces 6 and 7. In addition, forty-four of the fifty-one (86 per cent) unique names in piece 15 match exactly with names listed in pieces 1 to 7, suggesting with a high likelihood that the entries refer to the same location and time. Interestingly, of the fifty-one unique names in piece 15, 18 (35 per cent) could be matched exactly with at least one name listed in the Anderton material from 1790 (pieces 8 to 12), but all those 18 people from piece 15 could also be linked to pieces 1 to 7. Since more names from piece 15 could be linked with the 1788 pieces, it is most likely that it fits within that series rather than the 1790 material. For the purposes of this analysis, it has been assumed that piece 15 *does not* refer to 1792, but fits into the first series of pieces, precisely between the gap in dates between pieces 6 and 7. The handwriting on pieces 15 and 7 is also, upon visual inspection, very likely written by the same person, which provides further evidence for this reclassification. Three of the five names listed in piece 13 also appear in pieces 1 to 12, suggesting that the piece also refers to Oldknow's Anderton operations at the late date of 1792. Piece 16 is undated and so was not included in the analysis. Pieces 17 to 21 are severely damaged and did not include key information on yarn fineness or location and were not included either. Piece 22 only refers to data on winders, reelers, and slubbers, and was also left out. The pieces covered in this article are summarised below in Table 1.

[TABLE 1]

The Anderton data between 1788 and 1792 almost certainly refers to individual spinners returning their yarn production to Oldknow for payment. Importantly, each account entry in the Anderton set is attached to a specific individual (as shown in Figure 1). The relationship between the columns in Figure 1 is that the yarn production multiplied by the piece-rate is equal to the earnings. At Anderton, the consistently small quantities of yarn returned and the fact that each account entry is associated with an individual spinner's name suggests that the data most likely reflects individual-level production (see Figure 1 and Figure 2).

Of course, it cannot be said with absolute certainty that everyone listed in the Anderton accounts performed their own work. It is also impossible to infer whether others, like piecers, were working with them. In addition, we cannot disentangle the effects of coverture; for example, to ascertain whether the named spinner in the accounts received the payment for the yarn spun (for example, a man receiving the payment for his wife listed in the accounts). Nonetheless, as will be shown below, given the small and relatively uniform quantities produced it appears reasonable to assume that each account entry refers to individual-level production. The genders of these individual workers could be inferred from their first names. In total, 845 observations were compiled from worker names which could be used as a guide to infer their gender with no apparent ambiguity. That is, all the entries in pieces 1 to 7, 8 to 12, 13, and 15 were recorded except those for which worker names could not be used to infer gender (due to illegibility or incomplete entries, for example). This feature of the Anderton accounts is the principal reason why they were selected for the analysis in this article. They allow the historian the unique chance to investigate the relationships between mule-spinner gender and the piece-rates they earned by yarn count spun. They also give an indication of spinner productivity.[45] The Oldknow archives contain other sets of putting-out accounts, such as those at Stockport between 1786 and 1788.[46] However, in these accounts, it can be easily seen from the sheer amounts of yarn being produced that some of the names likely refer to

individuals running workshops comprised of multiple workers, or a household head returning an entire family's yarn production for payment.[47] Accounts like these cannot be used to understand the differences in piece-rates, production, and pay between men and women using the hand-powered mule.

(i) The Machinery Used at Anderton

The Anderton accounts do not give any indication of the type of machinery the spinners used. However, the accounts do specify the yarn counts produced, so the fact that the spinners were using the hand-powered mule can be deduced from what is known about the different machines' spinning capabilities. At Anderton between 1788 and 1792, the spinners were producing yarns between Ne 52 and 110, and the average count was Ne 80. Whether the yarns produced were wefts or warps is not stated. The average fineness of yarns returned was also increasing over time, averaging Ne 80 in 1788, 82 in 1790, and 90 in 1792.

[FIGURE 2]

By the time the accounts begin in 1788, spinning by hand methods like distaff and spindle and spinning wheel had been, at a minimum, severely reduced if not made completely redundant in Manchester and its environs. While spinners using the antiquated distaff and spindle technique could, provided they were very skilled, produce fine cotton warps, the process was very slow.[48] It was also labour intensive and therefore unrealistic and uneconomical for Oldknow to rely on spinners using this method to produce enough yarn on any scale or price necessary to produce muslins for the London market. The spinning wheel, in turn, could only be used to spin cotton wefts, with the most common counts likely between Ne 16 to 20, which was far too coarse for muslin production and below the counts spun at Anderton.[49] Therefore, it is highly unlikely that any of Oldknow's spinning suppliers were using these earlier technologies.

