



The U.S./China Global Trade War: A Case Study Examining the Net Economic and Sustainability Effects Focusing on the U.S.

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ABSTRACT

Whether trade wars are beneficial or hurtful for the countries involved has been widely debated, particularly with respect to the U.S. China Trade War that began in 2018 to the present. In this paper, we provide an overview of some of the theoretical literature for the expected economic and ecological effects of trade wars and provide a case study presenting the events of the U.S. China Trade War to compare theoretical views to actual net economic and sustainability effects occurring in the U.S., with a short overview of aftermath effects during the Covid19 pandemic in 2020.

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1. Introduction

As two of the world's largest economies, the trade war between the U.S. and China would be expected to have significant effects on these countries, as well as other countries globally. During January 2018 through 2020, the U.S. China Trade War encompassed an unprecedented series of major retaliatory tariff events and on and off negotiations, with the U.S. applying tariffs on China's products valued at US\$550 billion, and China retaliating by placing tariffs on U.S. goods worth US\$185 billion. On January 15, 2020, a Phase 1 truce was signed, with concessions by both countries. Despite the truce, repercussions continued in 2020, with additional tariffs imposed by the Trump administration and continued trade tensions during the global Covid19 pandemic in 2020.¹

Economists differ sharply on the benefits and costs of trade wars, with free market economists predicting that an escalating trade conflict will create market frictions increasing prices for supplies and consumers, and net unfavorable economic for the warring nations. Protectionists argue that trade wars by reducing foreign competition will help build up declining industries and reduce domestic country's dependence on foreign suppliers. From an ecological perspective, economists point out that if a trade war has negative economic effects, this could reduce the strain on scarce resources to benefit the environment, and lower global carbon emissions. Alternatively, negative effects are cited if a trade war creates a distraction away from government concerns for climate change and if the trade war reduces joint efforts and sharing of carbon-emission reducing technologies among the warring countries (Amadeo, 2019; WTO, 2018).

In this paper, we provide a review of the literature for the expected economic and ecological effects of trade wars and compare theoretical views with the actual economic and sustainability effects of the trade war, focusing on the U.S. Section 2 provides an overview of different theoretical perspectives for the net effects of a trade war, followed by Section 3 examining the economic effects of the trade war and Section 4, the net effects on sustainability sectors. Section 5 examines second best sustainability solutions in the U.S. Section 6 gives a brief overview of carryover impacts of cold relationships during the Covid19 pandemic, and Section 7 provides a summary and conclusion.

2. Overview Theoretical Perspectives on a Trade War

2.1: Overview Neoclassical and Ecology Economics Perspectives

Trade wars are often associated with protectionism, with one country raising tariffs on another country's products, to protect dormant industry sectors and jobs in a high wage country from competition with cheaper goods sold by a low wage country. Tariffs may be devised to revive fading industries, and they may involve one country perceiving another country's trading practices as unfair. Once trade wars begin they often expand to other industry sectors and countries. Protectionism may spur economic growth for the country initiating the tariffs, or slow growth with a loss of trade across countries and cultural exchange.

Free trade or *laissez faire* policies, from a neoclassical economics perspective, are often thought to be more likely to better economies, with barriers removed for the free exchange of goods. Under Ricardo's (1891) principle of comparative advantage free trade expands an economy's diversity of products, knowledge and skills, and encourages specialization and division of labor. Different goods can then be offered at lower relative opportunity costs based on a country's factor endowments and technological progress. Adam Smith's (1776) *The Wealth of Nations* argues that free trade is a necessity

¹ The U.S. also imposed tariffs on products of other trading partners (i.e., Canada, the European Union, France, India, Russia, and Turkey), with each of these countries retaliating with tariffs on U.S. products (Wong and Koty, 2019; ITA, 2019).

for a modern world for an optimal allocation of resources, with nations simultaneously making gains based on their absolute advantages, as long as capital, labor, goods, and services can move freely to where they can be used most efficiently.

Thomas Friedman (2006) suggests that free global trade can exist under a flat world concept, with technology allowing greater globalization to create a seamless global economy of ideas, concepts, and innovations. Other economists perceive the world as spikey versus flat, as the result of disruptions that include global service disaggregation (Mithas and Whitaker, 2007), governance problems (Feoick, Moon, and Park, 2008), and internalization challenges (Kim and Aguilera, 2015). In a spikey world, tangible and intangible costs create barriers for the free flow of goods and services, reducing an optimal allocation of resources.

Ecological economics focuses on the interdependencies between human economic and natural ecosystems including considerations for the environment, scarcity of non-renewable resources, the well-being of humans and social equity. Free global trade that maximizes economic growth can be detrimental, given biophysical limits and resource constraint problems, with global manufacturing and transport often creating environmental and social damages as by-products. These can sharply lower living standards and quality of life, particularly if negative externalities affecting the environment are not priced (Daly 2005, 2019; Constanza, Cumberland, Daly, Goodland, and Norgaard, 2014).

2.2: The Pollution Haven and Trading Up Hypotheses Effects with a Trade War

With a trade war, there may be relevant ecological wins and losses concurrently. A study by Bechtel, Bernauer, and Meyer (2011), using Swiss survey data, finds that more environmentally concerned individuals preferred protectionist trade policies, with objections for other aspects of foreign products beyond price and quality. Bechtel, et al. (2011) note that this is consistent with a *pollution haven hypothesis* (Levinson and Taylor, 2008) whereby large multinational corporations often locate their manufacturing and other operations abroad, seeking out the cheapest options in terms of resources, labor, land, material access, and the least stringent environmental standards. If tariffs imposed on foreign goods increase company costs, multinationals may relocate back to their home countries. If home countries have more stringent environmental regulations, this relocation could contribute to lower carbon emissions and help to reduce other environmental damages (i.e., destructive mining or manufacturing practices allowed in other countries).

