U.S.–China Solar Trade War:
Economic and Political Implications of the 2012 and 2014 Antidumping Disputes

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ABSTRACT

Following the 2011 flood of Chinese solar photovoltaic (PV) panels, SolarWorld and a conglomerate of six unnamed U.S. solar cell and module manufacturers filed a lawsuit in October 2011 against Chinese producers alleging that they were receiving unfair government subsidies and were selling their products into the U.S. market for less than fair market value. The artificially low-priced solar products, SolarWorld explained, would materially harm the U.S. solar manufacturing industry, an industry that already was struggling. By mid-2012, the U.S. Department of Commerce (USDOC) and U.S. International Trade Commission (USITC) had imposed preliminary duties ranging from 31% to 250% on Chinese solar cells and the modules that contained them; ultimately, the agencies affirmed these duties in November 2012.

The dispute divided the U.S. solar industry. Manufacturers argued that the duties were necessary to protect U.S. manufacturing, jobs, and fair competition. Meanwhile, U.S. installers claimed that the duties would put the brakes on the installation sector and the many jobs it promised. Still others surmised that the duties would have little effect. After all, Chinese producers had an easy out: thanks to the solar cell loophole, they could simply produce modules with foreign solar cells and ship them into the U.S. market duty free.

This analysis explores how the antidumping dispute may have shaped the U.S. import market and the U.S. industry, including domestic PV manufacturers and installers. It finds that despite the solar cell loophole, the dispute may have created opportunities for emerging partners to enter (or re-enter) the U.S. market and, perhaps, increased the price of solar cells and modules for U.S. buyers. Any such effects, however, must be understood in the context of the industry as a whole: booming installation markets, changing policy, and rising new players. With the dispute still ongoing, many chapters likely remain untold.

I. INTRODUCTION

In October 2011, amid the flood of Chinese solar photovoltaic (PV) panels into the world market, SolarWorld and a conglomerate of six unnamed U.S. solar cell and module manufacturers sued Chinese producers claiming that the producers were receiving illegal public support and were selling products into the U.S. market for less than fair market value. The artificially low-priced solar products, the petitioners explained, were materially harming the U.S. producers. In mid-2012, the U.S. Department of Commerce (USDOC) announced preliminary duties ranging from 31% to 250% on Chinese solar cells and the modules that contained them; ultimately, it affirmed these duties that November.

The dispute divided the U.S. solar industry. Manufacturers contended that without the duties the U.S. solar manufacturing industry would not recover, jobs would be lost, and Chinese manufacturers would be allowed to compete with an unfair upper hand. Meanwhile, U.S. installers explained that the duties would put the brakes on the installation sector, undermine job growth, and delay grid parity goals. Still others surmised that the duties would have little effect. After all, Chinese manufactures had an easy out: thanks to the solar cell loophole, they could simply produce modules with foreign solar cells and ship them into the U.S. market duty free.
This analysis explores how the antidumping dispute may have shaped the U.S. import market and the U.S. industry. It finds that despite the solar cell loophole, the dispute may have created opportunities for emerging partners to enter (or re-enter) the U.S. market and, perhaps, increased the price of solar cells and modules for U.S. buyers. Even so, any such effects, however, must be understood in the rapidly changing global PV landscape: booming installation markets, changing policy, and rising new players. The analysis proceeds in five parts: Section II highlights key events leading up to and during the litigation. Section III explains the scope of the 2012 antidumping duties and provides insight into nature of the manufacturing and installation industries. Section IV, the empirical analysis, evaluates trade and industry data to shine a light on how the dispute may have affected the U.S. import market and U.S. manufacturers and installers. Section V broadens the scope to consider the empirical results in the context of U.S.-China competition. Section VI concludes.

II. DISPUTE OVERVIEW

As the antidumping dispute between U.S. and Chinese manufacturers erupted, the global solar market changed rapidly. In the mid-2000s, global solar cell production grew exponentially. From 2003 to 2009, global production grew at about 45% each year. China quickly rose to the top, as Figure 1 shows (Algieri, Aquino et al. 2011, Tour, Glachant et al. 2011, Earth Policy Institute 2014). Each year, from 2006 to 2010, China more than doubled production. Other players, like Taiwan and Malaysia, also began to emerge. From 2007 to 2010, Taiwan’s growth rate tracked that of China. Malaysia, entering the global market in 2008, became the world’s fourth largest supplier by 2012. In the United States, production hit a high in 2010, nearly doubling 2009 production levels, only to fall by 30% over the next two years (Algieri, Aquino et al. 2011, Tour, Glachant et al. 2011, Earth Policy Institute 2014).

China owed much of its PV production boom to substantial public support for export driven industries, including solar PV, amid the global recession. National and local governments offered manufacturers generous subsidies, including export credits and tax breaks (Liu and Goldstein 2013, Nahm and Steinfield 2014). State-owned banks provided loans with rates as low as 2% and in sizable sums, about $37 billion all together, including to well-established players like Jinko Solar, which received nearly $1 billion from the China Development Bank to help the company with overseas expansion (2012, Nahm and Steinfield 2014). At the time, Jinko Solar already tapped into about 1.2 GW of production capacity for silicon ingots, wafers, solar cells, and modules (2012). All told, China invested about $41.8 billion in the industry (Zhang, Andrews-Speed et al. 2013).

By fourth quarter 2011, supply outpaced demand by 10% to 15% and module prices plummeted, falling by about 40% in both the world and U.S. markets from prices the year before, as Figure 2 demonstrates (GTM Research 2013, BNEF 2014). Solar manufacturing companies around the world fell into financial turmoil, closing plants and declaring bankruptcy; about one third closed up shop between 2011 and 2012 (Jordan 2014). Those innovating cutting-edge technologies, like U.S.-thin film producer Solyndra, were among the hardest hit; their high-value
products simply could not compete (GTM Research 2012). Chinese companies also struggled. Amid the turmoil, stock in Suntech, once the world’s largest PV manufacturers, lost a third of its value, and, in 2013, the company entered bankruptcy proceedings. By 2011, China’s ten leading solar PV producers had a combined debt of 111 billion renminbi (RMB), about 18-billion U.S. dollars (Zhang, Andrews-Speed et al. 2013).

Meanwhile, global demand for PV fell short of expectations as nations like Italy and Germany reduced or terminated market incentives in the wake of the global recession. The market that grew by 140% in 2010 slowed to a growth rate of a mere 17% in 2011 (Hart 2012). And, despite a banner year for U.S. PV installations, which increased by 109% over 2010 levels, valuable policy incentives, on the brink of expiration, like the Section 1603 cash in lieu of tax credit program, left project developers struggling to finance new solar projects (GTM Research 2012, U.S. Department of Treasury 2014). After all, the 2011 installation boom had been driven not only by falling module prices but also market-generating federal and state policy incentives.

Amid the turmoil, in October 2011, SolarWorld and a conglomerate of six unnamed solar PV manufacturers filed a petition with the USDOC and the U.S. International Trade Commission (USITC) seeking trade sanctions under section 732(b) of the Tariff Act of 1930 (Department of Commerce 2011). Almost immediately, sizable duties on Chinese solar products appeared

1 For many Solyndra’s September 2011 bankruptcy likely is a familiar story: Solyndra was a promising thin-film producer that had receive a $535-million loan guarantee from the U.S. Department of Energy issued Solyndra a $535 million loan guarantee in 2009. The next year, the Massachusetts Institute of Technology Technology Review named Solyndra one of the “50 Most Innovative Companies in the World” and the Wall Street Journal praised the company as “The Next Big Thing: Top 50 Venture Backed Companies.” Solyndra’s September 2011 bankruptcy preceded that of an upcoming solar PV wafer, sell, and panel manufacturer, Evergreen Solar, which had received $23 million in grants, a $17.5 million in low-interest public and private loans, and a $3-million land subsidy from the State of Massachusetts (2007). Governor Patrick Announces New Manufacturing Plant for Evergree Solar, Plan to Boost Clean Energy, Jobs, State of Massachusetts.


likely. The rest of this section highlights key turning points in the litigation and the spin-off disputes that arose in its wake. Figure 3 summarizes these events in a timeline.

Figure 1. PV Module Production (MW), China versus Rest of the World (ROW)


. SolarWorld’s U.S. headquarters is in Hillsboro, Oregon.
A. Litigation: Round One

1. October to December 2011: SolarWorld Files Petition; USITC Finds Material Harm Likely.

Two months after SolarWorld filed its petition in October 2011, the USITC, in December, found that Chinese manufacturers likely were causing “material harm” to the U.S. industry by selling underpriced solar cells and modules into the U.S. market. The finding was a prerequisite for the USDOC to later issue the antidumping duties.\(^4\) Among other factors, the


. In evaluating whether a product is being sold at less than fair market value, the Commission considers:

whether – (I) there has been significant price underselling by the imported merchandise as compared with the price of domestic like products of the United States, and (II) the effect of imports of such merchandise otherwise depresses prices to a significant degree or prevents price increases, which otherwise would have occurred, to a significant degree.

19 U.S.C. § 1677(7)(C)(ii) (emphasis added). In its preliminary December 2011 decision, the USITC rejected Respondents’ argument that the investigation should be expanded to include thin film products ibid.
USITC noted that, from 2008 to 2010, the value of Chinese imports in the U.S. market increased by nearly 412%, a fact which, according to the USITC, could not be explained by the increasing demand for PV products in the United States (U.S. International Trade Commission 2011). While the Commission acknowledged the many adverse economic factors at play, the legal standard, it explained, only required it to find that the adverse circumstances facing the U.S. industry could be reasonably attributed to the imports of PV products from China (U.S. International Trade Commission 2011).  

When the USITC handed down its preliminary determination, the scope of the dispute remained up for debate and, in particular, whether the investigation applied to all solar modules from China (U.S. International Trade Commission 2011).  

2. March to May 2012: USDOC Limits Scope of Investigation; Issues Preliminary Duties Averaging 31%.  

Nearly six months into the litigation, in late March 2012, the USDOC resolved the uncertainty regarding the dispute’s scope. The investigation did not extend to Chinese solar modules produced with foreign solar cells; it covered only Chinese solar cells and the modules

The Commission explained that, though a close question, enlarging the scope in that manner would be inappropriate: crystalline PV cells and modules “involve[d] very different technologies,” were produced in different facilities with different employees, were generally more efficient, and captured a larger market than their thin film counterparts; unlike crystalline PV, thin film generally was only used for utility-scale solar and thus were sold through different distribution channels ibid. The investigation also did not include crystalline PV cells less than 10,000 square millimeters that were incorporated into consumer goods for non-power generation purposes ibid.