Hargreaves' spinning jenny could only spin cotton wefts and only at counts into the Ne 20s.[50] Thus jennies were unsuitable for producing yarns fine enough for Oldknow's cotton muslins and could not spin yarns in the observed range of counts at Anderton. Arkwright's water frame could only spin cotton warps, and could spin yarns into the Ne 60s, which overlaps with some of the observed yarn counts in the Anderton records. However, given the fact that Oldknow was engaged in a putting-out relationship with his spinners at Anderton, and the fact that individual production is reported, it is highly unlikely that the yarns up to count Ne 60s were spun in factories using the water frame.[51] The spinners were most likely using the hand-powered mule for their yarns, whether for warp or weft.

Finally, further evidence that the Anderton spinners were using the mule comes from the list of spinner names itself. A certain Henry Stones appears listed in 1788 and 1790 in the Anderton accounts. In Edward Baines' 1835 account of the genesis of the spinning mule, he described how Henry Stones improved Crompton's original 1780 machine in Horwich, a village near Anderton.[52] Stones, as noted earlier, converted the rollers to metal and applied "clockwork to move them", thereby improving the machine's efficiency, allowing mules of "100 or 130 spindles" to be used. [53]

It seems highly probable that the innovative mechanic Henry Stones was also the spinner listed as working for Oldknow at Anderton in 1788 and 1790. Stones' village of Horwich is located a mere 2.5 miles south of Anderton. Examining Stones' production, he did produce some of the finest yarns yet spun for Oldknow, with counts ranging from Ne 73 to 95. Based on Baines' account, it is probable that Stones and others at Anderton were working on mules containing 100 spindles or more to spin yarns in this range of counts. The important finding that Oldknow was likely employing one of the chief architects of the mule's design is further evidence that Oldknow's spinners at Anderton were working on hand-powered mules and that Oldknow was at the forefront of spinning technology at the time.

Gender, Piece-Rates, and Pay

(i) The Gender Division of Labour

In terms of gendered employment at Anderton, between 18 September and 23 December 1788, there were 105 different men and 11 different women supplying yarn to Oldknow's warehouse across ten different return dates. By 1790, for the period covering a similar three months (93 days, 11 different return dates) from 9 September to 10 December, there were 50 different men and 12 women listed in the accounts. In the 1792 data (piece 13), covering a short period on the return days 31 July, 3 August, and 10 August, five men and no women were listed in the accounts. This evidence suggests that by 1788, women mule spinners were already scarce, and that by 1792, they may have even ceased to be employed altogether. Though the downward trend in women's employment is notable, given the very small 1792 sample, more data would be needed to confirm more conclusively that women were no longer employed in mule spinning. Further to this, recall that piece 14, which is dated from 27 March to 7 April, is listed as referring to the year 1792 in the JRL Oldknow Papers catalogue.[54] As mentioned above, this piece was left out of the analysis as no definitive year could be found on it in writing. However, if piece 14 does indeed represent accounts from 1792, it would provide some further evidence in support of the trend observed, as all 9 account entries are of men producing yarns of average count Ne 80.

The halving of the number of men working between 1788 and 1790 is also worth examining. This may be a function of the availability of surviving evidence, but it is unlikely this explains the greater than 50 per cent average decline in recorded male mule spinners between 1788 and 1790. As mentioned, it was precisely in 1790 that Oldknow established his factory system of producing yarn at Stockport, and this may have had an impact on the demand for spinning in Anderton at the time. Oldknow was also still recovering from a short trade crisis in 1787-88 which had been triggered by a large incoming shipment of competing

muslins from India, resulting in a period of market oversupply.[55] As a result, Oldknow had likely sought to secure work from fewer spinners in the wake of the trade collapse while he still had unsold stocks of cloth sitting in his warehouse. A letter from Richard Arkwright Jr. on 19 May 1787 shows that Oldknow had sought his advice on whether to sell his Anderton warehouse in the face of the trade crisis: "You are certainly a great way from Anderton and whether it would be right to give it up or not I cannot pretend to advise."[56]

A further letter from Samuel Salte, a prominent London warehousing merchant, to Oldknow dated 25 May 1787 shows how Oldknow was planning to reduce operations at his Anderton warehouse to focus his efforts at Stockport:

> We always cautioned you against doing too much…We applaud your resolution of leaving Anderton & contracting your designs…the times and the trade are both very precarious & no man has much encouragement to venture far. We think they will be worse. Everything is over done & in consequence every article sold for loss or no Profit.[57]

Oldknow was forced to sell his Anderton warehouse around 1794 because of financial difficulties. Salte's commentary in the above letter, taken in conjunction with the trends in employment, are useful in showing how Oldknow did apparently "contract [his] designs" at Anderton in response to the crisis. This contraction of operations would be consistent with the apparent decline in the number of spinners observed in the accounts between 1788 and 1790. At a minimum, despite the shrinking overall number of putting-out workers, the Anderton data shows much more precisely how, by 1788 at the latest, male labour already dominated the hand-powered mule, prior to the factory system that developed in the 1790s. It is unfortunate that the Anderton accounts do not specify any mule spindle counts, so it is not possible to track whether they had increased by 1792.

