Product Design and Cost Considerations: Clock, Watch, and Typewriter Manufacturing in the 19th Century

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This paper examines three products-- wooden movement clocks, watches, and typewriters-- to illustrate the heretofore overlooked importance of product design in 19th century manufacturing. It does this within the context of the scholarly debate on the rise of the American System of Manufactures.[1]

Nineteenth century mechanics and entrepreneurs were acutely aware of cost considerations in manufacturing. They designed products to be adjustable as an integral part of the manufacturing process due to the nature of the product itself and the materials with which they worked. They were driven by a technological imperative-- the product and its materials-- to lower cost through product design.

Mechanics and entrepreneurs used new designs to enter existing markets and compete with existing designs, thus creating such new industries as typewriter and watch manufacturing. These new industries followed similar development patterns, characterized by the appearance of a host of new firms with new products, intense competition, and the evolution of the industry from a highly competitive one to an oligopoly dominated by large firms with successfully designed products.

The American System Debate

Merritt Roe Smith fired the first shot in the debate on the origin of the American System with his prize-winning book, *Harpers Ferry Armory and the New Technology* [3]. Smith's study followed the evolution of fire arms manufacturing at a federal armory during the first half of the 19th century. According to Smith, the American System originated in the federal armories-- the public sector.

David Hounshell takes up the "Armory Practice" banner in his prize-winning book, *From the American System to Mass Production* [1]. Hounshell also believes the American System originated in the federal armories (hence the term "Armory Practice") and then spread through the migration of armory-trained mechanics to the private sector, notably in sewing machines, reapers, bicycles, and automobiles. His survey of the literature is exemplary and the technical accounts of manufacturing processes are excellent.

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[1] The data in this paper is drawn directly from my *Ingenious Yankees; The Rise of the American System of Manufactures in the Private Sector*, (New York: Columbia University Press, 1989). The reader is directed to that work for primary source citations.

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Smith and Hounshell have generated a paradigm for interpreting the rise of the American System-- government subsidized R&D that created a body of knowledge called "Armory Practice" followed by the appropriation of that technology by the private sector for its own enrichment. As David Noble has summarized [2, p. 337]:

> As is well known, the uniformity system developed in the armories became the basis of the so-called American system of manufactures, characterized by special machinery, precise gauges, and interchangeability of parts. Men left the arms business to set up the machine tool industry and went on from there to carry the principle of uniformity into the manufacture of railroad equipment, sewing machines, pocket watches, typewriters, agricultural implements, bicycles, and so on. The rest, as they say, is history, the history of progress.
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> But there was another side to this story, which we have not heard much about.

There certainly is! My own book on the American System focuses on developments in the private sector. My interpretation of the rise of the American System differs quite sharply from that of Smith and Hounshell.

The American System is primarily and overwhelmingly a *private sector phenomenon*. American private sector manufacturers held the technological lead in America throughout the 19th century and shared it only briefly (between 1820 and 1840) with the federal armories. While private sector manufacturers certainly derived some benefit from the technical developments in the federal armories, they developed new products, new methods, new materials, new sales and promotion techniques, and new designs without any federal subsidy.

One especially important aspect of the American System's development in the private sector is product design, a topic notably absent from my good friend David Hounshell's work. For example, he gives us the clearest, most concise description of Ford's production technology, but never once considered how the Model T's design changed between 1908 and 1927 and how those design changes influenced manufacturing technology and costs.

This paper examines two aspects of product design as it influenced the American System of Manufactures:

a) at the microeconomic level-- cost cutting.

b) at the industry level-- competition and patterns of industry development.

Cost Cutting

Cleverly designed products, particularly products *designed to be adjusted as an integral part of the manufacturing process*, cut final product costs by increasing the range of acceptable tolerances on many parts and reducing the assembly time required by including adjustable features that permitted the use of those parts with wider tolerances and eliminating the need to alter the parts themselves. During assembly, only the relationship between the parts changed, not the parts. Three 19th century products, wooden movement clocks from the antebellum period, and typewriters and watches from the postbellum period, illuminate this concept.