Under 19 U.S.C. § 1671b(a)(2), which governs preliminary determinations for countervailing duty investigations, the USITC must find:

(A) an industry in the United States—
   (i) is materially injured, or
   (ii) is threatened with material injury, or
(B) the establishment of an industry in the United States is materially retarded, by reason of imports of that merchandise or by reason of sales (or the likelihood of sales) of that merchandise for importation.

As the Commission explains, the statute does not define “by reason of,” which allows it to exercise reasonable discretion in interpreting the term. Congress used the same language in 19 U.S.C. § 1673b(a), preliminary determinations in antidumping investigations.

made from them (U.S. Department of Commerce May 2012).\textsuperscript{7} About a month later, in mid-May 2012, the USDOC announced preliminary antidumping duties, ranging from 31.14% to 249.96% (U.S. Department of Commerce 2012). Chinese companies, like Trina Solar and Wuxi Suntech, the USDOC explained, repeatedly sold solar products into the U.S. market at prices that differed substantially from other producers and regions. The USDOC also found that exporters, producers, and importers of Chinese solar cells had reason to believe, in September 2011, that an antidumping investigation would be likely. And yet, imports the companies’ solar products had increased by more than 15% between September 2011 to March 2012, compared to a base of February 2011 to August 2011, an increase that the USDOC deemed “massive” for such a short period (U.S. Department of Commerce 2012). The preliminary duties took effect immediately and were retroactive to 90 days before the decision was published (Bradsher and Cardwell 2012, U.S. Department of Commerce 2012).

3. October to November 2012: USDOC and USITC Affirm Preliminary Determinations; USITC Says No Retroactive Duties.

In October 2012, the USDOC issued a final decision that largely affirmed its preliminary decision from May (U.S. Department of Commerce 2012). The USITC followed suit in November, again finding material harm. Chinese manufacturers, it concluded, had undersold their U.S. counterparts, at significant margins, about 76% of the time.\textsuperscript{8} As domestic demand for PV boomed, the U.S. manufacturing industry fell into dire financial straits, as observed by their plummeting sales and spending on capital and research-and-development (U.S. International Trade Commission 2012).\textsuperscript{9} But the Chinese respondents did not lose on all accounts. Rather, the

\textsuperscript{7} In March 2012, the USDOC also announced preliminary countervailing duties of about 5% U.S. Department of Commerce (May 2012). Fact Sheet: Commerce Finds Dumping and Subsidization of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules from the People’s Republic of China (Preliminary).


\textsuperscript{9} The USITC painted a bleak picture for the U.S. manufacturing industry. From January 2009 to June 2012, the industry was faced

(1) with a steadily declining market share despite phenomenal demand growth, (2) that has lost market share due primarily to the significant and increasing volume of subject imports from China, (3) that has faced significant underselling by subject imports from China and depressed and suppressed prices, (4) that consistently lost money throughout the POI despite the tremendous demand growth and significant cost reductions, (5) that by the end of the POI experienced declines even in many of the performance indicators that previously had shown some improvement, and (6) that reported recognizing asset write-offs and/or costs related to the closure of production facilities, revalued inventories, and/or asset impairments.
USITC declined to authorize retroactive duties, which only would have been appropriate if Chinese manufacturers had sent a massive surge of Chinese solar products into the U.S. market after SolarWorld filed its petition and before preliminary duties were issued in an attempt to circumvent the investigation (U.S. International Trade Commission 2012). According to the USITC, the record contained no such evidence.

Subsequently, on November 30, 2012, the USDOC issued a final duty order. Consistent with its May and October decisions, duties were set at about 31% to 250% of import value (Department of Commerce 2012).

A. Aftermath: Round Two

Not long after the USDOC issued the final duty order, SolarWorld began to criticize the duties as ineffective. The solar cell loophole, it explained, allowed Chinese manufacturers to undersell their U.S. competitors simply by sourcing solar cells from a third country, namely Taiwan (Leone 2011, Wingfield 2012). Accordingly, on December 31, 2013, SolarWorld filed a second petition that targeted imports of PV cells and modules from both China and Taiwan, in an effort to close the loophole (U.S. International Trade Commission 2014).

The final decision on the second round of the dispute is due in December 2014. Similar to round one, in February 2014, the USITC found a “reasonable indication” of material harm: Chinese and Taiwanese producers and exporters appeared to be selling solar cells and modules into the U.S. market for less than fair market value (U.S. International Trade Commission 2014).\(^\text{10}\) According to the USITC, from 2010 through 2013, U.S. producers and those from other countries had lost market share and, despite the rise in U.S. PV demand, net sales for U.S. manufacturers dropped and operating losses increased (U.S. International Trade Commission 2014).\(^\text{11}\) Subsequently, on late July 25, the USDOC issued preliminary antidumping duties of

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\(^{11}\) The Commission also found anecdotal evidence that the 2012 duties had impacted the U.S. market. For example, the Commission found that Suntech’s U.S.-based operations at benefited from the solar cell loophole: once its China-based facilities were subject to the duties, it began sourcing solar cells from Taiwan ibid.
26.33% to 165.04% on Taiwanese producers and 27.59% to 44.18% on their Chinese counterparts (U.S. Department of Commerce July 2014). Unlike the 2012 duties, these new duties applied not only to solar cells, and the modules made from them but also to modules containing cells that used either ingots, wafers, or cells at least partially produced in China or Taiwan. It did not matter whether the cells were completed or partially manufactured in the other countries (U.S. Department of Commerce July 2014).

Meanwhile, a few months after the USITC issued its preliminary determination in the second round of the dispute, the U.S. Department of Justice, in mid-May 2014, issued a 31-count indictment against five members of the Chinese People’s Liberation Army for cyber espionage, which had allegedly targeted five U.S. firms for commercial advantage. SolarWorld was named among the victims. The indictment marked a first: the U.S. government had never initiated such an action against state actors (Morrison 2014). A few months later, in September, SolarWorld made its own claim with the USDOC, alleging that the Chinese military broke into its computers and stole documents related to the trade dispute. It asked the USDOC to investigate the matter and to impose additional trade sanctions (Cardwell 2014).

B. Spin Off Litigation

Tensions, throughout the dispute, have run high and have ignited litigation around the world. For example, in July 2012, as the first round of the U.S. litigation continued, SolarWorld filed a parallel action in the European Union, claiming that Chinese manufacturers were dumping solar cells and modules into the European market. One year later, in July 2013, the EU and China struck a deal: setting a minimum price for Chinese solar panels, a remedy designed to prevent Chinese producers from selling underpriced goods into the European market (Kanter and Bradsher 2014). Notably, just before the EU-China deal was announced, China imposed preliminary antidumping duties of more than 50% on U.S. producers of polysilicon, who ranked among China’s primary suppliers, and imposed lower rates on South Korean producers. Yet, though EU polysilicon producers also ranked among China’s top suppliers, producers in the EU were not subject to the duties. For U.S. polysilicon exporters, the duties posed a formidable threat; the duties placed them at risk of losing their largest export market (Cardwell 2013).

Meanwhile, in November 2012, as the first round of the U.S. antidumping dispute came to a close, India announced an antidumping investigation into solar cell imports from the United States, China, Taiwan, and Malaysia. The action included both PV and thin film producers (Pearson 2012). Subsequently, in July 2013, India threatened to add the EU and Japan to the list of targets (Pearson 2012). Then, just ahead of a visit from President Obama, in August 2014, India backed away from the dispute and dropped the antidumping charges (Kumar and Singh 2014, Roy and Chaturvedi 2014).

. U.S. importers also reported that the supply of PV products had decreased since the USDOC announced the duties and that importers increasingly had to rely on Taiwanese products ibid.
. As in the 2011-2012 dispute, the 2014 investigation did not include thin-film products ibid.
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Figure 3. Timeline, U.S. Antidumping Litigation & Spin-Off Disputes

Blue: U.S. antidumping litigation; Orange: Spin-off disputes
III. ANTIDUMPING DUTIES AND THE PV VALUE CHAIN

As noted above, the scope of the 2012 antidumping duties was limited. The duties applied to Chinese solar cells and the modules made from them imported into the U.S. market, not to modules produced in China with foreign solar cells. This opened the door for Chinese module manufacturers. To evade the duties, they simply could source solar cells from abroad and ship the modules made from them into the U.S. market duty free, even if those modules were made from Chinese wafers, one step higher in the manufacturing value chain as Figure 4 shows (GTM Research 2014). Notably, the duties applied to PV solar cells and modules only, not to thin film. This section describes the scope of the 2012 antidumping duties and highlights the shifting dynamics that characterize the solar industry.

A. Scope & Effect of the Duties

The 2012 antidumping duties fell at the end of the upstream manufacturing chain, as shown in Figure 4. In this downstream arm of the manufacturing sector, profit margins are thin and entry is easy, thanks to the availability of turkey production lines (Tour, Glachant et al. 2011). As a result, sharp changes in costs, arising perhaps from new duties, can have a noticeable effect on bottom lines. And, with easy entry, new and emerging producers may be able to step in quickly when the status quo shifts.

Meanwhile, on the installation side, large U.S. distributors and integrators enjoy considerable buying power and accordingly tend drive U.S. market prices (Friedman, Margolis et al. 2014). Compared to other countries, the U.S. market generally has fewer markups and middlemen, as shown in Figure 4 (Friedman, Margolis et al. 2014). Thus, U.S. installers generally pay near-wholesale prices for hardware like solar modules, within about 5% (Friedman, Margolis et al. 2014). Thus, the cost of hardware to U.S. installers likely approximates the wholesale price paid by U.S. importers. Any cost increases felt by importers likely translated into similar increases felt by U.S. installers.
Manufacturing a PV module requires four steps: First, quartz sand is purified from silica, a highly abundant mineral, into silicon. For solar PV panels, the purity level must reach at least 99.999% via an energy- and chemical-intensive process that requires considerable expertise. Second, ingots (silicon bricks) are grown from the purified silicon; the ingots then are sliced into thin wafers. Next, wafers are assembled into cells. This energy-intensive process creates junctions that produce the photovoltaic effect. Manufacturers can use a variety of methods to increase PV efficiency at this stage, which means some solar cells are worth more than others. Finally, cells are assembled into modules by joining the cells with electric junctions, either by hand or automatically, and encasing the joined cells in glass sheets (Tour, Glachant et al. 2011). On the installation side, large PV distributors tend to drive market prices (Friedman, Margolis et al. 2014).