Minoletti analysed a later spinners' production account from Oldknow's Stockport mule factory in 1793, and noted the fact that no women mule spinners were employed. Based on the 1793 data alone, Minoletti writes:

> The total absence of female spinners at the firm by 1793, gives an early indication of how the shift to a more hierarchical and formal work organisation entailed by factory production acted against the employment of women, particularly in the way that women lost access to the best-paying occupations. [58]

Centred on his interpretation of the 1793 factory data from Stockport, Minoletti discounts the traditional narrative that it was strength alone because of increasing machine size that led to a complete reduction in female mule employment. He also writes:

> Unfortunately, we do not know the number of spindles on the machines being used 1788-92, but these are provided in the 1793 data. Any possible male strength advantage due to an increase in the size of machinery cannot explain the complete absence of women by this date, since mules ranging in size from 108 to 256 were in use, so even if the largest was beyond the physical capability of women, the smallest certainly should not have been.[59]

Minoletti did not document how the gender division of labour in mule spinning remained relatively stable and heavily skewed toward men throughout the 1788-92 period, prior to the factory system. In addition, Minoletti contends that women could operate mules with spindle counts of 108 and possibly more. Burnette has argued that women could not operate mules with more than 90 spindles.[60] It is not clear, however, that either Burnette or Minoletti has definitively shown a defining spindle threshold beyond which females could no longer operate the hand-powered mule. Instead, this threshold was more likely to be a range that

depended on individual circumstances. Minoletti's claim that women could use mules with 108 spindles cannot be taken as definitive. The fact that the 1792 putting-out accounts show exclusively men certainly suggests that the rise of factory production in mule spinning cannot have been the initial cause of the demise of women as mule spinners, though the sample size is too small to draw this conclusion definitively.

Prior to the Industrial Revolution, as noted in the introduction, hand spinning had long been the most important women's employment. Arkwright's water frame factories relied most heavily on women's and child labour. Given the clear existence of a gender pay gap across the wider economy, why then would the earliest mule factories insist on hiring exclusively men? Given the history of spinning as a female-dominated employment, hiring an all-male workforce was in many ways the least obvious course of action. The reasons why women did not replace men when the mule became self-acting in the 1830s and reduced strength requirements has been debated at length, including engrained trade unionism, managerial views about men making more effective supervisors, and the high costs of switching an already entrenched organisational system. Yet if the technology were not an important factor, the earliest mule factory masters like Oldknow would have had a choice to employ exclusively women's labour instead of men. Why didn't they?

As will be discussed below, the piece-rate, yarn count, and production data from 1788 to 1792 reveals an important yet undiscussed relationship that larger mules were employed to spin the finer yarns that came to be demanded, suggesting that strength was the key factor in establishing the initial gender division of labour in mule spinning, which was ultimately carried through into the factory system.

(ii) Piece-rates, Production, and Pay

Spinners using the mule in Oldknow's putting-out arrangement at Anderton were paid at piece-rates. Surviving correspondence describes how set prices for spinning, weaving, and

winding were made under Oldknow's direction fortnightly, and applied to his Stockport and Anderton operations.[61] The piece-rate a spinner received was a function of the yarn quality he or she returned to Oldknow's warehouse. The higher the yarn count returned, the higher the piece-rate earned. Higher count yarns earned higher piece-rates not only because they were finer and more desirable, but also because, all else being equal (including the number of spindles on a mule), spinning fine yarns was a slower process that yielded less output per unit time. Finer yarns were also longer per pound of raw cotton spun. For example, spinning a low count yarn like Ne 20 would mean each pound of raw cotton would yield 16,800 yards of yarn (i.e., 20*840 yards/hank). However, spinning a fine count like Ne 80 would yield 67,200 yards (i.e., 80*840 yards/hank) per pound of raw cotton. Thus, a spinner producing count Ne 80 would have to perform the drawing action on the mule 4 times more often to spin one pound of cotton than a spinner producing Ne 20. Therefore, the piece-rate for mule spinners producing Ne 80 yarns ought to be four times higher than for mule spinners producing Ne 20 yarns. Of course, this simple picture is complicated by other factors, such as the number of spindles used per machine, a spinners' proficiency at using the machine, the differential vulnerability of different counts of yarn to breakages, and whether there were incidental workers assisting the mule spinner, usually referred to as piecers. The influence of these unknown factors is the reason why the quotient between two yarn counts does not always equal the quotient between their two respective piece-rates. That is, the piece-rate for an 80-count yarn could be more than four times higher than the piece-rate for a 20-count yarn. The critical relationship between mule size, yarn count, and strength will be developed in the next section.