Bechtel, et al. (2011) point out that more recent research (i.e., Bechtel and Tosun, 2009; Drezner, 2005; Copeland and Taylor, 2003, and others) supports a *greening* effect for free trade and globalization. Under Vogel's (1995) *Trading Up Hypothesis*, free trade provides greater economic openness and permits international transfers of *green* preferences, policies, and technology to developing nations. Governmental environmental protections help to assure this, such as the U.S. Presidential Executive Order 13141 of 1999, requiring an environmental consequences assessment for trade policy decisions, and the EU's required systematic evaluation of environmental considerations for its trade negotiations.

Consistent with the Trading Up hypothesis, Frankel and Rose (2019) find evidence that multinational corporations by bringing in clean, state of the art production techniques to host countries with previously low environmental standards, contributed to a net decline for three different types of air pollution for a cross section of developing countries in 1995.

Recent research incorporating climate and technological change in economic models by Nobel laureates, Nordhaus (1993, 2018) and Romer (1990, 1993) suggests that economic growth may overshadow the natural world's ability to sustain this growth, necessitating the sharing of technologies across countries to reduce negative global environmental effects. Trade wars may lead to costly policy delays and prevent the dissemination across countries of new technologies that are essential to reduce

greenhouse gas emissions (Zhang, 2019). UN Environment Executive Director Erik Solheim, points out that trade wars result in less trust and collaboration among nations, leading to suboptimal climate policy solutions, and fewer intergovernmental funds to fight climate change (WTO, 2018).

2.3: A Second Best Theory for Sustainability and Climate Action Solutions

Under Lipsey and Lancaster's (1956) second-best theory, when necessary conditions for an optimal allocation of resources are disrupted with a market distortion that is infeasible to remove, a second (or more) solutions may need to be introduced to partially counteract the distortion for a more efficient outcome. From a climate change action perspective, Krugman (2014) suggests, for instance, that fuel efficiency standards, clean energy subsidies, and loan guarantees for renewable energy projects may be second best solutions to counter a lack of public acceptance for market pricing for carbon emissions.

Strauss (2019) observes that in a world filled with political and economic realities, pragmatic second best policies are better than inaction. Examples include a proposal by a group of 3,554 U.S. economists, including 27 Nobel Laureate Economists, for a graduated carbon tax with revenues of the tax provided to citizens to cover any higher energy costs (with a similar bill proposed in January 2019 in the U.S. House (H.R. 763)). Another second best solution for uncooperative countries for reducing their carbon emissions is a *border carbon adjustment* (BCA), included in the European Union Green Deal of 2019. Under this BCA, a fee is mandated for the carbon emissions used to produce foreign steel, cement, or aluminum, at a similar carbon price to that paid by European companies to the EU Emission trading system to emit carbon (EU Commission, 2019).

2.4: Propositions for the Effects of the U.S. China Trade War

Based on the previous discussion, we propose the following propositions for the economic and environmental effects of the U.S. China Trade War as follows:

Proposition 1: (Economic Effect of the Trade War): *From a neoclassical economics free market perspective the economic effect of the trade war will be in net detrimental to the warring economies, with losses of trade for warring countries.*

Alternatively, from a protectionist economic perspective, effects could be positive if domestic sector manufacturing increases with protected industries from foreign competition thrive and dormant industries make strides and grow in the domestic economy.

Proposition 2: (Sustainability Effect of the Trade War): *From an ecological economics perspective, the sustainability effect of a trade war will depend on the net economic effects of the trade war on specific sustainability industry sectors, and other government actions.*

Sustainability industry sectors, such as alternative energy sectors (wind, solar power) that depend on suppliers in other countries could be adversely affected if tariffs increase their prices or if they lose trading benefits with the trade war, depending on government policies for subsidies to promote these sectors as well.

Proposition 3: (Second Best Proposition for the Trade War): *From a second-best theory perspective, if a trade war produces a market distortion that is infeasible to remove, efforts will be made to provide second best solutions to at least partially offset that infeasible market distortion, reducing some negative effects.*

How industry sectors and states and local governments respond to the trade war and come up with second-best solutions to adverse effects that may occur doing the trade war or ways to offset these could also determine the net economic/sustainability effects for different sectors.

3. An Examination of the Net Economic Effects of the U.S. China Tariff War

3.1: Overview of U.S. China Tariff War Events

The Trump administration began the trade war with China on January 22, 2018. Motivations included removing unfair trade practices, bringing manufacturing jobs back to the U.S., and national security concerns for intellectual property. Over the trade war, numerous tit-for-tat tariffs and on and off negotiations came about (see a summary of these in the Appendix), with the U.S. and China placing tariffs on the majority of traded products between the two countries. U.S. tariffs included duties on foreign washing machines, solar panels, aluminum and steel, and on China's products including manufacturing components, rail cars, solar modules, wind turbine and electronic components, consumer products, among thousands of others. China retaliated with tariffs on U.S. products including agricultural products, pulp/scrap paper, corrugated cardboard, other fibre products, liquefied natural gas, ethanol, cars, e-cars, bicycles and bicycle parts, among thousands of others, as well as reducing major purchases of U.S. agricultural products.

After many negotiations and threats for additional tariffs, on December 13, 2019, the U.S. and China came to a Phase 1 truce. China agreed to increase its purchases of U.S. goods and services by at least \$200 billion (including U.S. agricultural products worth US\$40 billion to US\$50 billion annually for the next two years), develop intellectual property protections for U.S. technology, enact a tariff exclusion process, improve access for U.S. financial services firms, and not purposely depreciate the yuan. The U.S. under Phase 1 agreed not to impose its December tariffs, and to reduce tariffs of 15% to 7.5% on \$120 billion of China's consumer and electronic products. Tariffs of 25% on \$250 billion of China's products remained, as leverage for future Phase 2 negotiations. U.S. Companies were also given procedures to follow to apply for tariff exemptions. Following the agreement, China eased tariffs on 859 U.S. products (Politi and Shepherd, 2019).