Wooden Movement Clock Design

The manufacture of hang-up or wag-on-the-wall clocks began in 1807 with the pioneering work of Eli Terry. In 1814 Terry invented a shelf clock that he perfected over the next few years. It was eventually manufactured in great quantities by over twenty different makers. The new shelf clock differed in many ways from its hang-up clock predecessor, most notably in its escapement, the device that regulates the clock's speed. The escapement is the most critical part of a wooden movement clock, the only part requiring a truly close fit. The escapement wheel and the verge must be properly "depthed" (located in relation to each other) in order to run properly. Depthing was a problem with Terry's 1807 hang-up clock, but not with the new shelf clock-- it featured an *adjustable escapement.*

Terry's new shelf clock design brought the escapement outside the clock plates. The escape wheel arbor was carried through a hole in the top plate and was supported by a bridge. Beneath it, the verge was mounted on an iron pin set off-center in a brass plug. To depth the escapement, the assembler had only to apply some pressure to the escape wheel, then turn the plug carrying the verge until the verge was in the proper position with respect to the escape wheel. Then the brass plug was nailed into place. In the late 1830s brass clock makers adopted this design. Indeed, the adjustable escapement remained a feature of American clocks through the 1920s.

The economic implications of this design are important. This design allowed clock makers to produce parts within a wider range of tolerances and to bring each clock "into beat" quickly and easily by adjusting the relative positions of the verge and the escape wheel, not altering the parts themselves but their relative positions. The same is true with watches and typewriters.

Watch Design

Like wooden movement clocks, watches required properly adjusted escapements to keep time. However, they were more complex and precise, requiring a more sophisticated approach than the clumsy wooden movement clocks.

Watches were routinely adjusted as an integral part of their manufacture. This is particularly true with the escapement and balance. A discussion of this mechanism, its assembly, and its adjustment will illuminate the extent to which all American System manufacturers and watch manufacturers in particular were driven by the nature of their products and the materials with which they were made to adopt particular technologies.

Waltham and most American watch manufacturers used the detached straight line lever escapement with a club-tooth escape wheel and an escape lever with jeweled pallets. Similarly, most manufacturers used a temperature compensating (cut), bimetallic balance with timing and poising screws in its rim and a blued steel (hardened and tempered) hairspring.

The entire mechanism consisted of the escape wheel and its arbor, the escape lever and its arbor, two pallet stones, two banking pins, a guard pin, the roller (and sometimes a double roller), roller jewel, balance staff, hairspring, hairspring collet, hairspring stud, hair spring stud screw, hair spring regulator, balance wheel, and up to twenty-two timing and poising screws (and perhaps timing washers), the cocks and screws to hold the escapement, and the end stones and hole jewels and jewel screws-- as many as fifty-six individual parts depending on the model. This was a complex precision mechanism.

"Matching the escapement" was a particularly skilled job, as the watch's performance depended greatly on the relationship between the escape wheel and the escape lever with its jewels. "Matching the escapement" consisted of cementing the pallet jewels into the pallet fork using heated shellac with special hand tools in an alcohol lamp flame. Despite the production of escape wheels and forks and jewels to precise standards, each had to be matched independently during the process of assembly. The pallet fork and its jewels were designed to be adjusted as an integral part of that assembly.

Watch manufacturers never automated the assembly and adjusting phases of production. Depending on the model and grade, adjusting could take up to five months. In the higher grades, adjusting consisted of timing the watch in six positions-- pendant up, pendant down, pendant sides, dial up, dial down-- in temperatures ranging from 38° to 95°, and adjusting for isochronism.

The adjusters could make as many as eleven adjustments in the process of escapement assembly. These include:

1) placement of the two pallet stones in the escape lever,
2) adjusting the two escape lever banking pins,
3) placement of the roller jewel in the roller table,
4) placement of the roller table on the balance staff,
5) placement of the hairspring collet on the balance staff,
6) adjusting the effective length of the hairspring with the regulator lever,
7) adjusting the placement of the balance jewels (hole jewels and end stones),
8) adjusting the timing and poising screws (may include adding timing washers or undercutting screws),
9) bending the guard pin on the escape lever,
10) repositioning the hairspring in its stud, and
11) raising & lowering the hairspring stud.

The watch escapement and balance was undoubtedly the most precise assembly produced by American System manufacturers in the nineteenth century. Typewriters, however, were more complex.

