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IPE 101

November 13, 2018

Carbon Fiber Mountain Bikes: A Journey through the Global Economy on Two Wheels

Carbon fiber burst onto the military-industrial scene in the late 1960s as a lightweight yet durable material with almost unlimited applications. Carbon fiber is made from 90% polyacrylonitrile (PAN) and 10% petroleum pitch (Zoltek). Beginning in the late 1970s, carbon fiber mountain bikes became popular among high-end consumers and since then, demand has increased steadily. As a result of the multibillion dollar bicycle industry, carbon fiber mountain bikes have a variety of economic, political, and social effects across the global value chain that define their interactions in the global economy. In recent years, carbon fiber production has dramatically increased, presenting United States firms with new opportunities for outsourcing manufacturing capabilities, while holding branding and carbon production abilities. With the rise of Taiwan for carbon bike production, the bike industry has created a global industry with international capital and goods being exchanged between the U.S. and Taiwan. Although the U.S.-China trade war represents a potential for a disruption in the carbon bike industry, direct to consumer sale models have provided cheaper alternatives to expensive bikes. Furthermore, the expansive resale market represents a free trade system based off of individuals setting prices while others search for the best deals. And as a carbon bike becomes waste, it has the potential to be recycled and begin a new life in a new industry.

The origin of carbon fiber is rooted in 1960s Japan's pursuit of innovation in order to repair the economy after the devastation of WWII. In the mid 1960s, researcher Dr. Shindo from Japan's former Government Industrial Research Institute (GIRIO) created PAN-based carbon fiber that was able to hold its strength in comparison to its weight (World Intellectual Property Organization 2012). The state sponsored research and development that Japan underwent in the post-war period signifies a shift that relies on the mercantilist notions of technological innovation as a method to compete in the global economy, which according to Bradford Dillman and David Balaam, is "a key determinant of economic growth" (Dillman and Balaam 2018, 259). Due to this investment in carbon fiber technology, Japanese firms remain dominant in carbon fiber with firms such as Toray representing 70% of the global carbon fiber market (Ministry of Trade and Industry 2010, 16). Due to the improvements in the knowledge structure, the mercantilist approach to state-run research and development benefits Japan with the majority of manufacturing capabilities and intellectual property licensing available.

Although carbon fiber technology spread to other developed nations with applications for carbon fiber, Japan sustained a leg up in carbon fiber manufacturing due to its history of production. Transnational corporations (TNCs), like Toray, created special formulas that make their carbon fiber unique in its physical and structural characteristics. This has created a system built to evade intellectual property disputes, where trade secrets about carbon fiber formulas remain dominant. Many companies and nations have undertaken carbon fiber manufacturing capabilities, especially highly advanced industrial nations such as the U.S., Taiwan, and China. Developing nations in Eastern-Europe and Mexico have also entered the market by means of foreign direct investment (FDI) through TNCs like Zoltek (Caliendo 2017). The spread of this

technology developed in a very liberal manner that reflected the post-WWII attitudes of Bretton Woods in regards to the principles of free trade that were practiced. Although carbon fiber has spread rapidly throughout the developed international community, trade secrets obscure different grades and types of carbon fiber. This has allowed firms to specialize in the type of carbon fiber they manufacture in order to meet demand while also maintaining a technological edge. Now, with developments in military grade carbon fiber, firms and nations alike are very careful with whom they share the technology, creating a mercantilist system based on the protection of intellectual property in regards to technological innovation. Overall, in the search for unique formulas, the Japanese firm Toray is dominant in the aerospace industry while firms Topkey and Giant in Taiwan have specialized in the creation of carbon fiber for mountain bikes.