**Figure 4. PV Value Chain**

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**B. Shifting Dynamics**

Competitive advantages in PV manufacturing are not country-specific; the availability of low-cost labor is not a necessary ingredient (Goodrich, Powell et al. 2013). Per the industry’s highly automated nature, producers can reap considerable savings from expanding facilities, developing well-established supply chains, and improving manufacturing equipment and technology (Dunford, Lee et al. 2012, Goodrich, Powell et al. 2013, REN21 2014). Large
factories can help companies achieve a 23% cost advantage over their competitors, such as plants in China which exceed the size of U.S. factories by about four times (Chandler 2013). Meanwhile, offshoring and locating facilities in strategic markets can reap considerable gains by slashing transportation costs and allowing producers to take advantage of foreign policy, for example, by avoiding tariffs and capitalizing on foreign subsidies (Dunford, Lee et al. 2012).

In fact, the move toward offshoring and locating facilities in strategic markets has become a common and lucrative affair. In October 2014, Risen Solar, a Chinese company, announced plans to invest $600 million in a 300-MW solar PV facility in Mexico (Woods 2014). The move promises to allow Risen to take advantage of growing solar markets in the United States, Mexico, and South America and avoid antidumping duties the U.S. litigation (EPIA 2014). Meanwhile, to capitalize on the African market, JA Solar, also a Chinese company, partnered with a producer in South Africa to open a module manufacturing facility with an annual capacity of 150 MW. Long term, JA Solar may expand the operation to produce 600 MW per year (Meza 2014). Meanwhile, in 2014, U.S.-based SunEdison announced plans to partner with local businesses to construct a $6.4-billion production facility in Saudi Arabia. The operation will produce materials across the entire upstream value chain: polysilicon, wafers, cells, and modules. The domestic partners will gain access to SunEdison’s advanced technology and its established deployment platform in the Middle East (Meza 2014). Malaysia, now home to manufacturer Hanwha Q-Cells, plays a central role in the industry; already Hanwha Q-Cells is vowing to match China’s low-cost prowess (Dunford, Lee et al. 2012).

Rapid change also marks the upper reaches of the manufacturing sector where profit margins are the greatest and expertise the hardest to acquire. China, for example, quickly gained traction in solar equipment manufacturing. In 2009, Chinese equipment makers captured 50% of China’s growing market, unseating traditional powerhouses, Germany, Japan, Switzerland, and the United States (Dunford, Lee et al. 2012). Aside from hefty government support, China’s longstanding expertise in the machine tool, semiconductor, and electronics industries fueled the market grab (Dunford, Lee et al. 2012). China also innovated rapidly to grab a foothold in the solar-grade polysilicon production market, an industry that requires a high level of expertise to achieve greater than 99.999% purity levels and in which companies viciously guard trade secrets rather than patenting them (Tour, Glachant et al. 2011). By 2010, China produced 30% of the world’s supply, up from near negligible amounts in the mid-2000s (U.S. International Trade Commission 2011, Zhang, Andrews-Speed et al. 2013). Substantial public support through the state-owned Emei Semiconductor Research Institution facilitated the market grab; after the lab developed the technology, it spread its knowledge to ready producers across China (Tour, Glachant et al. 2011, Zhang, Andrews-Speed et al. 2013).

With respect to transportation, a 2012 NREL study found that when shipping costs are taken into account, Chinese PV manufacturers are at about a 5% cost disadvantage to their counterparts in the United States; considering direct costs alone (i.e., excluding transportation), China enjoys only a 1% to 2% advantage before government subsidies. Goodrich, A., et al. (2011). Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry, NREL.
Meanwhile, thin film is moving in on PV. In April 2014, U.S.-based First Solar, among the Top 10 global solar manufacturing companies in 2013, recorded a record-breaking 17% efficiency for its thin film cells, up 1% from a record the company set the year before (2014, IHS 2014). To date, the United States (First Solar) and Japan (Solar Frontier) have enjoyed a top-tier competitive position, controlling about 75% of global production (Ali-Oetinger 2013). But, China soon may join their ranks. In 2013, Hanergy, a Chinese PV manufacturer, acquired several thin film companies, including U.S. producer Global Solar Energy (Colthorpe 2014, REN21 2014). Later that year, Hangery also announced plans to build a thin film production facility in Brazil (2013).

The shakeup in the PV value chain is not limited to the upstream manufacturing sector. For example, U.S. installer SolarCity in June 2014 acquired Silevo, a high-efficiency, low-cost solar cell producer and announced plans to build a 1-GW panel production facility in Buffalo, New York (Gold 2014, Lacey 2014). In the UK, Hanergy joined forces with IKEA to offer solar installation services to UK residents (REN21 2014). Such moves across the value chain offer the companies secure supplies and ready buyers, thereby shielding the companies from unexpected market shifts like supply shortages, price increases, and demand swings (Friedman, Margolis et al. 2014, Lacey 2014).

Many of the new entrants into the solar manufacturing market contrast sharply with longstanding players, like the United States, Germany, and Japan. For these countries, developing solar energy required giving birth to a new industry and new products (Dunford, Lee et al. 2012). In contrast, China, India, and Taiwan, had to catch up, both with technology expertise and market share. They did so through a variety of mechanisms: joint ventures, licensing, overseas acquisition, partnerships, and experts who studied abroad and returned home.

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13 Solar PV first burst on to the global scene in the early 1970s, fueled by the oil price shocks that left industrialized nations like the United States and Germany wary. During the 1970s, the crisis spurred the United States to develop new techniques for generating electricity, including solar energy. However, when oil prices dropped (to a now unthinkable) $15 per barrel in the 1980s, the U.S. focus, and the public support for renewable energy, virtually vanished. Jordan, P. G. (2014). Solar Energy Markets. London, Elsevier.


. As U.S. clean energy policy lay dormant in the 1990s, Germany and Japan pushed ahead, introducing innovative policies like the feed-in tariff and setting ambitious installation goal’s like Germany’s Thousand Rooftop Program ibid.


armed with foreign market knowledge (Dunford, Lee et al. 2012). As new market entrants pump in public financial support, longstanding players like Europe are stepping back in favor of more competitive markets (International Energy Agency 2014). In 2012, renewable energy investments made by developed countries dropped by 29% (Jordan 2014). Meanwhile, China increased such investments by 22%, much of which funded solar energy projects (Jordan 2014).

Given the rapidly changing face of the manufacturing industry, remaining a competitive edge in the industry appears to require constant innovation, strategic, cross-border partnerships, and, perhaps, crossing the manufacturing-installation gap. Emerging players have demonstrated that they can gain high levels of expertise quickly. Early on, in the mid-2000s, China developed solar-grade polysilicon in a few years time and captured the world market, thanks to its well-established manufacturing sector and focused government support. The next section, the empirical analysis, considers how the U.S. antidumping litigation fits into the solar dynamic market.

IV. Empirical Analysis

The empirical analysis evaluates how the 2011-2012 litigation may have altered U.S. PV market, including its effects on U.S. manufacturers and installers. It seeks to answer three questions: whether dispute reduced trade with China and diverted trade to other U.S. trade partners; which countries filled in the gap China left behind; and how, if at all, did the dispute affect U.S. manufacturers and U.S. installers.

This section proceeds in three parts. First, it summarizes the data and explains the methodology. Second, it notes the expected results. Third, it presents the findings, focusing on trends in U.S. imports of solar cells and modules and, as appropriate, trade flows between non-U.S. players. To close, it vets the sensitivity of the results with respect to how the quantity of trade is estimated.

14 Long before China burst on to the global scene in 2011, the country’s domestic market already had begun to take shape. From 1993 to 1998, China’s installed PV capacity grew by about 27% per year thanks to an array of policies supporting the distributed energy source Dunford, M., et al. (2012). "Geographical interdependence, international trade and economic dynamics: The Chinese and German solar energy industries." European Urban and Regional Studies 20(1): 14-36.

. By 1997, total installed capacity tallied 4.5 MW ibid.
. Government support for PV dates back to at least to the early 1980s when the Chinese government began financing research and development for the technology through its five-year plans ibid.
. In the mid 1990s, China began exporting solar panels ibid.
A. Data and Methodology

1. Data

Data was obtained for imports and exports of solar cells and modules, PV installations in the United States and China, and world and U.S. product prices for solar cells and modules. Table 1 summarizes the data.

a. Trade Flows

U.S. foreign trade data was obtained from the USITC Interactive Tariff and Trade DataWeb.\textsuperscript{15} The USITC categorizes export and import data under a number of trade schedules, including the Harmonized Tariff Schedule (HTS) cited in the USITC and USDOC antidumping decisions considered here. Data for solar cells and modules is available at the monthly time scale back to 1996 under HTS 8541.40.6020 (solar cells assembled into modules or panels) and HTS 8541.40.6030 (solar cells, not made into panels or modules).\textsuperscript{16} The data is updated two weeks after a month ends (USITC 2009). Accordingly, the most recent data for this analysis is from September 2014, the end of third quarter 2014. Important, as the USDOC acknowledges, the trade categories targeted by the duties include more than the solar products at issue (U.S. Department of Commerce 2012). Because other products may be included within the trade categories under consideration, observed changes in trade flows may reflect changes in the trade of other products not of interest here.

The USITC trade data includes information regarding the customs value, the price actually paid for imports before duties are assessed, and the quantity of trade, given in undefined units (U.S. Census Bureau 2014). As Figure 3 demonstrates, world and U.S. module and cell prices have fallen rapidly in recent years. As such, much of the analysis uses reported trade quantities rather than monetary values to evaluate dispute’s effect on the market. The sensitivity analysis explores alternatives.

\textsuperscript{15} To access the database, visit http://dataweb.usitc.gov.
\textsuperscript{16} The USDOC imposed duties on imports of solar cells and modules arriving under HTS 8541.40.6020 (modules), 8541.40.6030 (solar cells), 8501.61.0000 (AC generators (alternators: of an output not exceeding 75 kVA), 8507.20.80 (other lead-acid storage batteries: other), and 8501.31.8000 (other DC motors; DC generators: of output not exceeding 750 W: generators) U.S. Department of Commerce (2012). Fact Sheet: Commerce Finds Dumping and Subsidization of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules from the People’s Republic of China.

Because the later categories likely capture far more than solar PV modules and cells alone, the focus of the USITC determinations and as the USDOC acknowledges in its decisions, this analysis focuses only on the first two only, HTS 8541.40.6020 (modules) and HTS 8541.40.6030 (solar cells) USITC (2014). "HTS Online Reference Tool: By Chapter, Harmonized Tariff Schedule of the United States (2014)." 2014, from http://hts.usitc.gov.
To evaluate the solar cell loophole, trade data also was obtained for exports of Taiwanese solar cells to China and Malaysia from the Ministry of Finance, Taiwan. Taiwan categorizes trade data under the Harmonized System (HS); solar cells fall under HS 8541.40.3000 (“solar cell”).\(^\text{17}\) Like the U.S. import data, the Ministry of Finance, Taiwan, offers trade data in monthly increments for trade values (in both U.S. dollars and New Taiwan Dollars) and quantity units (measured in pieces) (Customs Administration 2014). As with the U.S. import data, quantity values, rather than monetary trade values, are used here.