In theory, if men and women working for Oldknow earned the same piece-rate for producing the same quality of yarn, then there was no direct pay discrimination and any differences in actual pay would be the result of productivity differences between them. Of

course, if men and women did not receive the same piece-rates for the same work in the first place, then any wage gap would be the result of other factors like discrimination.

[FIGURE 3]

In 1788, the primary evidence clearly shows women mule spinners working for Oldknow were not paid different piece-rates than men for producing the same yarn quality (Figure 3). Piece-rates followed a remarkably steady upward trajectory from around 5*s* per pound for Ne 60-count yarns to 15*s* per pound for Ne 100-count yarns.[62] Both men and women produced yarns along the entire spectrum of counts as well. While there were fewer women toward the upper end of the spectrum, they did produce yarns up to count Ne 100, and they were not paid differently to the men. Any differences in actual pay must have been the result of productivity differences (the amount of yarn produced). As Burnette has found across the wider economy, men and women were most often paid the same piece-rates for the same work.[63] The primary evidence from Oldknow clearly shows that this was the case in mule spinning as well.

In 1788, the evidence also shows that men were able to earn more in actual pay than women, though only noticeably above about the yarn count of Ne 80 (Figure 3). Across all yarn counts, men's actual pay averaged 25.5*s* per return, whereas women's pay averaged 27.4*s*. However, above yarn counts of Ne 80 a clear gendered pattern emerges. Above this count threshold, no women are observed earning more than 50*s* per return, whereas men could earn much higher amounts of up to 108*s*. The reasons behind men being able to earn noticeably more than women at higher yarn counts suggests that some men were perhaps more productive at spinning finer yarns. This result aligns with those displayed in Figure 2 above for the 1788-92 period, where men consistently produced more yarn than women at counts above Ne 80.

[FIGURE 4]

By 1790, a clear change had occurred at Anderton. In 1790, men were exclusively producing the finest quality yarns and earning the highest piece-rates for their work (Figure 4). Essentially, a functional gender wage gap had emerged, with men monopolising the production of the most lucrative yarns. For yarns of count Ne 90 or less, the 1790 piece-rate curve is less uniform than the 1788 curve, yet there is no apparent trend of direct discrimination against women. Men producing the highest count yarns were almost always able to earn more than women in terms of actual pay, once again suggesting higher productivity, and no women were producing yarns above count Ne 90. In 1792, there were no women producing yarns at all in the accounts, and the average yarn count had risen to Ne 90. The difference between the 1788 curve and the 1790 curve begs the question of why only men were producing the finest, most expensive yarns?

(iii) Larger Mules for Finer Yarns?

One key reason is that spinning these finest yarns came to be performed on mules with greater numbers of spindles, which required greater upper body strength to operate. Once again, the number of spindles is unfortunately not recorded in the Anderton accounts. Yet the fact that spinning the finest yarns was best performed on larger mules can be deduced from a variety of sources.

Intuitively, holding the yarn count fixed, a larger mule with more spindles has a productivity advantage over a smaller mule. This unfair advantage was recognised and was later acknowledged in the way mule spinners were paid. The fine spinning lists adopted at places like Bolton (as early as 1813) and Manchester (1829) fixed the piece-rates paid per pound of output yarn at a given count for a mule of a given size (number of spindles).[64] The lists paid higher piece-rates for finer yarns (to reflect the longer time necessary to spin them) but also discounted piece-rates for yarns of any count produced on longer mules, to reflect

the output advantage of mules with a greater number of spindles. For example, a Bolton spinning list from 1814 records piece-rates per pound for yarns of different counts spun on mules of 300 spindles. The list also clearly states that spinners producing at any count would earn "…a Halfpenny a Pound Advance upon this List for Spinning upon Mules of 252 Spindles or under."[65] Importantly, firms could not alter one price without changing the entire list. Huberman has shown that such lists, which came to predominate in mule spinning by mid-century, protected spinners from the "unremunerated intensification of their labour" and "reduced productive uncertainties for the firm."[66] The lists helped large urban millowners elicit maximum effort from their workers.

So, larger mules were more productive than smaller ones at any count. Yet as the yarn count increased to the finest end of the spectrum, there is evidence that larger mules were much better suited to spinning them. Evidence of this relationship between yarn fineness and mule size may be gleaned from Samuel Crompton's spindle census of 1811.[67] Crompton's census lists his observations of the total number of mule spindles per spinning district, which normally centres on a major town. In a well-known fine cotton spinning district like Preston, the total number of mule spindles in 1811 was 297,692, whereas in a coarse cotton spinning district like Oldham, the total number of mule spindles amounted to 196,316. However, what is needed is information on the number of spindles per mule to determine whether there was a relationship between yarn fineness and mule size. Crompton did occasionally record this information in his census. Daniels' analysis of Crompton's census shows that in fine spinning districts like Manchester, mules of 360 spindles were typical, whereas in coarse districts, mule sizes were smaller, usually around 216 spindles.[68] In the fine spinning district of Chorley, nearest Anderton, taking a weighted average of Crompton's numbers shows that the average mule contained 343 spindles. In Preston, also a fine spinning region, the average mule contained 334 spindles.[69] By contrast, in the coarse spinning regions of Oldham and

Rochdale, Crompton's census reveals average mule sizes of 255 and 266, respectively. This suggests that fine spinners generally used machines with more spindles; machines that would have required greater strength to operate.