3.2 Net Economic Impacts for the U.S. of the Trade War

Research on the net economic impacts for the U.S. of the Trade War conforms to proposition one's expectation of net negative economic effects for the U.S. The Federal Reserve reported that U.S. manufacturing production declined 1.5% in 2019 (BOG, 2019), and the U.S. Commerce Department reported a fall in the U.S. GDP growth rate for the third quarter of 2019 to 1.9%, along with declines in the U.S. sales to domestic purchasing ratio, capital expenditures, and personal consumption. Initially there was a boost in employment for industries exposed to trade with China of 0.3%, but this was offset by a drop of 1.1% in U.S. manufacturing employment with layoffs related to high tariff costs for necessary manufacturing parts and components from China.

Retaliatory tariffs from China also negatively affected U.S. exports, and U.S. factory jobs fell by 0.7% (Greeley and Badkar, 2019; Zumbrun and Davis, 2020). For the third quarter of 2019, the U.S. Department of Labor reported an addition of 266,000 jobs (with 54,000 of these reflecting striking workers return), and the U.S. unemployment rate fell to 3.5%, but the U.S. labor participation rate fell to 62.9%, its lowest level since 1977, and wage growth rose only by 3.1%, a low rate for a period of low unemployment. U.S. job growth in manufacturing slowed in July 2018, with manufacturing production peaking in December 2018, and falling, along with job growth in manufacturing thereafter, with factories discharging workers four to six months prior to the pandemic. Although there was a reported net gain of 400,000 U.S. manufacturing jobs from November 2016 to March 2020, about 75 percent of these increases happened prior to July 2018, when the first wave of U.S. tariffs on Chinese goods went into effect (Zumbrun and Davis, 2020).

The U.S. Census Bureau reported most U.S. companies found new suppliers in other countries, such as Vietnam, Taiwan, Bangladesh, and South Korea, rather than realigning their production and/or

suppliers to the U.S. The Institute for Supply Management (ISM) reported a decline for the ISM index for manufacturing levels to 47.2 (indicating contraction) in December 2019, the lowest reading since June 2009, with few companies bringing production back to the U.S., and 13 of 18 manufacturing sectors covered experiencing contractions, with declines in supplier deliveries, inventories, and imports (ISM, 2019) (Bureau of Labor Statistics, 2019; Gould 2019).

The U.S. Congressional Budget Office reported a rising total budget deficit of \$984 billion over the trade war, with the deficit to GDP ratio rising to 4.6% (from 3.8% in 2018) for the fiscal year ending on September 30, 2019. Tariff revenues of \$29 billion were overshadowed by \$28 billion and additional \$16 billion in subsidies paid to U.S. farmers hurt by China's drop in U.S. agricultural purchases (CBO, 2019).

U.S. Customs reported registered U.S. import companies paid the majority of the tariffs imposed on China products, and their costs rose as well with a higher cost for import bonds. These costs were passed on to U.S. manufacturers, who raised their prices to cover the higher costs, reducing demand for their products (Reuters, 2019).

A Moody's Analytics research report estimated that the trade war cost the U.S. about 0.3% in real GDP, and a loss of about 300,000 jobs, as of September 1, 2019, with the brunt of tariff duties passed on to U.S. companies and consumers (Zandi, 2019). As of August 2020, with the pandemic hurting the U.S. economy and trade as well, the U.S. trade deficit rose to 67.1 billion, the highest deficit in 14 years, and the U.S. trade imbalance hit a record \$84 billion (Wiseman, 2020; Zumbun and Davis, 2020).

Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2019) analyzed the impacts of the trade war in 2018 on the U.S. economy, by estimating import demand and export supply elasticity as U.S. and retaliatory tariffs changed over time. They calculated a potential decline of 31.5% in imports from targeted countries, and of 11% for targeted U.S. exports, with an aggregate welfare loss of \$7.8 billion, with less educated, trade-able sector U.S. workers to be the most negatively affected by the trade war.

Amiti, Redding, and Weinstein (2019) assessed the impacts of the trade war on prices and welfare over 2018. They found substantial rises in U.S. prices for intermediate and final goods, large changes in its supply-chain network, lower cost efficiency for U.S. companies, and higher prices and availability reductions for imported products. With tariff costs passed on to domestic customer prices, estimated costs for U.S. consumers were about \$3 billion a month more for products, with an estimated a U.S. real income decline of \$1.4 billion per month, along with real income and welfare losses for other countries.

A report by the Associated Press (2020) found the deterioration in U.S.- China relations posed risks to both countries, noting that with the Covid 19 pandemic, if further tariffs evolve and compromises aren't reached, U.S. companies and global trade could both suffer, with China the third largest market for U.S. exporter, a major market for U.S. companies producing goods and services in China, and the biggest agricultural export market for Iowa and other farming states. The U.S./China technology markets are intertwined, with major technology companies (i.e., Apple; Hewlett-Packard, among others) relying on China factories for the assembly of most of their products, and China also representing a top market for Apple and other U.S. technology brands.

3.3 Global Effects on GDP and China's Net Economic Effects

Consistent with Proposition One, the trade war had a negative global effect. The International Monetary Fund (IMF, 2019) in its 2019 World Economic Outlook estimated global economic growth to be about 3%, the lowest level since the great recession in 2008 to 2009. The IMF expected the US-China trade dispute would cut about 0.8 percent from global output by 2020, with growth for advanced economies projected to slow to 1.7%.