United Nations (UN) trade data also is available. While the UN data would allow the analysis to more readily capture a wider array of U.S. trade partners (and thus trade diversion), the UN trade data lacks the necessary level of detail to parse the trade of solar cells from that of modules. In fact, the UN provides data only for HS 85140, “photosensitive/ photovoltaic/LED semiconductor devices,” a fairly high level of aggregation (United Nations 2014). Moreover, given the political relationship between Taiwan and China, the UN does not provide specific trade data for Taiwan (United Nations 2010, United Nations 2014).

b. PV Installations

PV installation data is from Bloomberg New Energy Finance (BNEF) and the Solar Energy Industries Association (SEIA). BNEF provides country-specific annual and cumulative installation data that is broken into residential (less than 20 kilowatts (kW)), commercial (20 kW to 1 megawatt (MW)), and utility-scale (greater than 1 MW) projects from 2003 to 2014.\(^\text{18}\) SEIA provides quarterly installation data for the United States from third quarter 2010 to second quarter 2014 in its quarterly reports.\(^\text{19}\)

c. Market Prices

Market prices for solar cells and modules also are from BNEF and SEIA. BNEF provides data for monthly and quarterly world multicrystalline cell and module prices in dollars per watt.

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\(^\text{17}\) This analysis uses data for both exports and re-exports Customs Administration, M. o. F., Taiwan (2014). "Trade Statistics Search." from http://www.customs.gov.tw/statisticsweben/.

. Re-exports are goods that have previously entered the Taiwanese market but have not been changed before being sent back out into the market U.S. Census Bureau (2014). "Trade Definitions." from https://www.census.gov/foreign-trade/reference/definitions.

. Including re-exports allows the analysis to capture solar cells that might be filtered through Taiwan from elsewhere. To access the Taiwan Ministry of Finance trade database, visit http://www.customs.gov.tw/statisticsweben/.


\(^\text{19}\) SEIA Quarterly reports are available here: http://www.seia.org/research-resources/us-solar-market-insight.
SEIA provides quarterly data for U.S. cells and modules. As SEIA explains, U.S. module pricing varies considerably according to the manufacturer region, order volume, and firm; the price thus reflects an estimate based on that captures variations (GTM Research 2014).

2. Methodology

As noted, the empirical analysis considers foreign trade flow trends: U.S. solar cell and module imports from China, Malaysia, Taiwan, all other countries excluding China (AOC), and all countries except for China, Malaysia, and Taiwan, the rest-of-the-world aggregate (ROW). Malaysia and Taiwan are specifically identified in this analysis given the high level of attention they have received in the media. Trends in trade flows are evaluated graphically and with a linear regression model.

a. Exploring Trade Flows

To explore how the duties may have altered trade flows, the analysis follows Hufabuer and Lowry (2012), which considered the effects of U.S. tariffs imposed on Chinese tires in September 2009 after the tires flooded the U.S. market (Hufbauer and Lowry 2012). Similar to Hufabuer and Lowry (2012), the analysis uses quarterly data from first quarter 2007 to third quarter 2011, roughly a five-year period with 19 data points, to map trends, based on quantity data and unit values (trade value/trade quantity), before and after the dispute arose. As Hufabuer and Lowry (2012) explain, unit values approximate wholesale prices; recorded trade values reflect the cost of the goods, insurance, and freight before any duties are imposed (Hufbauer and Lowry 2012, U.S. Census Bureau 2014).  


21 Not all agree that unit values are reliable metrics. Rather, the USITC and International Monetary Fund both caution that unit values generally should not be used if trade categories are not homogenous, for example, as a result of factors like changes in products, variations in product quality, and changes in product composition. Such variations, they explain, can lead to inaccurate and unstable unit values that do not accurately reflect the effects of policies on trade Silver, M. (2007). Do Unit Value Export, Import, and Terms of Trade Indices Represent or Misrepresent Price Indicies. IMF Working Paper, International Monetary Fund.


These concerns may be at play here. After all, the USDOC rang a similar cautionary tone, explaining that the trade categories may be over inclusive. Moreover, solar cell and modules vary in their efficiency, which also raises to heterogeneity concerns. But, it seems, heterogeneity concerns are not limited to unit values; to a certain extent, they also apply to reported trade values and trade quantities. Unit values simply divide the two measures. Because heterogeneity concerns may undermine the accuracy of the results, they are identified throughout the analysis, both with respect to unit values and otherwise.
To evaluate the effect of the dispute on U.S. manufacturers, the analysis takes the ratio of total U.S. imports of solar modules and divides it by the pace of new PV installations over both quarterly and annual time scales. This metric assumes that installed modules must come from somewhere. Because imported PV modules might not be installed immediately, the quarterly metric lags new PV installation data by zero, one, and two quarters relative to the quarterly import data. The average of these values is divided by the quarterly installation data:

\[ \frac{\text{Imports}}{\text{New Installed PV(MW)}} \]

A declining ratio may suggest that installers have stockpiled modules, and thus do not need to buy them from abroad, or that domestic producers are gaining market share.

This import-to-PV installation ratio has limitations. Lagging the installation data by zero, one, and two quarters relative to the import data might not reflect the time horizons that installers, on average, act upon. An inaccurate lag structure could erroneously identify stockpiling and domestic producer gains. Moreover, the average lag could change over time. For example, solar modules might sit warehouses longer after a period of particularly low product prices or during periods when public policies spurring installation are weak. Thus, the ratio is, at best, a very loose approximation. U.S. manufacturing data would paint a far more accurate picture of how the duties might be affect U.S. solar cell and module manufacturers.

b. Linear Regression Model

To evaluate the significance of observed differences in trade flows, the analysis uses a simple linear regression model with an indicator variable that marks the periods of interest: before versus after the litigation commenced and before versus after the May 2012 duties were imposed:

\[ \text{Imports} = a + b \times \text{Dispute} + \varepsilon \]

where
- \( \text{Imports} \) is the quantity of solar cells or modules imported into the U.S. market during a given quarter;
- \( a \) is a constant; and
- \( \text{Dispute} \) is an indicator variable that takes a value of 1 from either October 2011 onward (litigation marker) or May 2012 onward (duty marker) and 0 otherwise.

Unlike the graphical exploration above, the linear regression model uses monthly data from January 2012 to September 2014. This shorter time period focuses on the period after China’s dramatic rise into the global PV market when its contribution to global PV shipments soared past 50% of global market share (Earth Policy Institute 2014). Thus, the linear model assumes that China’s capture of the global market was sustainable, absent, perhaps, the U.S. antidumping duties under consideration here. The sensitivity explores the effect of a longer data period.
set. Using monthly data rather than quarterly data for imports of solar cells and modules increases the sample size and, thus, the robustness of the results (n = 57).

As Figure 5 indicates, the residuals of the regression runs on untransformed data are not normally distributed; log transforming the trade flow data appears to cure the concern. Accordingly, all regressions use log-transformed trade data. The estimated effect size for the dispute indicator variable is derived via the following equation:

\[ Effect \, Size \, (\%) = e^b - 1 \]

where
- \( b \) is the coefficient of the indicator variable.

To address concerns arising from autocorrelation in time series data, the model uses Newey West standard errors. The truncation parameter, which affects the significance of the coefficients, is calculated based on the rule-of-thumb equation:

\[ m = 0.75 \times (T^{\frac{1}{3}}) \]

where
- \( m \) is the truncation parameter; and
- \( T \) is the number of time periods (Newey and West 1994).

Here, the truncation parameter for the Newey West estimator is 3 (\( m = 2.8 \), rounded for parameter).

![QQ Plot](image)

**Figure 5. QQplots of U.S. Imports, Taiwan Modules Example**
Finally, zero trade values, which are found in solar cell import data for Malaysia and Taiwan, present a problem because of the model’s log-linear form. For Malaysia, the data indicates that for 28 months of the 57 total the U.S. did not import any modules from Malaysian producers. China has one zero trade flow value in August 2014. When evaluating trade data, best practice cautions against omitting zero trade values or replacing them with a small number. Empirical studies have found that such methods can bias the results significantly (Gómez-Herrera 2013). Accordingly, because Malaysia has so many zero-trade flow values, the analysis does not develop a linear regression model for imports of Malaysian solar cells. With respect to China, the data set is cut off after August 2014. This likely renders comparisons with the results of the China solar cell model less reliable because the time series will be different.\(^\text{22}\) Because the truncation is only two months long and at the end of the period, the concern regarding bias arising from omitting data likely is lessened. Nonetheless, the timing of the omission could be significant: the USDOC announced the second round of preliminary antidumping duties in July 2014.

**B. Expected Results**

Given the solar cell loophole, China’s rapid rise in the U.S. import market in 2010 and 2011, and the relatively easy entry and thin profit margins that characterize the solar cell and module manufacturing industry, it is expected that:

- **U.S. Imports of Chinese Modules**: Immediately after the duties are issued, imports of Chinese solar cells and modules likely will decrease. In 2013, the solar cell loophole likely will lead to increased imports of Chinese modules. Moreover, because the second round of antidumping duties did not go into effect until almost the end of the time period considered here, which ends in September 2014, a subsequent decline in module imports may not be observed.

- **U.S. Imports of from Rest of the World**: Manufacturers in other countries likely filled in some of the gap left by China, particularly emerging PV trade partners like Malaysia (solar modules) and Taiwan (solar cells). Antidumping studies have shown that a duty on one supply source of a fairly homogenous product, perhaps like modules and solar cells, acts as an implicit import subsidy for other trade partners (Durling and Prusa 2006, Kinnucan and Myrland 2006).

