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Technological Convergence and Institutional Evolution in the Energy Sector

Working Paper No. 12

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Abstract: Over a span of more than a hundred years, fossil fuel production could be considered as a long-standing ceremonial technology in the Veblenian sense. However in recent times, due to rapid innovation through technological convergence, renewable energy is becoming just as cost effective and threatens to replace fossil fuels. Robert McCullough observes this change in renewable energy costs, in his report "The End of Big Iron". Thorsten Veblen's dichotomy between ceremonial and instrumental technologies, and his thoughts on institutional change can also aide in explaining this recent struggle between "ceremonial" fossil fuels and "instrumental" renewable energy technologies. Nathan Rosenberg should also be considered when explaining the recent drop in costs related to renewable energy production through his contributions on technological change and, technological convergence. This inquiry seeks to establish that technological convergence and the production capacity of the machine process in recent times serves as an indicator of ongoing institutional evolution in the energy sector. (147 words)

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The United States is widely recognized for its wide range of mechanization. By the 1920s the U.S. led the world in efficient production of autos, electrical equipment, and machines used to reap, mine, print, spin, and sew materials. This widespread mechanization rested on U.S. market size and structure, but also on American machine-making prowess. How did this prowess grow and spread among so many kinds of machines, crossing multiple industries? This is the classic research question. In a classic answer, Nathan Rosenberg highlights the importance of technological convergence among these early industries in the article titled "*Technological change in the Machine Tool Industry, 1840-1910*".

Early Examples of Technological Convergence

In Rosenberg's (1963, 422) view, industrialization across industries involved a relatively small number of broadly similar production processes. All mechanized production at the time — shared similar problems and thus similar solutions. The similar problem's being how to cut, mine, heat, and cool the necessary materials (mainly metals) for a firm's production. As an effect of this similarity, Rosenberg (1963, 422) notes, development in one industry could benefit another. Rosenberg (1963, 416)*,* stressed the crucial importance of machine tools in creating the mechanization that was at the heart of the

Industrial Revolution in the United States and Great Britain. Rosenberg (1963, 416) shows us that without the improvements in lathes, planers, milling machines and precision grinders, much of the growth of modern manufacturing could not have happened.

Rosenberg grasped the essential nature of the technical knowledge embedded in the machine tool industry, recognized how knowledge would at first, not fit easily into existing economic production. Rosenberg (1963, 415) explains how in the years prior to the industrial revolution, around 1820 or so, there was no separately identifiable machine tool industry or machine production industry in the America economy. There was of course machines being used for producing goods, but a specialization of firms had not yet developed.

Rosenberg (1963, 418) illuminates to us that the machine industry did only take off when a group of specialized firms devoted themselves to solving the unique technical problems and mastering the specialized skills and knowledge required for efficient machine production. Innovations solved production problems in particular industries, generating products that were cheaper to produce and higher in quality. Machine tools were at the core of this metalworking revolution. Rosenberg (1963, 417) argues that the machine tool industry should be seen as a center of learning that improved a host of products across many industries. The industry functioned as a transmission center for the new techniques, spreading them across multiple machine-using sectors. For example, a Firm once specialized in the making of cotton textiles, might find itself easily able to adapt its machine processes to producing locomotives. Rosenberg (1963, 420) recalls the early history of Rogers Locomotive and Machine Works, In Paterson, New Jersey. That firm in the early 19th century — which originally specialized in the production of machine tools related to cotton — would go on to be transformed into a top locomotive producer as a result of the growing demand for rail transit.

Rosenberg supposes all machines performing such operations in production of goods, confront a similar collection of technical problems. Problems such as, dealing with power transmission, control devices, feed mechanisms, friction reduction, and a broad array of problems connected with the properties of metals (for example: ability to withstand stresses and heat resistance). Rosenberg (1963, 417) demonstrates that, economic growth lies in the ability of the capital goods sector to assimilate and develop proficiency in new machine technology and to adapt itself to the continually altering technological requirements of ever industrializing economy. Essentially what Rosenberg illuminates, is once a new way of doing things was innovated by the machine tool industry, or a new more efficient machine itself was introduced to the capitalist production process; those in competition would want to follow. The end result was an overall more efficient product, made cheaper and sold at a high profit margin. Each firm had their specialization in what they produced but each firm used very similar machine tools in production. This technological innovation snowballed as more and more efficient processes were created and the industrial revolution boomed in the United States' 20th century history.