China's net economic effects were negative as well, with its GDP growth rate declining to 6.2% in the second quarter of 2019 and to 6.0% in the third quarter, the weakest pace since 1992, with declining exports and declines for industry sectors. China's exports for the first half of 2019 fell 1.3%, with imports, fixed-asset investment growth, and industrial output growth also falling. With China's economic downturn, its government engaged in fiscal stimulus measures by providing support to its coal and heavy manufacturing as key sectors. Both the U.S. and China also used monetary policy stimuli over the trade war to prevent their economies from worsening, with China continuing to use monetary stimulus following the Phase 1 agreement (Hornby and Liu, 2019; The World Bank, 2019).

The Institute of International Finance estimated that China lost a large market share for many products. A UBS Group AG research report found that Chinese factories responded to its economic downturn by reducing prices, workers, and investment. For a survey of 200 Chinese manufacturing heavily involved in exports, 86% reported a decline in orders, with 68% cutting prices on products, 23% laying off staff, 27% slashing capital expenditures, and 18% cutting wages. Some Chinese companies circumvented tariffs by opening factories in other countries or investing in U.S. companies (Bloomberg 2018; Hornsby and Liu, 2019).

With the Covid19 pandemic, China initially suffered an economic downturn, but recovered quickly with its exports rising 9.9% year on year in September 2020 and 11.4% in October, and 21.1% in November. China's domination of global trade is partially driven by its export products being heavily relied on by countries experiencing upsurges in Covid19 cases entailing frequent lockdowns. Exports from China include fabric products, face masks, medical devices, ventilators, and products needed for remote working such as electrical appliances. Despite trade difficulties with the U.S., total exports from China to the U.S. rose 45.5% on year in November, and exports to the EU rose by 25.9%, with non-pandemic exports also rising 21% for the third quarter of 2020 (Hale, 2020).

3.4 Effects of the U.S. China Trade War on Different U.S. Industry Sectors

With 25% tariffs placed on foreign steel in 2018, the U.S. steel sector was initially given a pricing edge, such as the U.S. Steel Corporation's prices becoming more competitive. But in 2019, U.S. Steel experienced lower revenues with steel pricing falling with a glut of steel and larger supply of recycled scrap metal and exempted imported steel on the market. In December 2019, U.S. Steel announced planned layoffs of 1,545 workers and a dividend cut (Reindl, 2019). Although 10% tariffs on foreign aluminum gave U.S. aluminum a more competitive price, large multinational aluminum companies, such as Alcoa, had higher costs having to pay tariffs on the primary aluminum that their foreign subsidiaries produced. Companies were also hurt in 2019 by a fall in the price of aluminum (Kilgore, 2019).

Many U.S. manufacturing sectors using tariffed products as factors of production experienced higher costs having to pay these tariffs. Examples include General Motors and Ford that use steel, aluminum, and other manufacturing components from China, who each paid about \$1 billion in tariff costs in 2018. With costs passed on as higher prices for products, this reduced their product demand, contributing to layoffs and some plant closures (Boudette, 2018; Kelleher, 2018). The Center for Automotive Trade estimated an average price rise of US\$2,750 in 2019 for U.S. produced light duty vehicles with an expected drop of about 1.32 million unit sales, as consumers sought cheaper used cars (Schultz, Dziczek, Chen, and Swiecki, 2019).

As Layne (2019) points out, five major U.S. industry sectors were hurt the most by the trade war: (1) Retailers selling electronic goods, with tariffs on imported consumer and electronic products increasing costs (i.e. Best Buy); (2) Tech and Telecom companies selling electronic products in China and companies, such as Broadcom, banned by the U.S. from selling to Huawei; (3) Manufacturers and

Suppliers (i.e. industrial suppliers) with higher costs for aluminum and steel and other components used for production (i.e. Rockwell Automation, Johnson Controls, Cummins, United Technologies); (4) Food and agribusiness (i.e. Tyson Foods; Archer Daniels Midland; Del Monte) and Beverage Companies (i.e. Coca Cola, Jack Daniels, Jim Beam) with tariffs on U.S. agricultural and beverage products, and China's curtailing its purchases of U.S. agricultural products and (5) Clothing and Footwear Companies (i.e., Macys, J.C. Penny, Target), with 92% of apparel, 68% of home textiles, and 53% of footwear subject to tariffs.

Some U.S. companies with minimal direct tariff exposure or with substitutable products to those tariffed benefitted, such as Whirlpool, with a 12% price rise for foreign washing machines as the result of tariffs (Brinkley, 2019). Companies producing substitute products for steel did well, such as Bedford Reinforced Plastics, an alloy manufacturer producing hard plastic products, Pearson Pilings, making fiberglass pilings for docks and waterfront construction, and Modumetal Inc. producing alloys to help reduce corrosion and lengthen the life of oil and gas platforms. With China's tariffs creating a U.S. glut of recycled cardboard and other fiber products, many small U.S. paper and cardboard companies took advantage of this and increased production, with some financed by U.S. subsidiaries of China companies (AP, 2019; Neuhauser, 2019).

4. Sustainability Effects of the Trade War

Environmentally-related effects of a trade war may depend on the costs they entail with the trade war and government actions as suggested under proposition two. During the trade war, analysts were particularly concerned that political leaders would be reluctant to press for more aggressive low carbon policies, if the trade war had negative economic effects. This appeared to be the case with the International Energy Agency (IEA) reporting that 2018 global emissions were at a record high, with energy-related CO₂ emissions rising by 1.7%. In 2018, China's CO₂ emissions rose 4.7% (versus 1.6% in 2017), with China's emissions accounting for about 25% of global emissions, and a global rise in emissions by 0.6% estimated for 2019 (Carbon Brief, 2019).