- **Effect on U.S. Industry**: U.S. manufacturers are expected to gain some domestic market share immediately following the duties for both solar cells and modules while other trade partners step in. However, because other trade partners, like Malaysia, already had growing module production industries at the time of the dispute, this gain likely will be

\(^\text{22}\) The shorter time period does not change the truncation parameter used to derive the Newey West standard errors \((T = 55, m = 2.9 \text{ rounded to 3})\). As suggested in Gómez-Herrera (2013), future studies could use a Poisson maximum likelihood estimate (PMLE) to address zero trade flow concerns Gómez-Herrera, E. (2013). "Comparing alternative methods to estimate gravity models of bilateral trade." Empirical Economics **44**(3): 1087-1111.
short-lived (Figure 1) (Earth Policy Institute 2014). Unit values, which reflect the wholesale price of imports, are expected to increase as U.S. importers replace Chinese products with higher-priced products from other trade partners and the domestic industry. Moreover, other trade partners may be hesitant to sell into the U.S. import market at cut-rate prices. Vandenbussche and Zanardi (2010) find, for example, that firms avoid antidumping litigation by maintaining higher prices and reducing trade volumes (Vandenbussche and Zanardi 2010). Because SolarWorld immediately voiced its discontent with the results of the first round of the trade dispute, the threat of litigation likely was a real concern for other trade partners.

C. Results

This section answers each of questions identified above:

1. Did the dispute divert trade away from China?
2. If so, did other trade partners fill in the gap left by China and, if so, who?
3. How, if at all, did the dispute affect the U.S. industry?

1. Did the dispute divert trade away from China?

To answer the first question, trade diversion from China, the analysis considers U.S. imports of solar cells and modules from China versus that from all other countries (AOC). Imports of modules and solar cells are considered separately.

a. Imports of Chinese Solar Modules

As Figure 6 shows, imports of Chinese modules fell by 92% in the first year after the dispute, from third quarter 2011 (19.5 million units) to third quarter 2012 (1.6 million units). At their lowest quarterly level, first quarter 2013, imports tumbled to a mere 910,000 units, a 95% decrease from third quarter 2011. After the USDOC issued the preliminary duties in second quarter 2012, imports did not exceed 3.8 million units. This suggests that the duties may have decreased U.S. imports of Chinese modules. The linear regression model confirms that difference between pre-duty and post-duty periods is significant at the 90% confidence level and estimates that imports of modules decreased, on average, by about 26% between the pre-duty period beginning in January 2010 and the post-duty period beginning in May 2012 (p-value = 0.096, standard error = 0.175, n = 57). While this effect size is notable, it smaller than that found by other antidumping studies, like Durling and Prusa (2006), which found antidumping duties tend to decrease trade with targeted partners by about 40% to 66% (Durling and Prusa 2006). The solar cell loophole may explain some of this difference, as explained in more detail below. In contrast, the regression model does not detect a significant difference in imports from

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23 Differences between the pre-litigation and post-litigation periods, however, are not significant at the 90% confidence level (p-value = 0.643, n = 57, standard error = 0.213, estimated effect size: -9.45%).
the all other countries aggregate in pre- and post-litigation periods or in the pre-duty and post-duty periods at the 90% confidence level. This suggests that U.S. domestic manufacturers may gained domestic market share following the dispute; the AOC aggregate did not increase trade significantly following the duties.

Figure 6 also reveals that imports of Chinese modules began to increase in second quarter 2013. Figure 7 suggests that this increase may have been driven by the solar cell loophole: From fourth quarter 2011, when the litigation commenced, to second quarter 2012, when the USDOC announced preliminary duties, exports of Taiwanese solar cells to China increased by 66 million units, a 126% rise. In 2013, this upward trend accelerated: by second quarter 2013, the last period for which data is available, Taiwan exported 108 million more solar cell units to China than it had in fourth quarter 2011, three times the amount. The linear regression module suggests that module exports increased by 24% after the litigation commenced in October 2011; this change in exports is significant at the 90% confidence level (p-value = 0.087, standard error = 0.122, n = 42, m = 3; January 2010 to June 2013). Thus, it seems, Chinese module manufacturers may have capitalized on the solar cell loophole by producing modules with solar cells.

Yet, immediately following the boom in Taiwanese exports of solar cells to China, U.S. imports of Chinese modules fell rather than increasing as would be expected if China, in fact, were using Taiwanese solar cells to regain a foothold in the U.S. market. Figure 8 demonstrates that the PV installation markets in both United States and China grew exponentially in 2013, particularly that of China. From 2011 to 2013, the rate of new installations in the United States increased by 2.5 times. Over the same period, China’s installation rate accelerated by more than 5 times, up from about 2,600 MW in 2011 to 12,920 MW in 2013. China, it appears, not only increased imports of Taiwanese solar cells to capitalize on the solar cell loophole, but also to feed its domestic installation boom.

Moreover, the United States was far from China’s only market. In 2013, Japan, ranking No. 2 that year for new PV installations, increased imports of Chinese modules by 55%, from 333 million units in 2012 to 515 million units in 2013 (Ministry of Finance, REN21 2014). Figure 9 shows that the 2013 uptick in exports of Chinese modules to Japan followed a sustained, two-year decline. From 2010 to 2012, imports of Chinese modules to China decreased, as Japan’s PV installation market grew. Before the pace of installation soared in Japan in 2013, Japan’s solar market may have been difficult for Chinese producers to crack: Japanese brand recognition and allegiance historically had driven consumer sales, even though such allegiance increased the cost of installations; hardware prices in Japan are about 6% higher than those in the United States (Friedman, Margolis et al. 2014).

China’s move toward Japan could have been motivated by a number of factors, including rumors of a second round of antidumping litigation in the United States or Japan’s installation boom.

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25 To access Japan trade data, visit http://www.customs.go.jp/toukei/info/index_e.htm.
boom. The later explanation seems plausible: as Japan’s demand for PV modules flourished, exporters in China seized the opportunity. But the primary beneficiaries in China might not have reflected the typical lineup of dominant Chinese manufacturers like Yingli Green Energy and Trina Solar. In second quarter 2013, Japanese companies accounted for nearly 50% of Japan’s import market (Friedman, Margolis et al. 2014). Two of Japan’s primary PV manufacturers have manufacturing facilities in China: Sharp and Kyocera (Friedman, Margolis et al. 2014, Kyocera 2014, Sharp 2014). Thus, Japan’s turn toward China in 2013 may have been driven not only by its installation but also likely reflects its continued preference for Japanese producers.

To sum up: First, the duties appear to have reduced U.S. imports of Chinese modules, as reflected by the sharp decline immediately after the preliminary duties were issued in May 2012. The second round of the litigation appears to have had less of an effect on module imports and, in fact, may have caused them to rise. This anomalous result likely reflects the fact that the second round of the litigation also targeted manufacturers Taiwan, who may be China’s primary foreign solar cell supplier. With this supply essentially cut off for U.S. export purposes (no longer cost effective), Chinese module producers simply shipped modules, made with Chinese solar cells, into the U.S. market, irrespective of the 2012 duty order (GTM Research 2014).

Second, while the solar cell loophole appears to have done some work, surging demand for PV modules in both China and Japan likely mitigated its impact. With these huge demand centers, Chinese manufacturers did not need the U.S. market.

Third, U.S. manufacturers may have gained market share after the duties were issued. The regression model finds the decrease in imports of modules from China significant between the pre-duty and post-duty periods; it did not find a significant difference in imports between the periods for the all-other-countries aggregate, regardless of whether time was split in October 2011, when litigation commenced, or in May 2012, when the USDOC announced the preliminary duties.

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26 In 2014, installations in China may fall below expected levels, suggesting that the margin between the supply of PV modules in China and domestic demand may widen Bloomberg News (2014). China Solar Project Delays Mean Japan Could Be Largest Market. Bloomberg.
Figure 6. Quantity of Modules Imported from China and All Other Countries

Figure 7. Taiwanese Solar Cell Exports to China
b. Imports of Chinese Solar Cells

As Figure 10 shows, U.S. imports of Chinese solar cells decreased sharply after the litigation commenced in October 2011 and did not recover. Imports fell from a high of 8.1 million units in fourth quarter 2011 to a low of 155,000 units in first quarter 2012, a 98% drop. At their lowest, in second quarter 2014, imports of Chinese solar cells declined to 9,500 units in second quarter 2014, coinciding with the announcement of the second round of duties. Throughout the post-litigation period, imports of Chinese solar cells rarely rose above 1 million units. The regression model estimates that from the pre-litigation to the post-litigation period, imports of Chinese solar cells fell by 71%; after the duties were issued, imports fell by 76%. These results are significant at the 99% confidence level (litigation marker: p-value < 0.000, standard error = 0.252, n = 55; duty marker: p-value < 0.000, standard error = 0.221, n = 55).
Thus, the dispute likely caused imports of Chinese solar cells to fall to near-zero levels; once the USDOC announced the preliminary duties, the effect of the antidumping litigation took an even greater toll on Chinese producers.

As imports of Chinese solar cells dropped, imports of solar cells from all other countries climbed rapidly after hitting a period low during fourth quarter 2011 when imports from all other countries increased from 3.1 million units to 13 million units, 319% (fourfold), into first quarter 2012. Imports of solar cells from all other countries also increased dramatically in second quarter 2011, just before the litigation commenced. This might reflect all-other-countries exporters dumping their products into the U.S. market at low prices, just ahead of China’s U.S. market dominance shortly thereafter. Indeed, the unit value of solar cells dipped to $6.03 in second quarter 2011 per unit from $7.27 per unit in the previous quarter, a 21% price drop. This pre-litigation increase may explain, in part, why the linear regression model does not find a significance difference between the pre-litigation and post-litigation periods: the pre-litigation boost balances the immediate post-litigation rise, a rise that was followed by a sustained drop in solar cell imports. Then, suddenly, in first quarter 2014 imports of solar cells rose by 308% from fourth quarter 2013, just as the second round of the litigation kicked off.

Thus, the antidumping dispute likely reduced solar cell imports from China considerably. The declines, and the timing of them, match key dispute events almost exactly, the commencement of litigation and the preliminary duty announcement. Meanwhile, other trade partners likely captured some of China’s void, particularly in the immediate aftermath. During the 2013 import dry spell, domestic manufacturers may have gained some domestic market share. But whether any such gains were caused by the litigation is not certain. After all, this dry spell arose as PV installation markets in the United States, China, and Japan accelerated (Figures 8 and 9). As with modules, this suggests that China may no longer have needed the U.S. market. The same may be true of suppliers in the all other countries group, as discussed in more detail below.