20th Century Innovations, and Contributions from Veblen

During the 20th century the machine tool industry shaped the course of modern day industrial institutions. World War I and II served as the catalyst needed for assembly line machine production to gain a permanent foothold. In Rosenberg's sense, these old factories used for weapons manufacturing could adapt and specialize new technologies for production. The noteworthy economist, Thorstein Veblen also observed in his research the effects the First World War exerted on industry. Veblen observed during the early 19th century, how these once refined processes for weapons manufacturing, would then be translated to general manufacturing in the U.S. consumer goods. In Veblen's research *"The Instinct of Workmanship and the State of the Industrial Arts"*, he proposes an analysis of what he regards to be important human instincts driving these technology shifts. Perhaps the most important instincts Veblen emphasizes is the instinct of workmanship and idle curiosity. Veblen (1914) emphasizes the instinct of workmanship, as something which encompasses the human proclivities that promote efficiency in the pursuit of some end, pecuniary or otherwise. The instincts of workmanship and idle curiosity is in Veblen's understanding, are at the basis of human ingenuity in the creation of tools, artefacts and are the driving force behind technological innovation.

In Chapter Two of Thorstein Veblen's influential book, *The Theory of Business Enterprise*, he introduces the advance of what he terms "The Machine Process." This process, in Veblen's view, involves interactions and connections by which everyday modern-life has been structured since the advance of big business manufacturing. We might be inclined to think of the machine process as merely the functioning of machines within an industry. However, Thorstein Veblen [1904] (2005, 9) informs us that the machine process involves a concatenation of industrial processes, interstitial sub-processes, raw materials, resources and labor. The nature of the machine process is that of a reasoned procedure of efficiency, standardization and operation of multiple machines working in interlocking tandem. Veblen [1904] (2005, 17) suggests that the successful coordination of the multiple machine processes together increases solidarity and hence efficiency of the entire process.

The factory process as we have discussed through Rosenberg, evolved from a modest beginning in the 19th century. Instincts of Idle curiosity and workmanship contributed to increased technological knowledge which in turn was integrated into industry such as the above discussed by Rosenberg, cotton and wool textile production. Veblen [1904] (2005, 13) notes that as operational complexity of the factory process increased, standardization became essential to the factory's quantitative precision and uninterrupted flow. Precision necessitated the standardization of tools, materials and components regarding their size, shape and gauge.

Veblen [1904] (2005, 13) recognizes what Rosenberg also observes that, part of the growth of these industrial processes was certainly a result of businessmen conquering the small business firms that had evolved earlier to organize craft production on a disjointed smaller scale. Veblen [1904] (2005, 5) argues that, The civil engineer, the mechanical engineer, the navigator, the mining expert, the industrial chemist and mineralogist, the electrician — the work of all these falls within the lines of the machine process. Where industrial processes are the concerns of these engineers and their quest for precision, the predatory businessmen in Veblen's view, are motivated solely by pecuniary gain through purchase and sale of goods. This standardization of processes also would be carried over into modern day renewable energy production. The production of energy shares that same dichotomy Veblen describes between ceremonial and instrumental. The renewables represent a newer perspective and the oil barons certainly represent an antiquated view.

Costs of Producing Electricity in Recent Times

Technology has converged and advanced ever further in recent times, in nearly all areas of production. Microprocessors, computers and robotics have changed the nature of the machine production, but the machine process as discussed by Veblen, remains relatively the same. An example of this convergence of technologies; telephone + internet, fueled by an assembly line and supply chain reinforced by the machine process, gave businessmen like Steve Jobs the opportunity to found what would become the world's first Trillion-dollar company. There is no question that the smartphone has also generated change in the institution of communication. Now the businessmen could place orders in any market in necessary globally, in seconds. The extension of the machine process also furthered development in manufacturing. Changes in these technologies in the Veblenian sense, shaped the course of institutional change and societal change.

Rosenberg also has shown us discussed above, firms may become increasingly specialized in order to adapt to new technologies. In the case of energy companies — which enjoyed immense economies of scale — ability to specialize in rising energy technology production like advanced coal plants and advance their political influence became easier with more capital, all thanks to the monopoly system utilized by those early firms. Projects conducted in the building of early power plants were massive in their scale. Entire cities, towns and railroads would be built in support of one power plants infrastructure. These projects required immense funding and benefited from economies of scale, as the bigger the plant and infrastructure behind it, the more electricity the plant could then turn around and sell.

Rosenberg adds to the discussion in his book “Perspectives on Technology” (1975, 76) stating that, Edison, in introducing the incandescent lamp, first made a very careful study of the gas industry. While he introduced a drastically new technical product, he also deliberately patterned many of his practices upon those of the old gas industry. In Rosenberg’s view, the most successful entrepreneurs, not only advance new novel technologies but their success with technological innovations usually involves a careful discrimination among those aspects of past practices which need to be rejected and those which need to be continued.