In response to China's economic slowdown during the trade war, China's government provided support for key industries with high carbon emissions (i.e., coal and heavy manufacturing) to stimulate the economy. China also reduced its subsidies for renewable energy and slowed funding for green energy projects and upgrades for transmission infrastructure. China's growth in renewable energy dropped about 40% for the first half of 2019. China financed 300 coal plants in different countries and approved 141 million tons of new annual coal mining capacity in the first half of 2019. In 2019, China reduced its share of coal in its energy mix by 1.5% to 57.7%, but the amount of coal used rose 1% with energy consumption growing 3.3%, and China's greenhouse emissions rose 2.6%. Analysts are concerned that the trade war created difficulties for China to engage in cleaner technologies with lower access for the non-coal energy supplies it needs (Barrett, 2019; Larson, 2019; Campbell, 2019; IEA, 2019ab; Reuters, 2020).

Over the trade war, with a U.S. pro-fossil fuel agenda under the Trump administration, U.S. carbon emissions grew by 2.8% in 2018 (versus 0.9% in 2017), with the U.S. emitting about 14% of the world's carbon emissions. For 2019, U.S. energy-related carbon emissions fell 2.8% offsetting a 2.9% increase in 2018, as the result of U.S. utilities moving away from coal for electricity generation to cheaper natural gas and renewable energy and more stringent environmental regulations in some states, supporting this transition (IEA 2019a, Carbon Brief 2019, EIA, 2020).

4.1 U.S. Sustainability Sectors Affected

Whether U.S. sustainability efforts were affected varied by industry sector depended on tariffs costs as well as government policies as suggested under proposition two and three.

U.S. Solar and Wind Industry Sectors: Tariff costs for solar panels, solar modules, lumber, steel, aluminum, turbines, and other components used for large scale solar and wind project affected both the U.S. solar and wind industries. Both industries prepared for the expected tariffs and reductions in government subsidies (such as the phasing out for the investment tax credit for wind power phasing out by 2020 and the Solar Investment Tax Credit phasing out by 2022) by becoming more cost efficient.

The majority of solar panels for U.S. solar assemblers come from other countries, with only 14 solar panel manufacturers in the U.S. in 2018 (about 2% of global solar panel production). The Solar Industry sector faced a 30% tariff on all foreign solar panels and tariffs on foreign steel, aluminum and wood, and China's solar module components used for solar project construction. U.S. solar installers protected themselves by stockpiling solar panels before the U.S. tariffs began. They also initially benefitted from a drop in the price of Chinese solar panels as the result of a glut on the market, as China phased out its solar energy subsidies.

Over time, the price for Chinese solar panels imported to the U.S. rose to be 50% percent higher than the price paid in China. With tariff costs for solar panels passed on as higher prices to consumers, U.S. homeowners paid on average a 3% to 4% higher price, reducing home solar installation demand in 2018. For 2018, the Solar Energy Industries Association (SEIA) calculated a U.S. loss of 18,000 solar energy jobs, and an expected \$8 billion loss in investments through 2022. SEIA reported a 2% decline in solar PV growth in 2018, and delays in the timelines for utility-scale solar projects. For example Xcel Energy had to delay three major solar power projects, with previous winning bidders not able to do the construction at the original bid price (Avery, 2019; Sun, 2019).

Demand for residential solar panels varied by state. In California with mandates for renewable energy for all new homes beginning in 2020, solar panel installations and solar jobs rose in 2018. For other states, such as Colorado, tariffs increased prices for solar panel and lumber for solar projects. Colorado's solar installation growth rate fell to 1% in 2018 (from 7% in 2017), and its new solar industry jobs in 2018 fell to 58 (from 785 in 2017).

Wind power developers depended on wind system component parts imported from China, with tariffs on these increasing wind power installation construction costs. Although the cost of wind power electricity became more competitive (falling about 35% from 2010 to 2018), protectionist policies affected the global supply chain for wind turbines, with complex global supply chains for different elements, such as rare earth elements and components made in China. The American Wind Energy Association (AWEA) reported that the trade war tariffs on aluminum, steel, turbine blades, gearboxes, crankshafts, and other internal components used in wind turbines resulted in costs for U.S. wind power construction rising as much as 10%, contributing to some delays or cancellations for new projects in 2018. With China the largest producer of some turbines, many wind power construction companies sought out new suppliers in other countries to mitigate tariff costs, while others held off on new projects and hiring (AWEA, 2019; Hook, 2019; Xin, 2019; Efstahiou, 2018; Paraskova, 2019b, WINDEXchange, 2019). In net, the tariffs negatively affected these sustainability sectors with higher costs and delays for new projects.

Recycling Industry Sector: China's tit-for-tat tariffs included a 25% tariff on old corrugated cardboard (OCC) and other recovered fiber, along with paper, scrap plastic, ferrous metal, copper, nickel, aluminum, lead zinc, tin, and other based materials. U.S. recyclers initially reacted by putting more of their materials in landfills or stockpiling them, and passing the net cost of curbside recycling to customers. Recycling firms, such as Resource Recycling, experienced a large fall in demand for scrap

plastic, while their supplies remained the same (Waste360, 2018).

But, the U.S. tariffs on steel stimulated the scrap metal recycling industry, with a rise in scrap metal demand increasing scrap metal prices in 2018 that created a stimulus for recyclers. The Northeast Recycling Council reported 17 North American paper mills increasing their processing capacity for handling recyclable paper and some facilities retooling to take advantage of a glut of cheap cardboard and other waste materials (previously sent to China). U.S. subsidiaries of China companies invested \$1 billion in U.S. paper processing mills to gain greater access to waste paper or flattened bottles to use as raw manufacturing materials. For example, NBD Paper (a U.S. affiliate of a Chinese owned company) made a \$500 million investment in paper mills in Maine, Wisconsin, and West Virginia in 2019. Chinese companies also invested in plastic and scrap metal recycling plants in Georgia, Indiana, and North Carolina to produce feedstocks for manufacturers in China (AP, 2019a).