With ever growing consumption of carbon fiber mountain bikes in the U.S., the global value chain has shifted the location of production from developed nations to developing nations. Production before the 1970s was centered in the U.S. with brands like Schwinn, but as of the 1970s, bicycles boomed in popularity as manufacturing was exported to Japan (Felton 2017). Soon after, during the late 1980s, the value of the dollar dropped dramatically and bikes began a new manufacturing life in Taiwan with cheaper labor and a better exchange rate (Felton 2017). According to The National Bicycle Dealers Association, “in 2014, more than 99 percent or 17.8 million bicycles were imported into the [U.S.], primarily from China and Taiwan” (Felton 2017) with the American bicycle market sized at approximately $6.1 billion in 2014 (National Bicycle Dealers Association 2015). This move in manufacturing was also due to a change in the bottom line that led competing firms to the race to the bottom for the cheapest production rates, while maintaining the highest quality bicycles that high-end customers demand. This led firms such as

Trek, based out of Wisconsin, to move manufacturing to China and Taiwan, where they previously faced competition from the Taiwanese brand Giant, the largest producer of bicycles in the world. In China and Taiwan, firms have access to highly skilled labor for a low cost and are technologically equipped to manufacture their own carbon fiber—ready for mountain bikes—from raw carbon fiber sheets. With these abilities, developed nations like the U.S. and Japan no longer have a comparative advantage in bicycle production, thus resulting in a new service based brand industry in the U.S., while manufacturing by OEMs has moved to Taiwan.

The carbon fiber PAN base is bought by original equipment manufacturers (OEMs) in Taiwan that create mountain bikes with a contract from U.S. bicycle companies like Trek or Specialized. Once OEMs like Topkey obtain the carbon fiber base from firms like Torray or from carbon fiber producers in Taiwan, they apply the petroleum pitch and manufacture their own type of specialized carbon fiber for bike production. Topkey is the largest carbon fiber bike manufacturer in the world and is a major OEM with the capacity to produce 200,000 frames per year. Topkey obtains contracts from bike companies based in the U.S. like Trek and Specialized who have found the ‘bottom’ of the market at the doors of the Topkey factory in Taichung, Taiwan (Walton 2017). These contracts contain the blueprints for the bikes that are designed in developed nations by firms that have no capacity to manufacture and instead provide the service of branding bikes according to their status in the bicycle industry. At this point, the OEMs utilize the blueprints to manufacture mountain bikes for each brand, with many different bikes representing different brands being produced under the same roof, raising the issue of whether or not OEMs have the ability to brand competitively in face of competition from brands in the U.S.

The majority of OEMs are at the will of the brands for which they produce and they are involved in the struggle of developing from a manufacturer of the peripheral to a service based brander like a developed nation. Brands like Topkey are unable to brand their own high end carbon bikes, thus they manufacture them, but the ultimate hope is to develop into a brand that has control over both manufacturing and branding. This step is increasingly difficult to take due to the lack of access to highly educated marketers and those with white collar educations. Furthermore, in Taiwan "nobody will ever think of making their own brand, if you are [exporting]" (Fuchs 2017) because manufacturing alone is very profitable and there is the challenge of breaking into the U.S. market as a brand. Also, brands like Trek are so deeply integrated into the American status quo that individuals in the U.S. find it difficult to deviate away from standard brands. Moreover, the high likelihood of losses associated with breaking into a market is both cost and intellectually prohibitive. Although it is difficult to begin branding to the developed market, there have been exceptions.

A unique exception to the developmental struggle is Giant, a powerhouse in carbon bike production based in Taiwan. As of 1988, Giant was a predominant OEM actor aiding many bike brands around the world as a reliable and quality bike manufacturer. During this same year, Giant became the first company to produce carbon fiber bikes under "project 88" and after three years of experimentation was able to manufacture 20,000 carbon frames per year (Pfenninger). Soon after the ability to mass produce carbon bikes, they began to brand their own bikes as Giant with the intention of being cheap and reliable not only to brands, but to consumers in the U.S. Now "Giant produces five and a half million bicycles [per year] and generates approximately two billion USD in turnover, making it the largest bicycle manufacturer in the world"

(Pfenninger) with 70% of production for Giant and 30% for contracted brands (Latz 2013). Clearly Giant is an exception in the international bike market where the company is vertically integrated, able to manufacture and brand their bikes with a competitive edge. This is an example of the rising power of nations such as Taiwan in the ability to compete with developed nations by means of the service industry. More telling is their continued service of producing bikes for other brands in the ability to manufacture in a surplus manner.