Typewriter Design

The most important performance criterion for typewriters was "perfect alignment," the degree to which the lower edges of the letters line up when typed. Typewriter manufacturers realized that their extremely complex product required adjustment to accomplish "perfect alignment," and they designed adjustability into their machines.

The design ingenuity in the Remington typewriter is evident in the typebar hanger, which was secured with a machine screw. Another clever design aspect of the typebar hanger was its reversibility. The same hanger suspended all the typebars, but, to provide clearance for the typebar arms, every other hanger was installed at 180° from the hanger on either side of it.

This is not the only Remington typebar adjustment. Another adjustment was the steel wire connecting the typebar to the key lever. This adjustment assured that the keys on the keyboard could be adjusted to the same height without affecting the typebars themselves. The Remingtons advertised their earliest machines, the *Sholes & Glidden*, as being adjustable by the user.

> If any type should get a trifle out of alignment, a gentle pressure against the inner end of the type-bar, one way or the other, as may be needed, will put all right again. If a type should get radically out of place, it can be adjusted by loosening the screw of its hanger-bearing, but this should not be attempted till one is fully familiar with the machine.

The Remingtons developed special tools to insure the proper alignment of the type, notably a special typebar adjusting fixture, which insured that when the type was hung in its hanger, each type would strike a common point. The typebar ring was placed in a frame supported on four legs, similar to the typewriter's top plate. The typebars hung as they would when finally assembled. Across the back of the fixture was an adjustable iron bar on which was mounted an indicating arm which marks the center point of the typebars.

Despite specialized machinery, a gauging system, and its dedication to the interchangeable system, the American Writing Machine Company also found it necessary to build adjustability into its writing machine, the *Caligraph*. The examination of a *Caligraph* reveals four separate adjustment points between the steel type face and the wooden type lever. First, there was a turn buckle joining the "Long Connecting Rod" with the "Short Connecting Rod" between the typebar and the wooden type lever, allowing each bank of keys to be adjusted to a single height. Second, there was the typebar hanger, held in place by the "Hanger Washer" and a machine screw. Third, the typebar and its hanger featured adjustable conical bearings to take up wear. Fourth, each type was forced into a tapered hole in the steel block brazed onto the end of the typebar. Additional *Caligraph* adjustments included the rack, dog, carriage tension, paper feed, ribbon feed, and finger-key tension adjustments.

The complexity of the typewriter and its thousands of moving parts forced typewriter mechanics to develop "exercising machines" to manipulate these mechanisms mechanically before final adjustment and aligning. This idea of making parts work together during the manufacturing process appears not to have been unique to the typewriter industry, but apparently was not widely practiced. Only a sewing machine manufacturer, Wheeler & Wilson, is known to have adopted the practice of "breaking in" its machines with a machine as a step in the manufacturing process [1, pp. 68, 75].

The American Writing Machine Company exercised its *Caligraph* typebars in 1886 before final assembly. The typebar and hanger assembly was screwed into place on a "Working Jack" as it would be later in the machine itself. A reciprocating rack and pinion arrangement rapidly moved the typebars, forcing the bearings to wear into each other. The result was to "obtain an accurate and easy movement of the type bars when . . . inserted in the machine." In 1903 the "Oliver Exerciser" worked the completed machine rather than a particular sub-assembly. After it was "exercised," each Oliver typewriter was again subjected to another rigid inspection and alignment. In 1924 the L. C. Smith & Bros. "Typebar Exerciser" worked each ball bearing typebar for two hours, the equivalent of 36,000 keystrokes, before the typebar was assembled into the machine. Even the Hall Type Writer Company, which produced an inexpensive index or indicator machine, used a special "device for easing the 'motions,' that they may run smoothly."

The complexity of the typewriter forced typewriter mechanics to organize their factories to accommodate the assembly, adjustment, and alignment of the machine. Each sub-assembly took place in a separate department. As early as 1886 the Remington factory had at least three different departments, an assembly department for "Putting in Connecting-rods and Levers," an "Aligning Room," and an "Adjusting Room."