Bicycle, E-Bicycle, and E-car and Mass Transit Sectors: Over 95% of bikes sold in the U.S. and 90% of bike components used by U.S. bike assemblers are manufactured in China, and China is the world's largest producer of batteries and electric vehicles. U.S. tariffs of 25% on popular Chinese brands of e-bikes, cycling computers and bicycle components resulted in higher costs of 10% to 25% for U.S. bicycle shops and assemblers, with few U.S. companies producing these components. U.S. electric car sales in China were also affected by China's tariffs, such as Tesla experiencing a 20% rise in price, leading to Chinese consumers delaying purchases. However, Tesla received a 10% car purchase tax exemption, from China and built a new plant in Shanghai in 2019, with demand in China for its e-cars rising over 175% (Sheetz, 2019).

For public transportation light-rail, subway, and rail car lines, costs for new construction and car projects rose during the tariff war. With almost 6,000 products imported from China currently subject to tariffs, including aluminum and steel and other products used for rail cars and construction products, construction costs for transit agencies rose. An example is the Chicago Transit Authority's (CTA) planned overhaul of 50% of its rail car line, with CRRC Sifang America, a subsidiary of a China rail car company, winning a 10-year contract to produce up to 364 rail cars for the CTA. Although the cars are made in the U.S., about 15% of the parts, including stainless steel rail car shells (subject to a 25% tariff), come from China, adding \$59,000 to the price of each rail car. CTA also receives federal funds to help pay for the cars, but to qualify a majority of the components used must be made in the U.S., with new restrictions imposed under the Trump administration requiring that 95% U.S. steel and iron be used (versus 50% previously for federal projects). With transit ridership already on a decline, higher fares to cover these costs may dampen transit ridership further (Wisniewski, 2019).

4.2 Other Spillover Effects of the Trade War on Sustainability

Spillover Effects with China Reducing U.S. Agriculture Purchases:

China retaliated for U.S. tariffs by reducing its U.S. agricultural purchases, seeking other countries as agricultural suppliers. Brazil, for example, vied to be one of China's suppliers. Developers in Brazil given incentives to clear forests for planting, which may have contributed to devastating fires and destruction of the Amazon jungle in 2018 with the deforestation resulting in a loss of about 3,000 square miles of forest. Since the Amazon jungle acts as a carbon sink to absorb greenhouse gases, this clearing had devastating ecological effects (Cullen, 2019).

In 2017, the U.S. exported about 50% of its soybean production, with approximately 57% sold to China. With the trade war, China imposed a 25% tariff on U.S. soybeans and reduced its purchases, resulting in a dramatic fall in U.S. soybean exports in 2018 to 2019. Farmers suffered huge losses in 14 different states, and U.S. farmers in response reduced their soybean cultivation, shifting corn or other crops. Soybean cultivation absorbs nitrate soil pollution, so this shift potentially increase nitrate levels

in U.S. drinking water (Giri, Wesley, Peterson, and Sharma, 2018). Under the Phase 1 truce, China agreed to purchase U.S. \$40 billion of agricultural goods, including large quantities of soybeans in 2020. But, analysts expressed concerns, since China's highest annual purchase was \$25.9 billion (in 2012), and it could be locked into contracts with other countries for agricultural purchases. (Funk, Wiseman, and McDonald, 2019).

Spillover Effects for the Environment: Over past decades, the U.S. and China actively collaborated on research to develop commercial ventures for deploying clean energy technology. This changed with a loss of federal government collaboration over the trade war and a pro-fossil fuel stance under the Trump administration. China is a leading manufacturer for solar panels, wind turbines, and electric vehicles, including two-thirds of solar cells worldwide, with U.S. tariffs reducing U.S. access to these.

China is also one of the top investors for global clean energy for nine out of ten previous years, financing and supplying cutting edge technology for green projects in Kenya, Argentina, Scotland, and Brazil among other countries, with China Three Gorges (CTG) the world's largest hydropower provider with operations across 47 countries. China's global exports of renewable technology puts China in the position of having the most renewable energy patents, giving China a leading position, along with related technologies including electric vehicles (Campbell, 2019; IRENA, 2019).

As pointed out by Huang (2020), the U.S. has less leverage over China's green policies, with the Trump administration's decoupling with China with the trade war, and with incentives for countries hurt by Covid-19 to stimulate their economies at the expense of the environment, particularly with the suspension of most official mechanisms for bilateral dialogue between the two countries.

5. U.S. Second Best Solutions in the U.S. in Response to Federal Climate Inaction

Under Second Best Theory, when there is a market distortion, distorting an optimal allocation of resources, other second best actions must be engaged in to counteract the distortion for a more efficient outcome. Although there were negative effects for U.S. sustainable energy sectors with the trade war and a pro-fossil fuel stance by the Trump Administration, many U.S. states encouraged greater use of renewable energy, including nine states (California, Colorado, Hawaii, Maine, Nevada, New Mexico, New Jersey, New York, Washington, along with Washington D.C., and Puerto Rico) making pledges to get all their electricity from clean or renewable sources by 2050 or earlier. Utilities such as Xcel Energy and Idaho Power committed to future 100% clean energy targets in the future. Other states including Minnesota, Wisconsin, Illinois, and New York are considering this target, and New Jersey, New York, and Oregon have increased their mandates to 50% by a targeted year, with Vermont increasing its renewable portfolio standard to 75%. New policy changes by states are also expected to help ease the shift to clean energy (IEA, 2019a; Barrett, 2019; Race to Zero, 2019).