This was the case because spinning fine yarns was less power intensive per spindle than spinning coarse yarns. That is, the ratio of spindles to horsepower was greater in fine spinning than in coarse spinning.[70] In 1824, Robert Brunton noted that:

> One horse's power, at a medium, is calculated to drive 500 spindles, with preparation of, mule yarn, no. 48. Ditto ditto 1000 spindles, with preparation of, mule yarn, no. 110. – The intermediate numbers in proportion.[71]

This means that, as fine spinning was less power intensive but more time consuming than coarse spinning, a larger mule with more spindles made more economic sense to use. A larger mule could produce more yarn to compensate for the longer amount of time it took to spin finer counts. In 1834, George Murray, the owner of one of the largest fine cotton spinning mills in Manchester reported that "…he doubted whether it would be possible to apply such large mules as now used in fine spinning to coarse spinning."[72]

However, it is important to remember that Crompton's census was taken in 1811, and that Brunton's and Murray's observations were written in 1824 and 1834, all more than 20 years after 1790, when the shift in piece-rate curve is observed in the Oldknow data. The mules described by Brunton and Crompton would have been assisted by steam power in the action of drawing the carriage back and forth. In 1790, Oldknow's mule spinners would have been working on purely manually powered machines at Anderton. On a fully manual machine, it is possible that if a spinner possessed the requite strength, a larger mule with more than 100 spindles could be more readily used to spin the finest yarns.

Maw et. al have shown that the average size of a mule around 1790 was in the region of 100 spindles, but that mules grew rapidly in the 1790s to average over 200 spindles by the time of Crompton's census in 1811 (probably around 216, as Daniels reported).[73] Assuming it is true that spinning the finest yarns typically came to use larger than average mules, Maw et. al's results and Crompton's census imply that around 1790, above average size mules would have been used to spin the finest yarns – mules containing more than 100 spindles. The presence of Henry Stones in the accounts – whose improvements increased mule sizes to up to 130 spindles, adds strength to this conclusion. While the precise spindle threshold beyond which women could no longer operate the hand mule remains impossible to determine with certainty, the fact that no women are observed using mules of 108 spindles or more in the 1793 Oldknow data may support Burnette's claim that 90 spindles was the upper limit.

A final piece of important evidence comes from the piece-rate lists discussed briefly above, which came to dominate mule-spinning by the mid-nineteenth century. Prior to the adoption of fixed price lists like the Manchester list (1829), piece-rates increased with a yarn's count, regardless of the length of the mule (the number of spindles). This meant that for any given count, a spinner operating a larger mule could earn more, given the output advantage of having more spindles. As discussed, urban mule-spinning firms eventually incorporated a system of discounting into their piece-rate lists, so that spinners working on smaller mules would not be disadvantaged if firms decided to increase the quality of their output. Given that Oldknow's piece-rate system did not account for the size of mules, and that the upper body strength limit for women appears to be roughly 90 spindles, then it follows that men would seek to spin the finest, most lucrative yarns on the biggest mules possible to reap the rewards in terms of greater output. The fact that some women were spinning yarns above count Ne 90 in 1788 but none in 1790, suggest that machine size had increased for spinning the finest

counts, and that strength had become a key factor in terms of productivity. Larger mules had a clear productivity advantage over smaller mules at any count produced, but what has not been discussed in the literature is the advantage that larger mules had for spinning yarns of finer counts. This is crucial to understanding the productivity and pay advantages that men built up as finer yarns became demanded in the market.

The increasing demand for luxury fabrics like muslins in the late 1780s and 1790s also strengthens the case that manufacturers like Oldknow had to adopt larger mules to produce the finest yarns most effectively. As mentioned in the second section, Oldknow had shifted his production mix in response to this general increase in demand for fine cottons. While there had been a short trade crisis in 1787-88, the market had recovered by 1789 and demand, especially for the finest muslins, grew rapidly.[74] By 1789, muslins accounted for around 90 per cent of Oldknow's yarn production and sales.[75] In the late 1780s, in response to the crisis and the perceived threat from Indian muslin imports, British muslin manufacturers had pressured Parliament for protection against Indian competition in muslins. Parliament instituted a duty of nearly 100 per cent on Indian muslins in response, effectively shutting them out of the British market.[76] This constraint on Indian supplies at the end of the 1780s likely gave Oldknow the impetus to increase fine muslin production and adopt larger mules to meet the demand previously supplied by competitive Indian imports. The timing of the demand-side story aligns well with the changes to the piece-rate curves observed in Figures 3 and 4.