In 1906 shortly after its "recent enlargement," the Remington Typewriter Company's new factory was divided into production and assembly sections. Production required 70 percent of the factory complex. The remaining 30 percent was used to assemble, adjust, and inspect the individual machines. In Remington's "great machine hall" some 3,000 machines were in process of assembly at any one time by "several hundreds of skilled assembling experts." "After receiving a registered number," the machine "rapidly [grew] . . . to a frame . . ." The various components of the machine (the type basket, carriage, ribbon mechanism, etc.) were added at various stages of the assembly process as the increasingly complete machine progressed through the factory. There were several sub-assembly areas in which the various components were assembled, while some minor assemblies were put together in the production wing. After its assembly, the machine was ready for its first adjusting, followed by its second or "touching up" alignment, and then its "ordeal of final inspection and adjustment." "Seldom [was a machine] passed without criticism."

Significantly, in 1906 the Remingtons illustrated their promotional literature with only three production machine illustrations and six assembly and adjusting illustrations. Assembly and adjusting and aligning were the highly skilled, labor intensive aspects of typewriter manufacturing at

Remington in the early 20th century. Interestingly, they seem to have approached the concept of an assembly line-- the typewriters moved down the length of the building as they gradually grew from frame into completed machine -- and perhaps William K. Jenne (who designed the factory and much of its machinery) considered such an idea only to discard it due to the problems of intricate assembly. Perhaps in the interest of quality, assembly was not rushed.

The Oliver Typewriter Company also developed an extensive assembly, adjustment, and alignment organization in its Woodstock, Illinois factory. Their organization consisted of at least six separate departments: Type Bar Department, Carriage Department, Assembly Department, Tabulators and Adjustment, Inspection Department, and Aligning Room.

L. C. Smith & Bros. divided their factory into production and assembly departments. They divided the assembly process according to the parts and mechanisms of the machine itself. Each department employed many operatives for each assembly. At least forty men assembled ball bearings into the typebars. Each machine passed through a series of ten assembling departments and "in each department certain parts [were] added until finally the machine [was] complete."

The need for adjusting assembled and aligned typewriters continued at least through the early 1950s. In the Royal Typewriter Company's factory in 1954 the final adjuster was an especially skilled person who adjusted only three or four typewriters per day.

Like other private sector American System manufacturers, the typewriter industry faced a technological imperative in producing its machines. The typewriter had special assembly problems, problems that were related to the nature of the typewriter itself, not the process of manufacturing its various parts.

All the manufacturers faced the problem of assembling, aligning, and adjusting a very complex mechanism. All the manufacturers responded by subdividing the assembly process into the various components of the typewriter and hiring vast numbers of highly skilled people to do the complex assembly, adjusting, and aligning work.

Competition and Patterns of Industry Development

Product design played an important part in bringing competitors into an industry. In the case studies of wooden movement clocks, and particularly watches and typewriters, a familiar pattern repeats itself. Once the pioneering firm had created a market by manufacturing and selling its product, other firms began to compete, usually with newly designed products. The typewriter industry provides the best illustration of this phenomenon.

The variety of new typewriter designs that appeared following the Remingtons' pioneering work is astounding, not to mention the firms that simply copied the Remington designs. Between 1873 and 1890 some twenty-four new firms appeared. Between 1890 and 1900 another twelve tried their luck in the typewriter market. In 1900 there were thirty-seven typewriter companies in addition to the twenty-five that had already failed. Most firms were based on new typewriter designs, and most failed after a few years, often due to unworkable designs. Yet out of the chaos of newly invented typewriters came the new designs (visible writing) that were to change the typewriter industry and provide new corporate leadership. By 1910 such firms and L. C. Smith & Bros., and especially Underwood, had wrested design leadership from Remington.

Product design quickly became an advertising tool used to compete with existing manufacturers. New firms often advertised their newly designed typewriters as superior to the old designs. For example, its multiple adjustments were an important advertising point for the American Writing Machine Company and its *Caligraph*. The firm took special pride in promoting its adjustable features, notably the typebars, both in its advertising and its instruction manuals.

> DURABILITY. This is an important consideration, as writing machines are expensive and subject to continuous use and in this respect we claim the *Caligraph* is far ahead of all competing Machines. Its type-bars are adjustable, and in event of any lost motion in the journals, it can be taken up easily, no other machine possesses this unquestioned advantage. The paper feed bands on the *Caligraph* are of tempered steel and always adjustable, a great improvement over machines using rubber bands for this purpose [the *Sholes & Glidden* and the *Remington Nos. 1 & 2*].
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> ALIGNMENT. The following cut, which represents the new type-bar hanger, has an adjusting screw and shows how the wear can be taken up, from time to time, by the operator. Remember this is the only machine that can be aligned by users, and shows the best work under hard strain and rapid manipulation. The parts which move, in any kind of machinery, will wear. The faster they move the faster they wear. This is common to all; and the *Caligraph* alone is adjustable. Look out for durability!