Second best solutions, consistent with Proposition 3, came about in the U.S. during the tariff war with private and state actions and actions by members of the U.S. Climate Alliance (25 state governors, over 407 U.S. Climate Mayors, and over 1,650 large corporations and investors) continuing their pledge to work to meet the U.S.'s previous UN Paris Climate Accord commitments for carbon emission reductions. An increase in state initiatives for the use of solar power by utility companies, large corporate non-residential community projects (such as for Target, Walmart, Amazon, and Apple), and greater residential demand for renewable energy contributed to the growth of solar PV in 2019, despite high costs for components with tariffs. Low interest rates in financial markets also encouraged U.S. utilities to sell more than \$90 billion in bonds in 2019 to fund new solar project and transform and modernize grids to use wind, solar, and cleaner-burning natural gas generators (Cooper, 2019; Race to Zero, 2019;

SEIA, 2019). New technological improvements for the solar energy storage industry also offset tariff costs by allowing allowed utility projects to be more efficient with oversized DC-AC ratios, up to 60% capacity factors, providing greater solar energy capacity (Weaver, 2019).

With wind power companies accelerating projects before the phase out of ITC credits, in 2019, U.S. wind power construction grew. The industry commissioned 3,667 Megawatts (MW) for the first three quarters of 2019, a 123% increase over the same period in 2018. Nineteen states had over 1,000 MW under construction or advanced development, and 22,651 MW under construction (WINDEXchange, 2019; Frangoul, 2019). Similarly, with prices falling for solar installations, greater demand by utilities, and developers accelerating their build-outs ahead of reductions in ITCs, U.S. solar growth rebounded by the 3rd Quarter of 2019, with a 45% increase from 2018, and U.S. residential solar installation setting a new record, installing over 700 megawatts (Solar Jobs Census Colorado 2018; Solar Foundation, 2019; SEIA, 2019).

Although federal joint research projects with China have declined, individual states also are engaging in joint research renewable energy partnerships, such as California's 23 cooperative partnerships that include partnerships with the Ministry of Ecology and the Environment of the People's Republic of China, the Chinese People's Association for Friendship with Foreign Countries, among others, and California university collaborations with China universities (CA.GOV, 2019).

6. Trade War Effects for Pandemic Shortages of Medical Equipment in the U.S.

The Trade War also had carryover effects as well during the Covid19 pandemic in 2020 given the interrelationships between the U.S. and China and their pharmaceutical industries with the U.S. continuing to play a leading role in drug discovery, but the majority of U.S. drug and pharmaceutical products being manufactured in China, including many antibiotics no longer produced in the U.S. (i.e., the last U.S. manufacturer of penicillin closing in 2004), as well as numerous other medical supplies that moved to China over time). As noted by the Peterson Institute for International Economics, about 50 percent of personal protective equipment (PPE) items imported by the U.S. come from China, with higher percentages for other PPE items such as 70% for mouth-nose protective equipment, 57% for goggles and visors, 45% for protective garments and 39 percent for gloves (GTN, 2020; Bown, 2020).

Under the Phase One Deal initiated in January 2020, exemptions for tariffs on China's products in the areas of medicines and medical devices were put in place for the upcoming two years. However, filing for tariff exemptions by U.S. companies with the trade office for necessary supplies entails a cumbersome process given the urgency of medical supply shortages in the U.S. This contributed to a dangerous shortage for front-line hospital workers for medical masks and gloves and digital thermometers, among other needed medical supplies (CGTN, 2020; Frieden, 2020).

In mid-March 2020, the U.S. provided tariff relief temporarily during the coronavirus pandemic on some medical supplies imported from China. However, President Trump signed a "Buy American" order for federal agencies for purchasing essential Medical Supplies on August 7, 2020, to encourage domestic drug and medical supply production, an order questioned by many analysts, given the effort this would take for drug companies to change their production from China to the U.S. with the on-going pandemic. Despite this, with huge needs for drugs and medical supplies by the U.S. during the pandemic, U.S. pharmaceutical and medicine imports from China almost doubled as of May 2020, compared to the previous year in May (White, 2020; CGTN, 2020; Bowen, 2020; Frieden, 2020).

7. Summary and Conclusion

From a protectionism perspective, a trade war is considered to be beneficial for a domestic economy, stimulating dormant industries by sheltering them from foreign competition, bringing back manufacturing to the domestic country. With the U.S. China Trade War, however, this did not happen. Few corporations brought back their manufacturing or supply chains to the U.S. and net manufacturing growth and GDP growth fell over 2018 to 2019. Similarly, China suffered economically from the trade war, and both countries had less resources available to work on climate change efforts, pushed more by economic concerns.

Carbon emissions increased for both China and the U.S. in 2018. In 2019, the U.S. had lower carbon emissions, however, as the result of state and local government actions and regulations promoting the use of alternative, cheaper, cleaner sources of energy by utilities, helped along also by lower interest rates for financing these. Technological innovations also helped to reduce alternative energy costs to offset tariff costs.

With the U.S. and China as the two largest global carbon emitters, the trade war reduced their research collaboration and sharing of technologies for climate change action. The need for further cooperation was also emphasized with the large negative effects of the trade war during the Covid19 epidemic in terms of the U.S.'s shortage of medical supplies and drugs, putting medical professionals at greater risk. It is hopeful that in the future with a new approach on American alliances, that the two countries will work together on climate change for the benefit of both countries and the world.

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APPENDIX Table 1: Sequence of Major U.S. China Tariff War Events

2018 Events

Jan. 22: US imposes 30% tariffs on all imported solar panels and 20% washing machines.

March 1: US puts 25% tariffs on imported steel & 10% on imported aluminum for most countries.

March 22: US announces tariffs of 25% on US\$50 bil. worth of China products, particularly electronics

April 2/3/4: China puts tariffs on US\$3bil.worth of 128 US products including U.S. steel & aluminum, and a list of 25% tariffs on US\$50 billion for specific US products, soybeans and automobiles

June 15: US moves ahead with its 25% tariff on US\$50bil of exports from China to take effect on July 6 for US\$34 billion with US\$16bil. tariffs to occur later.