Therefore, the evidence points to male strength being an important factor behind female exclusion from producing yarns above counts of around Ne 90 or more. As the demand for fine yarns increased, the average mule size increased as well, but what has not been well identified is that the finest yarns were more easily done on the largest mules – lending a significant comparative advantage to men.

Another possible explanation of the increasing exclusion of female spinners could be collective action between the male spinners to monopolise control over the production of the finest yarns. However, there is no evidence to suggest that the mule spinners working for Oldknow's Anderton warehouse had formed an exclusionary union as early as 1788. While mule spinners' unions did grow from the 1790s onward, the earliest evidence for male spinners forming unions to protect their interests is for Stockport spinners in 1792.[77] Instances of male spinners using violence to exclude females from employment are not documented until the nineteenth century.[78] The primary evidence from Oldknow's accounts clearly suggests that strength was the factor that initially shifted mule spinning employment toward men in the late 1780s.

Conclusion

This detailed case study of an important industrial innovator, Samuel Oldknow, has demonstrated when and how the spinning mule, the most important spinning technology of the Industrial Revolution, became the enclave of male labour. There was a highly gendered transfer in the division of labour. Women's pre-eminence in traditional hand spinning was overturned in a short number of years, narrowly predating the concentration of spinning in factories. The analysis of Oldknow's unusually detailed records shows that the relationship between larger mules being used to spin finer yarn counts has not been sufficiently explored or acknowledged in the literature. That is, mules with more spindles were used to spin finer yarns, which could generate more lucrative pay for the spinner. The fact that payments were not discounted for production on longer mules also favoured men. It gave men a potential incentive to spin the finest yarns, which happened to be done most easily on longer mules which required a level of upper body strength that was unattainable for most women.

This previously unstudied relationship has a direct implication for the strength requirements needed and explains why a functional gender pay gap began to emerge in the

late 1780s. It also confirms Burnette's theory as to why men came to dominate mule spinning. Crucially, and to reiterate an important finding, the shift toward male dominance in mule spinning likely predated the factory system, with this large mule-fine yarn nexus providing a clear explanation for the trend. So, while gender ideology and trade unionism may have been crucial in *cementing* the occupation as male, the initial dynamic that led to male dominance was based on strength. Of course, a question for future study is why men were employed at all on the very first mules. In addition, more research is needed on why the shift toward male dominance persisted into the factory system and mule spinners retained their semi-independence. When analysing the gender-wage dynamics of Industrial Revolution era technologies, understanding the technicalities of each machine and their respective systems of payment becomes key.

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Figure Legends

m = male (black dots)

f = female (white dots)

Units

lbs = pounds

oz = ounces

Ne = Yarn Count

£ = pounds

s = shillings

d = pence

Figure Captions

Figure 1: Anderton accounts sample photo, JRL, SO/4/2. Columns from left to right: Spinner name; Production (lbs, oz); Yarn count (Ne); Piece-rate (s, d); Earnings (£, s, d). Copyright of The University of Manchester.

Table 1: Anderton accounts summary. Source: Data from JRL, SO/4/2. *Piece 15, originally catalogued as referring to 1792, has been reclassified based on the analysis of names and dates conducted to refer to December 1788. In terms of date order, it fits between pieces 6 and 7. Piece 14 has been omitted.

Figure 2: Yarn quantities returned by count, Anderton, 1788-92. Source: Data from JRL, SO/4/2.

Figure 3: Piece-rates and actual pay by gender, Anderton, 1788. Source: Data from JRL, SO/4/2. Lines intended as a visual guide to demonstrate the gendered nature of earnings at higher yarn counts (Ne).

Figure 4: Piece-rates and actual pay by gender, Anderton, 1790. Source: Data from JRL, SO/4/2. Lines intended as a visual guide to demonstrate the gendered nature of earnings at higher yarn counts (Ne).

[1] Muldrew, "'Th'ancient Distaff' and 'Whirling Spindle'," 498; See also Berg, *The Age of Manufactures*, 144-149; Valenze, *The First Industrial Woman*, 68-112. At the time of writing, a new working paper has expanded upon Muldrew's findings, showing that perhaps 20 per cent of women and children spun for at least part of the year around 1770. See Schneider, "Technological Unemployment in the British Industrial Revolution".

[2] Catling, *The Spinning Mule*, 34-42.

[3] A recent debate has focused on the productivity and wages of hand spinners, and whether Britain had a unique "high wage economy" that incentivised the invention of spinning machines like the jenny. For the "high wage economy thesis", see Allen, *The British Industrial Revolution*; "The Industrial Revolution in Miniature";

"Spinning Their Wheels". In response, see Humphries and Schneider, "Spinning the Industrial Revolution"; "Losing the Thread".