In recent times this method of building massive plant projects is shown to no longer be as cost effective. Robert McCullough of McCullough Research offers his recent findings on the cost of producing energy using real transactional data from Lazard Asset Management, the U.S. Energy Information Administration, and Hawaii Electric Solar, in the report titled "The End of Big Iron: How Wind and Solar Became Cheaper than Hydro, Coal, and Nuclear".

McCullough (2019, 1) begins by stating that, the era of big project coal is rapidly ending as smaller more maneuverable, and less expensive options take the center stage in electric utility production. Historically, the competition between renewables and traditional thermal was easily dismissed as renewables were too expensive compared to cheaply produced thermal energy. McCullough (2019, 1) points out, that traditional trade-off makes less sense today as he describes the Levelized Cost of Energy (LCOE) from wind and solar generation has now dropped below the LCOE of hydro and most thermal energy resources. The LCOE, measures a power source that allows for comparison of different methods of electricity generation. The LCOE, considers the average total cost to build and operate power-plants over a defined lifetime. LCOE can be regarded as the average minimum price at which electricity must be sold in order for an electricity firm to break even and turn a profit over its lifetime.

McCullough (2019, 1) stresses that in the case of aging nuclear and coal plants, renewables are shown to have a lower LCOE than those aging plants. The LCOE of renewables has fallen 60% since 2015. Again, we should consider Rosenberg on this discussion of technological change. Rosenberg (1975, 75) illuminates that, the substitution of a new technology for an established one needs to be understood as the resultant of the combination of forces driving down the supply schedule for the new technology and conversely raising the supply schedule for the old one. We can see evidence of this in McCullough's report when he outlines the importance of "Just in Time" (JIT) delivery.

McCullough (2019, 9) explains that (JIT), is a transformative concept, pioneered in the 1950s by the Toyota industrial engineer Taiichi Ohno, and is a foundational principle of what we today call Lean Production. (JIT) reduces input inventories to the minimum necessary to meet real time production needs. In the case of Toyota, if the assembly line called for an order of 100 car hoods, they would order exactly 100 car hoods as they needed and have them delivered to be assembled on the factory floor. Whereas before this process, a plant like Toyota would be inclined to order as many car hoods as possible in order to stock pile the parts and drive cost down, eventually leading to inefficiencies. Similarly, in the case of electricity production, a coal fired plant would often be built to meet some demand further on in the future. Where as in the case of Renewables, electricity can be produced to meet the current electricity demands, and then expanded in the future as demand increases.

McCullough (2019, 9-10) observes this problem with recent activity in British Columbia's. Hydroelectric development of the Site C dam. British Columbia does not need 1,100 MW of new installed capacity, but it may need more capacity decades from now. B.C hydro then must overestimate its customers' future demand and overestimate the wholesale prices they will get selling this power in the Columbia market. This is in line with Rosenberg thoughts on technology adoption and Veblen's Machine Process.

However, Solar and Wind are not without their weaknesses, namely in the intermittent nature of production. McCullough (2019, 1) acknowledges this weakness, and states that renewables can be backed up by cheap natural gas peaked plants, and perhaps someday soon, new battery technology. Overall, despite claims by the owners of older fossil fuel plants, McCullough argues the nation's capacity for surplus through renewables is enormous. Just as Rosenberg states above, the success for these new technologies will come from entrepreneurs able to adapt the new efficient methods, while supplementing what works in transmission, storage and natural gas alongside renewables.

Conclusion

Through careful observation of the McCullough report, along with considerations of Rosenberg's, and Veblen's contributions, we can observe clear evidence of a transitionary period taking place in modern day utility electricity production. This inquiry has not touched on the societal influences, climate change has on this transitionary period which could be further explored. The transitionary period described in this inquiry, is that of solely economic principles. It should be important however — in perhaps the Veblenian sense — to consider the institutional implications of climate change, and the magnitude by which climate change is affecting this transition to green energy.

Established by Rosenberg, technological convergence paved the way for the early machine manufacturing power of U.S. firms. Further, Veblen illuminates the machine process, by which the manufacturing standardized precision processes would propel U.S manufacturing to its highest limits, and spill over into modern day life. Rosenberg also illuminates the success of past inventors, how the likes of Edison and others, were able to introduce and adapt new technologies that would take advantage of existing systems and drive changes in supply lines and operating costs. These changes can be observed in the McCullough report, in the analysis of the LCOE between renewables and traditional thermal electricity production. This inquiry has sought to establish that technological convergence and the production capacity of the machine process in recent times serves as an indicator of ongoing institutional evolution in the energy sector.

(2,811 words)

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