June 19: China threatens 25% tariffs on US\$50 bil. of US products.

July 6: US & China tariffs of 25% on US\$34bil. for each country's goods takes effect.

Aug. 23: US & China tariffs on additional US\$16bil. for each other's goods takes effect.

Sept. 17: US announces new tariffs of 10% on additional US\$200bil.worth of Chinese goods to occur on Sept. 24, and rise to 25% on Jan. 1. China announces 10% tariffs on US\$60 bil. worth of US goods

Sept. 24: US & China tariffs of 10% go into effect, with a total US tariff on US\$250bil. value of China goods, and China, tariffs on US\$110bil. value of US goods

Dec. 1: US & China agree on a truce, and US delays Jan. 1st rise in tariffs to 25% on US\$200 bil. of China's goods to Mar. 1; China agrees to purchase a substantial amount of U.S. products.

2019 Events

Feb. 24: President Trump postpones the March 1st deadline indefinitely, given progress on trade talks

May 8: Trump announces rise in tariffs on US\$200 bil. worth of China's goods to 25% in effect May 10th.

May 13: China announces increase in tariffs on \$60 bill. worth of U.S. products.

May 16: US places Huawei on its "entity list" banning Huawei from purchasing US companies and US companies from selling to Huawei without US government approval.

May 31: China establishes "unreliable entities" list on foreign groups that violate contracts, block or cut off supplies for non-commercial reasons or damage the legitimate interests of Chinese companies.

June 1: China tariffs on \$60 bil. of US products goes into effect, with tariffs of 25%, 20%, and 10% on \$60 bil. US. products. China curtails purchases of soybeans and threatens to curtail sale of rare earth materials. U.S. has public hearings on additional tariffs proposed.

June 21: US adds five Chinese entities to its entry list barring them from buying US parts and components without government approval.

June 26: US & China agree to tentative truce leading to resumed talks at the G20 Summit

June 29: Trade talks resume with U.S. relaxing its ban on U.S. companies selling to Huawei with exceptions for U.S. security, & US will not add the \$300billion additional tariffs on China goods.

July 9: US exempts 110 Chinese products, including medical equipment related to cancer treatments from the 25% tariffs previously imposed for one year.

July 16: President Trump threatens tariffs on another US \$325 billion of Chinese goods.

July 30-31: Two-day trade talks in Shanghai result in little progress being made.

August 1: U.S. announces 10% tariffs on an additional US\$300 billion of Chinese goods to start on Sept. 1, affecting almost all of China's imports to US including electronic and clothing consumer goods.

August 6: China companies suspend U.S. agricultural products purchases. U.S. Treasury declares China to be a currency manipulator (with Yuan falling 7% against the U.S. dollar).

- August 13:** US delays tariffs to Dec. 11th on certain products affecting costs for US consumers, such as cell phones, laptops, and other computer products, among others consumer goods
- August 23:** China announces tariffs on US\$75 billion U.S. goods (with 5% and 10% tariffs imposed on 5,078 US goods in two sequences with a 1st list of 10% tariffs on 270 agriculture products 10%; on Sept. 1 and 2nd 10% tariff for 646 agriculture products, and some industrial products on Dec. 15. China approves reinstatement of 5% and 25% tariffs on U.S. automotive and auto parts for Dec. 15.
- Sept. 1:** US begins implementation of tariffs for over US\$125 billion value of China's goods, and China imposes additional tariffs of US\$75 billion value for US products, including a 5% on U.S. crude oil.
- Sept. 5:** U.S. and China agree to resume a 13th round of trade talks in Washington in October, but President Trump states a rise for tariffs to 30% from the current 25% on \$250 billion of China's goods.
- Sept. 11 & Sept. 13:** China presents a tariff exemption list for 16 types of U.S. imports from additional tariffs for a year, and exempts various agricultural products from additional tariffs, including U.S. for soybean, pork, and other farm goods.
- Sept. 19-20:** US & China hold mid-level trade talks in Washington & U.S. releases new tariff exemptions for over 400 Chinese goods from tariffs
- Oct. 11-12:** US initiates a "Phase 1" deal that puts a delay on a tariff rise for China goods.
- Oct. 18:** US announces tariff exclusion process for US companies to apply for concerning specific products for the 15% tariff in effect on Sept. 1, 2019 for US \$300 billion value on Chinese products applying to China's products previously subject to an additional 15% tariff in effect September 1, 2019.
- Nov. 1:** China wins World Trade Organization (WTO) case allowing China to impose compensatory sanctions on US imports worth US\$3.6 billion for the US failure to abide by anti-dumping rules on Chinese products (a WTO case originating 6 years previously).
- Nov. 2:** More than 3,000 companies file about 44,000 requests for exclusions from the first three rounds of Trump's tariffs on \$250 billion of Chinese imports, with about 28,000 under review as of Nov. 1, 4,900 requests granted, and 10,970 denied, and many more expected.
- Nov. 7:** Negotiations make progress on finalizing a partial trade deal for the US and China.
- Dec. 5:** President Trump objects through the U.S. representative on the World Bank Board. to a \$1 billion per year from 2020 to 2025 World Bank Loan Programme for China to fund green investments.
- Dec. 13 to 15:** China & the U.S. a Phase 1, trade deal announced, and China began its exclusion process.
- Dec. 31:** After legal vetting, the U.S. China Phase 1 Trade Deal to be signed on January 15, 2020.
- Sources include: Wong and Koty (2019); Williams, Hammond and Morrison (2019); Politi and Shepherd (2019), and other general news article announcements over 2018 to 2019. Note: With the U.S./China Trade War, as a rapidly evolving situation, new events may have occurred following the submission of this article.