[4] Warp yarns are the threads which run the length (of the fabric) on the loom and are interlaced with the weft threads to form the fabric. Warps must be stronger than wefts, as they are stretched horizontally under tension on the loom.

[5] See Fitton and Wadsworth, *The Strutts and the Arkwrights*, 12-13 for a rich discussion of Paul and Wyatt's attempts at roller spinning before Arkwright.

[6] Farnie, "Cotton, 1780-1914," 723.

[7] For yarn count symbols, see Denton and Daniels, *Textile Terms and Definitions*, 403. In this article, the symbol Ne_c has been abbreviated to Ne. For a comprehensive summary of the different yarn count systems used across various fibre types since the Middle Ages, refer to Jeremy, "British and American Yarn Count Systems," 336-368.

[8] Catling, *The Spinning Mule*, 42.

[9] Baines, *History of the Cotton Manufacture*, 201.

[10] Baines, *History of the Cotton Manufacture*, 202.

[11] Marsden, *Cotton Spinning*, 226-227.

[12] Tunzelmann, *Steam Power and British Industrialization*, 241-244.

[13] Maw et al., "After the Great Inventions," 39.

[14] Lazonick, "Industrial Relations and Technical Change," 231-262; Freifeld, "Technological Change and the 'Self-Acting' Mule," 319-343; Huberman, *Escape from the Market*.

[15] Burnette, *Gender, Work and Wages*, 171.

[16] Minoletti, *The Importance of Gender Ideology and Identity*, 69.

[17] Minoletti, "The Importance of Ideology," 121-146.

[18] For more information on the imitation of Indian muslins in Britain in the eighteenth and nineteenth centuries, see Raman, "Indian Cotton Textiles and British Industrialization," 7-26.

[19] Howe, "Oldknow, Samuel (1756–1828), Cotton Manufacturer," https://www.oxforddnb.com/view/10.1093/ref:odnb/9780198614128.001.0001/odnb-9780198614128-e-37821.

[20] Unwin, *Samuel Oldknow and the Arkwrights*, 2.

[21] Unwin, *Samuel Oldknow and the Arkwrights*, 30-32.

[22] Daniels, *The Early English Cotton Industry*, 123-124.

[23] Styles, "Re-fashioning Industrial Revolution," 60.

[24] Wrigley, *Energy and the English Industrial Revolution*, 62-63. Calico cloths were often referred to as "callicoes" at the time.

[25] Unwin, *Samuel Oldknow and the Arkwrights*, 7-20; For more information on the London sales system at the time, see Maw, "Provincial Merchants in Eighteenth-Century England," 568–618.

[26] Unwin, *Samuel Oldknow and the Arkwrights*, 69-71.

[27] Edwards, *The Growth of the British Cotton Trade*, 5.

[28] Unwin, *Samuel Oldknow and the Arkwrights*, 69-70.

[29] Unwin, *Samuel Oldknow and the Arkwrights*, 130-131.

[30] Baines, *History of the Cotton Manufacture in Great Britain*, 202.

[31] Unwin, *Samuel Oldknow and the Arkwrights*, 44, 244.

[32] For a detailed account of the difficulties embezzlement and quality standards in the putting-out system, see Styles, "Spinners and the Law," 145–170.

[33] Letter from Samuel Salte to Samuel Oldknow, 10 May 1786, quoted in Aspin, *The Water-Spinners*, 31.

[34] See Letter quoted in Unwin, *Samuel Oldknow and the Arkwrights*, 95.

[35] For a detailed account, see Fitton and Wadsworth, *The Strutts and the Arkwrights*, 81-86.

[36] Maw et al., "After the Great Inventions," 36, Figure 6.

[37] There is clear evidence that from 1787, Oldknow increasingly sourced finer-spun warps from spinners using mules at Stockport. See Tertzakian, *Wages, Employment, and Technological Change*, 190-197. This supports Maw et al.'s conclusions on the timing of diffusion of the mule. See Maw et al., "After the Great Inventions," 36. See also Sugden, "An Occupational Study," 160 for more evidence on the timing of diffusion.

[38] Fitton, *The Arkwrights*, 237.

[39] Fitton, *The Arkwrights*.

[40] The date when Oldknow's Stockport steam-powered spinning mill began producing remains uncertain. See Unwin, *Samuel Oldknow and the Arkwrights*, 128.

[41] Fitton, *The Arkwrights*, 237.

[42] For information on the evolution of Oldknow's warehouses, see the Royal and Sun Alliance Insurance Group records at the LMA, items CLC/B/192/F/001/MS11936/326/500894, CLC/B/192/F/001/MS11936/345/531757, and CLC/B/192/F/001/MS11936/376/582836. Tertzakian, *Wages, Employment, and Technological Change*, 190-191.

[43] JRL, item SO/4/2, Accounts, 1788-1792.