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27 Unit values, as explained in the methodology, can be used to approximate the wholesale price paid by importers Hufbauer, G. C. and S. Lowry (2012). US Tire Tariffs: Saving Few Jobs at High Costs. Policy Brief. Washington, Peterson Institute for International Economics.
Figure 10. Quantity of Solar Cells Imported from China and All Other Countries

2. Did manufacturers in other countries fill in the gap left by China?

From the above, it already appears that other trade partners stepped in to fill at least some of the void left by China in the U.S. market. The analysis that follows focuses on two, Malaysia and Taiwan, to evaluate whether any single country may have reaped particular benefits from the U.S. trade dispute.\(^{28}\)

a. Malaysia

Figure 11 indicates Malaysia captured the U.S. import market mid-2012, just as the USDOC announced preliminary duties on Chinese solar cells and the modules that contained them. From second quarter to third quarter 2012, imports of Malaysian modules increased by nearly 140\% from about 3.4 million units to 8.2 million units, more than four times the third quarter 2011 level of 1.9 million (pre-litigation). The linear regression model estimates that imports of Malaysian modules increased, on average, by about 155\% in the post-litigation period and 113\% in the post-duty period. These estimates are significant at the 99\% confidence level (litigation marker: p-value < 0.000, standard error = 0.21, n = 57; duty marker: p-value = 0.004, standard error = 0.25, n = 57). As Figure 9 shows, Malaysia’s rise continued until mid-2013 when imports of Malaysian modules abruptly fell from a high of 23.3 million units in second quarter 2013 to 8.7 million units in the fourth quarter. This reflects the lower estimate of the regression model for the post-duty period. By 2014, Malaysia shared the U.S. import market with China and Taiwan and, in the third quarter, the rest-of-the-world aggregate, just as China re-claimed the top position (third quarter: China 40\%, Taiwan 23\%, Malaysia 19\%, ROW 18\%).

\(^{28}\) Malaysia and Taiwan were selected because they are periodically mentioned in newspaper and journal articles as well as industry publications. Even so, before honing in on Malaysian and Taiwan, import flows from another of other countries were evaluated, including Canada, Germany, Indonesia, Japan, Mexico, Singapore, South Korea, and Thailand. Malaysia and Taiwan offered two of the more compelling stories.
Curiously, China, Taiwan, and ROW rose from near de minimums levels just as the second round of the litigation unfolded.

A number of factors could explain Malaysia’s mid-2013 drop, a drop that, perhaps, opened the door for China, Taiwan, and ROW to step in 2014 and, peculiarly, also coincided with a historic high in U.S. installations (Figure 6). First, as the dominant player in the U.S. import market for modules, Malaysia may have felt vulnerable; SolarWorld, in mid-2013, voiced its discontent with first round of the litigation and signaled that a second round of litigation was likely. To avoid being a target, Malaysia may have reduced the volume of imports, either to persuade SolarWorld to focus on the China-Taiwan nexus or to mitigate the level of any resulting duties. A drop in volume is one of the strategies that exporting firms might use to minimize the threat of pending antidumping litigation, as Vandenbussche and Zanardi (2010) observed in a study of the dampening effects of antidumping laws (Vandenbussche and Zanardi 2010). For Malaysian producers, the incentive to avoid antidumping litigation may have been strong. Not only did Malaysian manufacturers control the U.S. module import market, Malaysian manufacturers also were the target of three U.S. antidumping litigations in 2013 and 2014, a notable uptick from the absence of any such U.S.-initiated disputes during the ten or so years before (2013: frozen warmwater shrimp, welded stainless steel pressure pipe; 2014: steel nails) (2014). What’s more: in 2013, India named Malaysia in an antidumping action over solar PV products (Ali-Oettinger 2013, Roy and Chaturvedi 2014). Thus, Malaysian manufacturers may have turned to other foreign markets.

Second, Malaysian module producers may have run low on solar cells. As the 2014 USITC preliminary determination suggests, in 2013, Taiwanese solar cells were in high demand and short supply (U.S. International Trade Commission 2014). Solar cells from Taiwan may have fueled Malaysia’s 2012 rise in the U.S. market. For example, Figure 12 reveals that in second quarter 2012, when the preliminary duties were issued, exports of Taiwanese solar cells to Malaysia increased by about 4 million units over the average for the previous four quarters, a rise of more than 50% (2.3 million increase over first quarter 2012, 24%). This increase came on the heels of a substantial increase in third and fourth quarter 2011, when the dispute began. Yet, in mid-2013, the last period for which data is available, exports of Taiwanese solar cells to Malaysia decreased by nearly 6 million units from the fourth quarter 2012 level, a fall of nearly 40%. As Taiwan decreased its exports to Malaysia, exports to China grew, as shown in Figure 5 above. Taiwanese solar cell manufacturers, it appears, pulled out of the Malaysian market to send solar cells to China where the PV installation market grew rapidly and with whom Malaysia

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29 Since 2000, Malaysia has been a target eight times. For comparison, since 2000, China has been targeted 149 times, Mexico 18 times, and Taiwan 19 times (2014). Antidumping and Countervailing Duty Investigations Initiated After January 1, 2000. United States Department of Commerce. Washington.

shared a close, and complicated, political and economic relationship (Rosen and Wang 2011).³¹
What’s more: Figure 13 indicates that Malaysia entered the U.S. solar cell import market in 2014. From fourth quarter 2013 to first quarter 2014, the quantity of solar cells from Malaysia increased by 5.4 million units, a rise of more than 450% (about 5.5 times). Its market share grew to 72% in the fourth quarter. Previously, Malaysia had never been a player. Malaysia’s rapid entry into the U.S. solar cell market suggests that Malaysia may have been building its solar cell production capacity in the post-dispute period, perhaps by shifting module production facilities to solar cell facilities.

Yet, the solar cell shortage theory likely does not tell the whole story. Trade data from Japan and the UK, two countries with healthy PV installation markets, reveals that as Malaysian module exports to the United States decreased, exports of Malaysian modules to Japan and the UK increased or, at least, remained stable (Ministry of Finance, 2014, HM Revenue & Customs 2014).³² For example, Figure 14 shows that the UK imported few, if any, solar modules from Malaysia until late 2013 when exports from Malaysia to the UK soared, a rise that coincided with the drop off in exports to the United States. Meanwhile, Japanese imports from Malaysia increased by 700,000 units from 2012 to 2013. Malaysian manufacturers may have shifted trade from the United States to other partners, like those in Japan and the UK, perhaps to ride out the litigation threat.

To recap: Malaysia appears to have benefited from China’s fall from the U.S. module import market. Imports of Malaysian modules increased considerably in the post-dispute period, a finding that is supported by the results of the linear regression model. Malaysia, however, did not maintain its market dominance. In 2014, Chinese and Taiwanese module exports to the United States both surpassed those from Malaysia, and the rest-of-the-world aggregate was close on Malaysia’s heels. Malaysia’s drop from the U.S. import market could be explained by a number of factors, including a shortage of solar cells and a fear of becoming another antidumping litigation target. After Malaysia fell the U.S. module market, however, it appears to be settling into the U.S. solar cell market as new entrant. This solar cell rise coincides with the second round of the antidumping litigation that pegs both Chinese and Taiwanese solar cells.

³¹ Rosen and Wang (2011) explain that Taiwan-China economic relationship runs deep. Taiwanese manufacturers, for example, have long shipped products to China for final processing in large numbers; China is one of their key customers Rosen, D. H. and Z. Wang (2011). The Implications of China-Taiwan Economic Liberalization, Peterson Institute.


. For Japan installation trends, see Figure 7 above. For UK trade statistics, visit https://www.uktradeinfo.com/Pages/Home.aspx.
Figure 11. Quantity of Modules Imported from China, Malaysia, Taiwan, and ROW

Figure 12. Taiwanese Solar Cell Exports to Malaysia
Figures 11 and 13 reveal that Taiwan historically has exported far more solar cells into the U.S. market than modules. That is, perhaps, until 2014, when the second round of the antidumping litigation commenced and module imports from Taiwan increased as solar cell imports from Taiwan faltered. Imports of Taiwanese modules peaked in third quarter 2010 at about 9,210,000 units, one year before China seized control of the U.S. import market. As the antidumping investigation began in fourth quarter 2011, imports of Taiwanese modules declined.
by 1.9 million units, an 88% drop, over the same quarter the year before, fourth quarter 2010. As Figure 9 shows, imports of Taiwanese modules remained below their pre-dispute levels for much of the post-dispute period, even in 2014 when Taiwan’s market share, as a percent of import value, grew to 24%. On average, exports of Taiwanese modules to the U.S. market decreased by about 34% in the post-litigation period and 26% in the post-duty period; these results of the linear regression model are significant at the 99% and 95% confidence levels, respectively (litigation marker: p-value < 0.000, standard error = 0.105, n = 57; duty marker: p-value = 0.032, standard error = 0.139, n = 57).

As Figure 13 reveals, Taiwan was a notable player in the U.S. solar cell market before the litigation began. But, it lost nearly all its market share when imports of Chinese solar cells increased markedly in 2011. When the antidumping dispute hit, Taiwan returned, coming back even stronger. From fourth quarter 2011 to third quarter 2012, imports of Taiwanese solar cells rose from 530,000 units in third quarter 2011 to 5.6 million units in third quarter 2012, an eleven-fold increase. In first quarter 2012, the volume increased again to 8.4 million units, far outpacing its pre-dispute levels. Throughout 2012, Taiwan dominated the U.S. import market, commanding more than 60% of the market share in second quarter 2012. Then, suddenly, from third quarter 2012 to fourth quarter 2012, imports of Taiwanese solar cells plummeted from 5.5 million units to a mere 1.3 million units. Import levels did not recover and, throughout 2013, no other country stepped up to fill Taiwan’s shoes. Taiwan’s rapid fall from the U.S. market likely explains, in part, why the regression model finds the difference between the pre- and post-litigation (and pre-duty and post-duty) periods insignificant at the 90% confidence level (litigation marker: p-value = 0.235, standard error = 0.213; duty marker: p-value = 2.31, standard error = 0.273).

As explained above, China’s booming domestic market for solar PV may explain Taiwan’s fall from the U.S. solar cell market (Figure 8). To recap, from second quarter 2012 to second quarter 2013, Taiwan’s solar cell exports to China increased by 33%, up from 118 million units to 161 million units. Over the same period, exports of solar cells to Malaysia dropped by 25%, from 12.1 million units to 9.1 million units. Meanwhile, exports to the United States cascaded by 87%, from 7.4 million units to a mere 940,000. At the same time, U.S. module imports from China increased by 180% from fourth quarter 2012 to second quarter 2013, a rise of nearly threefold. The solar cell loophole did at least some work in early 2013.