With the manufacture of different brands of bikes under the same roof, firms seek to keep the factories, in which their bikes are being produced, secret to ensure that the customer believes that the brands are different. In all likelihood, traditionally American brands like Trek are being produced side by side in the factories of Topkey or Giant. With the use of OEMs to manufacture bikes in Taiwan, firms in the U.S. depend on branding for revenue, thus they brand their bikes with unique technologies and bike designs. Because of this tactic there is the "risk [that] people make the shortcut and equate 'same OEM' to 'same product' when a shared OEM doesn't actually mean that" (The Inner Ring 2017). This is problematic for bike companies in that their stream of revenue is dependent on branding instead of production, which has led to an industry guised in trade secrets about where bikes are being produced, how, and with what type of carbon fiber. This has the potential to confuse consumers, pushing for a more open market, which would be detrimental to the bottom line of bike brands in the U.S. With the existing shrouded market, consumers happily purchase cheap bikes from overseas without noticing where they are produced or under what situations labor and the environment are held, resulting in a competitive edge, potentially at the cost of labor and the environment.

OEM producers handle intense competition from brands trying to lower margins with cheap labor that is treated, in many cases, under industry standards. In May of 2013, Giant opened one carbon fiber bike producing factory to the public, but they did not "open all of Giant's doors to visitors, so the exact procedure [of carbon fiber creation] remains a company secret" (Pfenninger). The lack of opening of factories hints at the obscurement of the potential treatment of labor, as well as disposal methods of waste carbon fiber. In the carbon factory they opened they have "2,000 factory workers, plus 150 staff in the global head office" with base factory workers making $15,000 per year (Latz 2013). The base pay grade is quite high in comparison with other entry level manufacturing jobs, but the use of toxic chemicals to cure carbon fiber can be detrimental to the health of the workers. During the week, laborers work six day work weeks with days ranging from 12-16 hours in the high season. Although they have long hours and equally long weeks, carbon fiber factories have air conditioning and the workplace is impeccably clean to ensure that carbon fiber is produced according to the quality that is demanded from Giant and other OEMs (White 2018). Even though the conditions within manufacturing plants are markedly better than many entry level manufacturing jobs, there is the possibility of the obscurement of poor working conditions by means of keeping the doors of certain factories shut. Though carbon fiber bike production yields a higher quality work place, the effects on the environment are concerning.

Mass producing bikes by huge OEMs owned by equally large brands with tremendous budgets yield to waste with poor disposal processes. Torray notes that in aerospace applications the scrap rate of carbon fiber is up to 20%, but for bike manufacturers scrap rates are pegged at "about a third of every carbon sheet is wasted" (Max 2017). This rate is kept low because raw

carbon fiber costs approximately $20 per pound (Cunningham 2018). Because of the high cost, manufacturers are keen on using every ounce of the carbon fiber they purchase. Even large brands like Giant keep the majority of left over carbon fiber for patch jobs, but still must dispose of faulty test frames. Furthermore, this waste is largely unrecyclable because there is not enough waste created to catch the attention of recyclers, leaving many carbon bike frames in the landfill.

With environmental concerns in mind, brands such as Pole have stopped their pursuit of producing carbon bikes. In 2016, the founder of Pole Bicycles, Leo Kokkonen, visited China searching for a carbon frame manufacturer as the next step in producing high end mountain bikes (Max 2017). When visiting the factories, Kokkonen encountered OEMs that, when asked where they disposed of waste, they said they "dump it in the ocean" (Max 2017). Because of the lack of ability to work with OEMs over environmental concerns, Pole Bicycles decided not to manufacture frames using carbon fiber, especially seeing that there were few expensive options for recycling wasted carbon fiber. Furthermore, Pole established that they would not be able to work with Chinese manufacturers because of the lack of quality due to carelessness that was represented in their environmental dealings. Overall, the environmental impacts of carbon fiber bike manufacturing have left firms like Pole deciding to stick to aluminum frames. Those that decide to manufacture carbon bikes continue on in the global value chain to export.