[44] See Oldknow Papers Catalogue, JRL: https://archiveshub.jisc.ac.uk/search/archives/10ef722a-c2e8-31a3-a761-8b29dd307e49?component=8bb316b1-0376-3d78-985e-d7eca4ff8556

[45] Accurately calculating productivity is complex. Productivity is usually measured as output per unit of time. As the Oldknow records only give the dates of yarn returned to Oldknow's warehouse, it is not possible to determine the actual time that individuals took to produce their mule-spun yarns. The actual pay earned by spinners only gives an indication of their productivity. Future research is planned on the workings of the putting-out system, including estimating spinner turnaround times.

[46] See JRL, SO/4/1, Ledger, 1786-1788.

[47] For a detailed analysis of the 1786-88 Stockport Accounts, see Tertzakian, *Wages, Employment, and Technological Change*, 186-197.

[48] Singer et al., *A History of Technology*, 202.

[49] Chapman, *The Cotton Industry in the Industrial Revolution*, 21.

[50] Chapman, *The Cotton Industry in the Industrial Revolution*; See also Aspin and Chapman, *James Hargreaves and the Spinning Jenny*, 44; Styles, "The Rise and Fall of the Spinning Jenny," 14, Figure 6.

[51] While it is known that Oldknow had a supply agreement with water frame spinners like Arkwright Jr. from 1786 until at least 1787, there is no evidence that any of the names listed in the Anderton accounts were linked with his distant factories in Derbyshire (including Lumford Mill in Bakewell and Cromford Mill). Given the individual nature of the Anderton records, it is highly unlikely that they contain the production or payment data of water frame warps supplied by Arkwright Jr. See Tertzakian, *Wages, Employment, and Technological Change*, 184-185 and chapter 2 for further discussion and an analysis of Lumford Mill.

[52] Baines, *History of the Cotton Manufacture in Great Britain*, 201.

[53] Baines, *History of the Cotton Manufacture in Great Britain*.

[54] See https://archiveshub.jisc.ac.uk/search/archives/10ef722a-c2e8-31a3-a761-8b29dd307e49?component=8bb316b1-0376-3d78-985e-d7eca4ff8556

[55] Unwin, *Samuel Oldknow and the Arkwright*, 96.

[56] Quoted in Unwin, *Samuel Oldknow and the Arkwrights*, 89-90.

[57] Unwin, *Samuel Oldknow and the Arkwrights*, 90.

[58] Minoletti, *The Importance of Gender Ideology and Identity*, 69, see footnote 37. It appears Minoletti incorrectly referenced this document at SO/4/3, which refers to an 'Output Book' covering May 1790 to

October 1791. This book does not include any information on mule spinning or individual mule spinners. The book Minoletti must have meant is SO/4/4, a 'Spinners' production account' from March to December 1793, which records weekly and fortnightly spinning production at Oldknow's Stockport mill. The book lists spinner name, spindles, yarn weight, yarn counts, and hanks.

[59] Minoletti, *The Importance of Gender Ideology and Identity*, 69-71.

[60] Burnette, *Gender, Work and Wages*, 40.

[61] Unwin, *Samuel Oldknow and the Arkwrights*, 50.

[62] Note that the 15s./lb piece-rate for 100-count yarns is more than 1.67 (100/60) times higher than the 5s./lb piece-rate for 60-count yarns, probably because of the factors described on the previous page.

[63] Burnette, *Gender, Work and Wages*, 93.

[64] Huberman, *Escape From the Market*, 134-36; Huberman, "Industrial Relations and the Industrial Revolution," 371-376.

[65] BALS, ZZ/220/1.

[66] Huberman, "Industrial Relations and the Industrial Revolution," 372.

[67] BALS, Crompton Papers, Spindle & Enquiry Papers (1811), ZCR/16A, ZCR/16B.

[68] Daniels, "Samuel Crompton's Census of the Cotton Industry in 1811," 110.

[69] Atwood, "Localization of the Cotton Industry in Lancashire, England," 194-195.

[70] Tunzelmann, *Steam Power and British Industrialization*, 186.

[71] Brunton, *A Compendium of Mechanics*, 98.

[72] B.P.P., 1834 (167) XIX, 119 *h*.

[73] Maw et al., "After the Great Inventions," 40.

[74] Unwin, *Samuel Oldknow and the Arkwrights*, 103.

[75] See Berg, "Quality" in *How India Clothed the World*, eds. Riello and Roy, 407; Unwin, *Samuel Oldknow and the Arkwrights*, 244.

[76] For a detailed discussed of competition with Indian muslins at the time and protectionist policies, see Parthasarathi, *Why Europe Grew Rich*, 130-131. See especially chapters 4 and 5. See also Riello, *Cotton*, chapter 10.

[77] Smelser, *Social Change in the Industrial Revolution*, 318-320.

[78] See for example Burnette, *Gender, Work and Wages*, 1-3.