Another story is possible: U.S. solar cell manufacturers may have begun to capture more of the U.S. solar cell market. In 2013, as noted above, the U.S. installation market grew rapidly, fueled by federal and state policy incentives. The market had be fueled either by modules from aboard (e.g., Malaysia) or produced domestically with solar cells from somewhere. Figure 15 indicates that the ratio of solar cell imports into the U.S. market to new PV installations has declined since 2006, which may support the improved domestic market theory. However, the more fine-grained quarterly graph reveals that imports of solar cells relative to new installations increased 2011 just before the antidumping litigation and increased again as the second round of the litigation commenced. This suggests that U.S. module manufacturers may have been stocking solar cells in anticipation of antidumping duties, which would increase the prices of the foreign components. Figure 13 (solar cell imports) reflects this stockpiling theory: the uptick of solar cell imports was considerable in those pre-litigation and early-litigation periods. Once the duties took
effect, the ratio of cell import-to-installation dropped precipitously. This suggests either that
domestic module producers resorted to the domestic market or that they relied upon their
reserves. Alternatively, the declining ratio could reflect the increasing efficiency of solar cells.
As solar cells become more efficient, the same quantity can produce more MW of power.33

To sum up: Imports of Taiwanese modules generally were below their pre-dispute levels
in the post-litigation period. In contrast, Taiwan dominated the U.S. solar cell market, at least
immediately following the filing of the petition. But, Taiwan had been a notable player before,
that is, until China far outpaced Taiwan in 2011. The influx of Taiwanese solar cells into the
U.S. market did not replace all of the trade that was lost following the litigation. This suggests
that U.S. module manufacturers either were losing domestic market share or were relying more
on domestic solar cell producers. In 2013, Taiwanese solar cell exports into the U.S. market
plummeted, and no one stepped in to fill Taiwan’s void until 2014, when Malaysia entered for
the first time. Taiwan’s eventual fall from the U.S. market could be explained by a number of
factors: China’s PV installation boom, U.S. module manufacturers stockpiling solar cells just
before and in the early stages of the litigation, or, perhaps, domestic solar cell producers gaining
domestic market share.

33 The USITC does not define quantity “units,” so it is also possible that the USITC is, in fact,
measuring solar cells in megawatts. In which case, this concern would be eliminated.
3. How did the dispute affect the U.S. solar PV industry?

A number of effects on the domestic industry already have been suggested. As noted, for example, domestic manufacturers of both solar cells and modules may have gained domestic market share in 2013 when imports of both modules (late 2013) and solar cells (much of 2013) dropped. But these events might not have reflected the antidumping dispute. Rather, 2013 marked a banner year for solar PV installations worldwide and, across the globe, the supply-demand imbalance that characterized 2011 began to right itself (REN21 2014). This section explores two additional metrics: first, the module import-to-installation ratio and, second, unit values for solar cell and module imports, a metric that reflects the wholesale price paid by U.S. importers and, hence, installers (Hufbauer and Lowry 2012).

**Figure 15. Solar Cell Import-to-Installation Ratio, Annual (top) and Quarterly (bottom)**

![Solar Cell Import-to-Installation Ratio, Annual (top) and Quarterly (bottom)](image-url)
a. Module import-to-installation ratio

Figure 16 suggests that module imports relative to new installations generally have decreased since 2004. A notable exception pops out in 2010 when Chinese modules flooded the global market and pushed down prices. This likely reflects U.S. installers taking advantage of low module prices and, perhaps, stockpiling them in anticipation of higher prices later. The quarterly graphic provides further insight. Imports of modules also spiked as the litigation commenced in fourth quarter 2011 and when Malaysian imports peaked in second quarter 2013, two quarters before the second round of the litigation commenced. Thus, the quarterly graphic also supports a stockpiling theory; U.S. installers took advantage of lower prices ahead of the duties. Such stockpiling might negate the general downward trend in the ratio, which otherwise might support a boost in market share for U.S. module manufacturers.

Figure 16. Module Import-to-Installation Ratio, Annual (top) and Quarterly (bottom)
b. Unit values

i. Modules

Figure 17 indicates that unit values for Chinese modules fell sharply third quarter 2011 and then steadily increased after the litigation began. This trend maps the trends for modules already observed: the 2011 surge in U.S. imports was followed by decreasing imports of the products (Figure 11). As imports of Chinese products increased in 2013, unit values for Chinese modules began to stabilize, before sharply declining in 2014 when the second of the litigation began. As Hufbauer and Lowry (2012) explain, price drops that precede duty orders likely reflect inventory buildup ahead of the duty: importers reduce inventories and exporters take a price hit (Hufbauer and Lowry 2012). Thereafter, unit values increase as the duties push the unit value toward the price in the import market (Hufbauer and Lowry 2012). Thus, the drop in unit value of Chinese modules in third quarter 2011 and third quarter 2014 may reflect buildups in inventories while Chinese exporters took a price hit. Meanwhile, the subsequent rise in unit values likely reflects the price moving toward the price in the U.S. market as a result of the duty. This suggests that, with respect to Chinese solar cells, U.S. module manufacturers may have benefited from a higher wholesale price of Chinese modules in the U.S. market. Figures 17 and 18 reveal that similar pre-litigation and pre-duty trends also are observed in the unit values for modules from the all other countries group, Malaysia, and Taiwan. As such, the combined wholesale price increases may have had a noticeable affect on the U.S. market, to the benefit of U.S. manufacturers but not U.S. installers.34

Nonetheless, Figures 11 and 18 show that unit values for Malaysian modules declined as U.S. imports of the goods increased in late 2012 and early 2013. This drop in unit values coincided with the PV installation surges in the United States (Figure 8). This suggests that U.S. installers may have been to insulate themselves from the higher module prices.

34 Because China’s unit value is consistently higher throughout the entire period, the high value may reflect a lack of homogeneity in the trade category. Other products, not subject to the antidumping duties, may be pushing up the unit value of Chinese modules relative to other trade partners. The higher unit value does not necessarily suggest that Chinese modules were, in fact, more costly. Indeed, such a result would suggest that U.S. buyers opted for higher priced Chinese products during the 2011 flood of Chinese solar modules into the U.S. market rather than those from other suppliers, like Malaysia who prior to China’s rise was a dominate player in the U.S. market. It also would cut against the well-accepted conclusion that the flood of low-priced Chinese modules caused prices of the goods to plummet in 2010 and 2011.
ii. Solar Cells

Figures 19 and 20 and Table 1 indicate that unit values for Chinese solar cells increased steadily from mid-2012 to mid-2014 and were consistently above the values for the all other countries group. This post-dispute spread above the world price contrasts sharply with the pre-dispute period during which unit values for Chinese solar cells generally tracked that of other countries. This suggests that the dispute may have caused the unit value of Chinese solar cells to increase. But, as above, the U.S. litigation cannot be considered alone. This climb in unit values coincides with the accelerating demand for solar products that arose from installation booms worldwide. Even so, the regression model does not find the difference between the unit
values of Chinese solar cells in the pre-litigation and post-litigation or pre-duty and post-duty periods significant at the 90% confidence level (litigation marker: p-value = 0.167, standard error = 0.091, n = 55; duty marker: p-value = 0.899, standard error = 0.108, n = 55).\(^{35}\)

The general increase in the unit values of Chinese solar cells corresponds to near-negligible U.S. imports of the goods observed in Figure 13. This suggests that the higher wholesale prices of the products may have persuaded U.S. buyers to substitute other solar cells, such as those from Taiwan or, perhaps, U.S. producers. However, the Taiwanese solar cells were not necessarily the lowest-cost option. Table 1 compares unit values for Taiwanese solar cells and U.S. and world prices. It suggests that U.S. buyers may have paid more for Taiwanese solar cells than the going rate. In 2012, the unit value of Taiwanese solar cells decreased as U.S. imports of the products increased, as shown in Figures 13 and 20. After the price drop, however, Taiwanese solar cell unit values stabilized. Meanwhile, the world and U.S. prices for the goods continued to fall. In first quarter 2013 and first 2014, the world and U.S. solar cell prices dropped by about 5% to 10% more than the unit values of Taiwanese solar cells, when compared to a first quarter 2011 baseline (pre-litigation). This suggests that Taiwanese producers may have had the upper hand vis-à-vis U.S. buyers. Despite continued declines in the world and U.S. prices, Taiwanese producers were able to secure a comparatively higher price thanks, in part, to demand for the cells outpacing supply (U.S. International Trade Commission 2014).

Given the above, trends in unit values of Chinese and Taiwanese solar cells suggest that U.S. importers may have paid comparatively more for products in the post-litigation period. Unit values of Chinese solar cells increased and the unit values of Taiwanese solar cells stabilized while the U.S. and world prices continued to fall. However, as above, the stabilization of the Taiwanese price likely reflects more than the dispute alone. After all, as noted many times above, demand for the cells likely increased not as a result of Chinese manufacturers capitalizing on the solar cell loophole but also per the booming installation markets in China, Japan, and the United States.

\(^{35}\) Because Figure 19 indicates that unit values that unit values in 2010 were highly erratic, particularly compared to their relative stability from 2011 onward, a regression also was run on data restricted to 2011 and thereafter. While still not significant at the 90% confidence level, the p-value for the log-linear regression run with litigation marker decreases to 0.109 and estimates that in the post-litigation period unit values for Chinese solar cells were, on average, 17.6% higher (litigation marker: p-value = 0.109, standard error = 0.099, n = 45; duty marker: p-value = 0.899, standard error = 0.108, n = 45). The Newey West truncation parameter, per the rule-of-thumb calculation remains the same, \(m = 3\) (2.67, rounded).
Figure 19. Unit Value of Solar Cells for China versus All Other Countries

Figure 20. Unit Value of Solar Cells for China, Malaysia, Taiwan, ROW, World Average

Because Figure 18 omits the particularly high first quarter 2012 unit value for China to facilitate analysis of unit value trends, Figure 17, which includes the value, is included.
Table 1. Change in Module, Solar Cell Unit Value, World Price, & U.S. Price

<table>
<thead>
<tr>
<th>Period</th>
<th>Unit Value (China)</th>
<th>Unit Value (AOC)</th>
<th>World Spot Price</th>
<th>U.S. Price</th>
<th>Unit Value (China)</th>
<th>Unit Value (AOC)</th>
<th>Unit Value (World)</th>
<th>World Spot Price</th>
<th>U.S. Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-2011</td>
<td>baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1-2012</td>
<td>-32.7%</td>
<td>78.3%</td>
<td>9.9%</td>
<td>-46.3%</td>
<td>-47.2%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1-2013</td>
<td>-9.8%</td>
<td>-14.0%</td>
<td>-47.0%</td>
<td>-58.0%</td>
<td>-64.0%</td>
<td>8.1%</td>
<td>-65.6%</td>
<td>-64.4%</td>
<td>-69.4%</td>
</tr>
<tr>
<td></td>
<td>3.6%</td>
<td>202.5%</td>
<td>80.9%</td>
<td>-58.0%</td>
<td>-59.0%</td>
<td>117.7%</td>
<td>-70.3%</td>
<td>-69.9%</td>
<td>-66.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Unit Value (Malaysia)</th>
<th>World Spot Price</th>
<th>U.S. Price</th>
<th>Unit Value (Taiwan)</th>
<th>World Spot Price</th>
<th>U.S. Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-2011</td>
<td>baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1-2012</td>
<td>+167%</td>
<td>-46.3%</td>
<td>-47.2%</td>
<td>-60.8%</td>
<td>-58.1%</td>
<td>-61.9%</td>
</tr>
<tr>
<td>Q1-2013</td>
<td>-41%</td>
<td>-58.0%</td>
<td>-64.0%</td>
<td>-59.5%</td>
<td>-69.4%</td>
<td>-77.0%</td>
</tr>
<tr>
<td>Q1-2014</td>
<td>+71%</td>
<td>-58.0%</td>
<td>-59.0%</td>
<td>-61.5%</td>
<td>-66.9%</td>
<td>-68.3%</td>
</tr>
</tbody>
</table>

a AOC: All countries other than China
b All percentage changes are calculated as a percent change from the first quarter 2011 baseline.