The vast majority of manufactured bicycles end up in the United States, but with the Trump administration, a once free trade system may now be coming to an end. As of September 2018, Trump rose the previously imposed tariff on bicycles and all related products (minus safety gear) from 10% to 25%, on top of pre-existing 11% tariffs on imports of completed bicycles, scheduled to take effect in December of 2018 (Brandom 2018). These tariffs have been

put in place to revitalize U.S. manufacturing, but with only 1% of bicycle production originating in the U.S., the demands of consumers will not be satiated without immense price increases. These tariffs have instilled fears in many carbon bike brands that produce in mainland China, especially seeing that the impacts of U.S. tariffs on Chinese bicycle products will cost the industry $250 million in 2019 alone (Brandom 2018). Although a majority of high end carbon bikes are produced in Taiwan, which is not subject to U.S.-China tariffs (Chung 2018), brands are looking to move manufacturing to countries such as Vietnam and Cambodia for low end bicycle production (White 2018). Whether or not this is due directly to the increase in tariffs singularly or if it is significant of China's increased influence in the global value chain is not entirely known at this point, but it can be correlated that these tariffs have the potential to displace a portion of Chinese carbon bike manufacturing.

Even in the midst of a looming trade war and the possibility of tremendous price increases, thousands of carbon bikes are imported into the United States every day. Traditionally, the global value chain of bike sales followed from the blueprints of the brand, to the OEM manufacturer, to a distributor of the brand, to a bike shop, and finally to the consumer. Recently the chain has shifted. High end carbon bike brands have begun to sell bikes with a direct-to-consumer model. This shift in sales is a result of the prohibitive costs to enter the sport of mountain biking, placing value on the consumer over brick and mortar dealers (Ritter 2018). This has resulted in high end carbon bikes costing as much as 30-40% less, reducing the need for cheap unreliable bikes for newcomers in the sport (Ritter 2018). As consumers demand lower prices for carbon bikes, the shift signifies a change in relative power from the brands to the consumers. The direct-to-consumer model also stands as a way to reduce the cost of carbon fiber

bikes with the looming tariffs of the trade war. Now people are able to more affordably enter the sport of mountain biking, which leads to more people riding reliable carbon bikes.

Although affordability is key in ensuring access to mountain bikes, a decline in local bike shops as a result of online sales and the use of the direct-to-consumer model have detrimental effects on local bike communities. Fred Clements, executive director of the National Bicycle Dealers Association, says that without local bike shops there would be "75 percent fewer bike brands, and a 50 percent decline in adult cyclist participation" (Clements 2013) which, in the long run, would decrease participation in mountain biking while also raising prices due to the consolidation of power in a few large brands. Additionally, local bike shops bring together communities of mountain bikers that are able to collectively bargain with state and federal agencies that control access to public lands, potentially increasing the number of people with access to public lands. Although direct-to-consumer sales inevitably will not destroy the mountain bike market, online sales have posed a threat to producers, extending the effects of the race to the bottom, with the potential to degrade international labor standards in bicycle manufacturing.