There were other factors in the rise and fall of many of the new firms, including capital resources, marketing expertise, management quality, and patent conditions. Nevertheless, the workability of new typewriter designs played perhaps the most important roll. Those firms with exceptional product design-- Royal, Underwood, and L. C. Smith & Bros.-- succeeded, while no firm with a poor design survived.

Conclusion

The American System is primarily and overwhelmingly a *private sector phenomenon*. Although private sector firms briefly shared the technological lead with federal armories in the 1820-1840 period, the armories soon stagnated and the technological action quickly shifted to the private sector. Many private sector industries shared a common technological ground with the armories, but they quickly expanded to include areas far outside "Armory Practice." This paper stresses the importance of looking at 19th century objects to interpret business and technological history. Product design, notably adjustability as an integral part of the manufacturing process, is an important idea that must enter the debate on the rise of the American System.

Just for fun, lets take this concept of product design and adjustability and suggest a reinterpretation of a small piece of David Hounshell's work, his bicycle chapter in *From the American System to Mass Production*. Our sharply different perceptions lead David and me to interpret the same data in very different ways. David's outstanding chapter provides historians with the first detailed history of bicycle manufacturing. "Clearly," says Hounshell, "the bicycle industry as a staging ground for the diffusion of armory practice cannot be overemphasized" [1, p. 8]. But what Hounshell describes instead is a private sector industry that initially used *some Armory Practice* but which then quickly departed radically from it to develop and adopt new technology. Such techniques as electric resistance welding for wheels, the manufacture and use of seamless steel tubing for bicycle frames, and the development of presswork are all outside the "Armory Practice" experience. Furthermore, the bicycle's frame and wheels and chain were specifically designed to be adjusted as an integral part of the manufacturing process. Even such assembly tools as Pope's wheel truing stand were described as "adjustable all over." One could argue convincingly that Pope's manufacturing process parallelled other private sector manufacturers (such as typewriters and watches), particularly in responding to the technological imperative of the bicycle. Pope was forced for technical reasons related directly to the nature of the bicycle to develop and adopt particular (non-"Armory Practice") technologies.

Following Pope's creation of the bicycle industry in 1878 and the expiration of his patent protection in 1886, competing firms rapidly entered the bicycle market. Predictably, many chose to produce cycles that were, by Pope's definition, "awfully cheap looking." Yet these new cycle manufacturers with their innovative press work and stamping techniques captured a greater share of the cycle market. Notice particularly that press work and stamping are not "Armory Practice." They were new techniques developed in the private sector that enabled their users to compete very successfully with the so called "Armory Practice" producers.

The firms like the Western Wheel Works not only brought new techniques to the industry, but broadened the bicycle's public appeal by producing cycles over a range of quality, precisely what Pope had sneered at. Thus the bicycle industry represents not so much a transfer of "Armory Practice" into the private sector as it is the appearance of a new industry with *some-- but very little-- Armory Practice*, noted particularly for developing new materials, technologies, and designs, and attracting new innovative firms which broadened the range of available quality. This is precisely what happened in the watch and typewriter industries, both of which used *some-- but very little-- Armory Practice*, but neither of which relied heavily on it.

In conclusion, I recognize the hazards of drawing such sharp distinctions between my work and my friend David Hounshell's. Time marches on and as certainly as Eli Terry manufactured fully interchangeable clock parts in 1814, there is some hot shot graduate student out there ready to challenge my thesis and *clean my clock*. When he does (to continue the horological analogy), I hope he'll *ream my pivot holes and polish my pivots* with zest. I hope he'll *adjust my rate to six positions, temperature, and isochronism* with the same exhilaration and pleasure as I had in *adjusting David's escapement*.

As the late Lynn White, Jr., wrote, "The most important thing that can be said about any scholarly pursuit is that it is fun. The history of technology is, emphatically, fun" [4, pp. 349-51]. Let the fun continue!

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