After the primary use of a carbon mountain bike is complete, it has potential for resale in secondary markets. Many individuals find it difficult to purchase a carbon mountain bike new from a dealer or—although cheaper—directly from the brand. Jeff Barber of Singletracks.com has found that bikes in 2017 "are currently selling for 45% of their original MSRPs" (Barber 2017) in 2016 . Much like the depreciation of a car, high end carbon mountain bikes depreciate, indicating that the resale market is a much more viable option for the majority of people looking for a carbon bike. The resale of high end carbon mountain bikes is representative of a truly free

unregulated market where consumers are able to set prices that they deem most fit with a wide variety of consumers searching for the best deals. This free market system is opposed to the bike industry practices of trade secrets and high prices that act under the shield of mercantilist interactions. Moreover, buying a used carbon bike proves to many that the bike stands the test of time, and that it is more than just the initial publicity (Waldman 2015). Also, the ability to repair carbon fiber to its previous strength at a low cost indicates that carbon fiber bikes are more durable in terms of reliability and lifespan. Clearly the resale market is immeasurable. When researching used bikes there are endless websites that advertise services for the perfect used bike, including Pinkbike, Ebay, and Craigslist. By the end of a bike's life, the value drops close to nothing, thus resulting in a proud owner hanging it as art, or deeming it as waste.

Bikes that are not resold have a few pathways: the landfill or, with advancements in technology and pressure from the bike industry and consumers, recycling. Thrown away carbon mountain bikes are "neither biodegradable nor photodegradable" (Suciu 2011), which means that if the bike frame is deposited in a landfill it will never decompose. Because of these properties, bike firms have pursued the ability to recycle carbon fiber. The central issue is the low quantity of waste that the majority of OEMs and brands produce. The inability to attract recyclers combined with a general lack of recyclers in areas with the highest amounts of waste, such as Taiwan or China, results in stockpiling or the deposition of waste in landfills. Large firms like Trek, as of 2010, partnered with South Carolina recycler Carbon Conversions "to recycle the carbon prototypes, damaged frames, noncompliant parts, and waste coming from its U.S. manufacturing facility" (Max 2017), but these efforts do not deal with the majority of waste in the hands of the Taiwanese and/or the Chinese. Although steps have been taken in the right

direction, recycling efforts have not removed the amount of wasted carbon deposited in the ocean. Trek, Specialized, and other U.S. bike brands have begun to look into the ability to recycle carbon fiber in China or Taiwan, but face a lack of infrastructure to be able to recycle these products. Overall, efforts at recycling have been increasing, but have achieved limited success.

Although the technology for recycling carbon fiber in China and Taiwan is not readily available, the infrastructure in the U.S. has the ability to process high amounts of carbon fiber waste. Interestingly enough, Washington state has the highest capacity to recycle carbon fiber due to the high application of carbon fiber in Boeing airplanes created in the state. Torray's expansive recycling factory in Port Angeles, Washington captures enough carbon fiber to "make 400,000 carbon trail bike frames a year" (Cunningham 2018), but because of the relatively low amounts of carbon bikes that end up thrown away or as scrap material, recycling facilities, like the one in Port Angeles, are unable to process it profitably. When it is processed, it is turned into chopped carbon fiber that has uses only in non-structural locations, severely limiting the post-recycling opportunities. At this point carbon fiber recycling is in its infancy and with pressure from the bike industry and consumers, brands like Ibis are trying "to initiate [their] own recycling program[s], but when [they] tried, [they] couldn't get them [recyclers] to return our calls" (Cunningham 2018). In recent years, there has been progress in recycling carbon fiber in the bike industry, but the recycling potential has yet to be reached.

In this global value chain, carbon fiber mountain bikes begin as raw carbon fiber sheets produced in developed countries, in this case the U.S. and Japan. Carbon fiber sheets are consequently sold to factories known as Original Equipment Manufacturers (OEMs) in Taiwan

and China, contracted by bike brands, and developed into mountain bikes. After production, the carbon bikes are shipped to the second largest bicycle market, the U.S. (the first being the European Union), where they are distributed and sold. Once in the hands of consumers, these bikes are thoroughly loved, but eventually become old, unuseable, or broken, and in many cases begin a new life as a recycled material. This global market is particularly important in a time where manufacturing is trying to be brought back to the U.S., but as seen is hardly a possibility without huge price increases and a decrease in cycling participation. The carbon fiber bike industry represents a small portion of the tremendous bicycle market, but demonstrates a fitting example of a truly global market that must be accepted with open arms.

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