Data: USITC (imports); BNEF (world price); SEIA (U.S. price)

D. Sensitivity

In addition to using the quantity provided by the USITC customs data, the quantity of solar cells and modules imported also can be calculated by dividing the customs value, which following the reasoning in Hufbauer and Lowry (2012), supra, regarding unit values, reflects the aggregate wholesale cost paid by importers (Hufbauer and Lowry 2012).36

\[
\text{Customs Value (qtr)} = \frac{SEIA \ U.S. Price (qtr)}{SEIA \ U.S. Price (qtr)}
\]

Figure 21 suggests that estimates based on trade data values and those based on market price data closely track each other until mid-2013 when quantity estimates for modules diverge considerably. The general consistency across the two estimates suggests trade quantity likely is a reliable indicator of trade flow trends, despite having come under attack in the past (Silver 2007, World Trade Organization 2012). Curiously, the divergence in the estimates for modules coincides, as above, with mid-2013. The world and U.S. price-based estimates suggest higher quantities of modules were imported into the U.S. market in 2013 than the quantities derived from the trade data. This implies that U.S. and world prices may have been lower than the unit prices of U.S. imports beginning in mid-2013. As such, U.S. importers may have paid more than

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36 Though this value could also approximate the total MW imported from a given trade partner (or the world aggregate), as noted in the USDOC decisions, some of the trade categories at issue in the litigation contain products other than those considered here, for example, thin film. Because the module and solar cell categories may be over inclusive with respect to the products of interest, an absolute MW value cannot be automatically assumed.
going rate for imported modules in the lead up to the second round of the litigation. The increase unit values for modules observed in Figures 17 and 18 supports this conclusion.

**Cell Quantity**

**Module Quantity**

**World Spot Price (BNEF)**

**USITC**

**U.S. Price (SEIA)**

Figure 21. Import Quantity Estimates: Trade Data and Market Price-Based
V. Discussion

As the above analysis demonstrates, the effect of the U.S. antidumping dispute is hard to tease out from the broader market events. Even so, it appears that dispute likely decreased imports of Chinese solar cells and modules, which may have increased wholesale prices for U.S. importers. The solar cell loophole likely contributed to this outcome by increasing demand for Taiwanese cells, known for their high-efficiency. But, booming demand in China and Japan likely mitigated the effect of the loophole: Chinese producers had two ready markets for their products; the U.S. market, though also thriving, became less important. Meanwhile, while Malaysia stepped in temporarily to fill in the module void left by China, its burst into the U.S. market was short lived. Its rather quick exit, in part, may reflect concerns about becoming a target in the second round of the litigation or, perhaps, a dearth of solar cells. After all, Taiwan reduced supplies of solar cells to both Malaysia and the United States while increasing exports to China.

To be sure, many other stories could explain the observed trends. The propensity for duty evasion, macroeconomic context, and the ebb and flow of policy incentives, at home and abroad, could play an equal or greater role than the factors considered here.\(^{37}\) But the point is not to recount exactly how and why the market shifted. Rather, the antidumping dispute offers an opportunity to reconsider how U.S. PV manufacturers fit in to the global industry given the many moving pieces at play and how rapidly the environment can, and has, changed. To be sure, antidumping studies tend to agree that such disputes rarely yield long-term benefits to the protected domestic industries (Durling and Prusa 2006, Konings and Vandenbussche 2008). More often, as observed here, antidumping disputes simply shift trade from one partner to another and effectively subsidize untargeted producers (Kinnucan and Myrland 2006). The consequences for the targeted producers can be significant. Imports from targets can fall even when cases are rejected and no settlement is reached (Prusa 2001). Those that are successful have been known to reduce trade volumes by 40% to 70%. Indeed, domestic industries can use antidumping petitions to harass foreign competitors with tangible benefits (Prusa 2001, Durling and Prusa 2006).

With 2014 now marked by accusations of corporate espionage, tensions appear to be rising on both sides. The U.S. market is an important one for China. Meanwhile, China, if not already, promises to be a superpower in solar technology innovation. Increasingly, China has

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\(^{37}\) Ferrantino, Liu and Wang (2012) find that duty evasion, in the context of bilateral trade between the China and the United States is widespread and significant, particularly when are parties are related through the multinational corporate structures that characterize a number of the players in the global solar PV market. The concern over related parties may have motivated the USITC, for example to exclude Suntech from its evaluation of the domestic PV manufacturing market in its final 2012 determination. The interests of Suntech, the USITC explained, aligned more with importers than U.S. producers even though it began manufacturing modules in the United States in 2010. U.S. International Trade Commission (2012). Crystalline Silicon Photovoltaic Cells and Modules from China. U. S. I. T. Commission. Washington.
demonstrated that is no longer a just low-value, high-volume manufacturer, also but a high-value, high-volume one.

Chinese manufacturers already lead world in scaling up production of new products, manufacturing products efficiently, improving current designs, and creating and commercializing products based on existing designs, including those that others have cast aside as too risky or too costly (Tour, Glachant et al. 2011, Kanellos 2014, Nahm and Steinfield 2014). Strengthening domestic innovation in high-technology sectors is a priority for Chinese leaders, as announced by China’s former president, Hu Jinato, and in documents issued by the Central Committee of the Communist Party of China (Zhang, Andrews-Speed et al. 2013). China’s share of high-tech manufacturing has increased markedly, up from a mere 8% in 2003 to 24% in 2012, placing China just a few percentage points behind the United States, the world leader, at 27% (National Science Board 2014). While China’s innovation in the PV sector largely has built on advances in the United States and Japan, China appears to be seeding domestic innovation through public institutions like national labs and universities (Wu and Mathews 2012).

In 2006, China announced that it would boost research-and-development funding to 2.5% of GDP by 2010, double its rate in 2005 and on par with the United States (Wolff 2007). Such national public support, as Wu and Mathews (2012) explain, is crucial to PV innovation (Wu and Mathews 2012). In 2011, after five years of construction, China launched the Dalian National Laboratory for Clean Energy, a research center with 600 scientists and a $45.3 million budget (Jiang 2011). In 2012, the China Renewable Energy Center opened, a national renewable energy think tank with close ties to Denmark (Juan 2012, China National Renewable Energy Centre 2014).

Meanwhile, Chinese university graduates with engineering degrees dwarf the U.S. ratio. In China, 31% earned such degrees in 2013; in the United States, only 5% did (National Science Board 2014). From 2003 to 2011, China’s share of peer-reviewed journal articles, a metric for research activity, increased by nearly four times, up from 3% to 11%; 0.6% of the articles ranked in the top 1% of citations worldwide, a six-fold increase over the period (National Science Board 2014). High-level Chinese officials and business leaders also have vowed to reform China’s intellectual property regime, recognizing the nexus between protective legal systems and entrepreneurship (Intellectual Property 2013). Given such metrics, in its 2014 report to Congress, the U.S. National Science Board concluded that research-and-development and technology-intensive activity in China “is comparable to or exceeds most long-standing developed countries” (National Science Board 2014).


39 For comparison, 1.6% to 1.8% of the world’s most-cited articles were written by U.S. authors, the world leader for the metric, and 0.7% to 0.9% were from EU authors. National Science Board (2014). Science and Engineering Indicators 2014. U. S. N. S. Foundation. Washington.
Examples of China’s move toward high-value manufacturing include those in the solar PV sector. China’s PV manufacturers, nearly all of which are privately held, have increased solar cell efficiencies to be on par with the global standard, about 22%, through company-established national labs (NREL 2013, Nahm and Steinfeld 2014, Sun, Zhib et al. 2014). In a study of PV patents, Wu and Mathews (2012) concluded that China was on track to leapfrog competitors to become an international PV leader (Wu and Mathews 2012). Already Chinese companies like Hanergy are moving in on thin film, an industry that to date has been marked by U.S. innovation.

Outwardly, it appears opportunities are ripe for collaboration between the United States and China. Innovations in both nations could be scaled up and tested in the growing markets that characterize each. Yet politicians and business leaders send mixed signals: the tit-for-tat trade war, corporate espionage, and the recent Trans-Pacific Partnership, a U.S. trade agreement in the making that includes many Asian nations, except China (2014). As the trade case ticks on, it is hard not to wonder whether solar could become the next hot-rolled steel, an industry embroiled in antidumping litigation since the 1980s.

And, for what? Sure, this next round of litigation likely will set Chinese PV manufacturers back, perhaps just like the 2012 litigation may have. Undoubtedly, the dispute will shift trade to other partners and perhaps tighten supplies from hubs favored by U.S. installers, like high-efficiency solar cells from Taiwan. These shifts may benefit solar cell and module manufacturers in the United States in the near-term, particularly if global and domestic demand for solar PV remains strong.

But, maybe, that’s just the ticket. Ensuring the U.S. industry, both manufacturers and installers, that the demand is there. After all, competitive advantages in solar manufacturing do not turn on geography (Goodrich, Powell et al. 2013). The antidumping litigation does not promise such market-driving benefits. And, its effects, thus far, appear short-lived and dwarfed by other factors, including the increasingly global nature of the industry, which allows other trade partners to pick up where others have left off. But, perhaps, all U.S. manufacturers need is a little more. After all, SolarWorld recently announced plans to expand its module manufacturing capacity by 40% and solar cell production capacity by 30% (Cardwell 2014). And, as noted,

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40 As de la Tour et al. (2011) explains, some of these advances are a result of skilled executives who have spent time in foreign companies or universities and brought knowledge capital with them Tour, A. d. l., et al. (2011). "Innovation and international technology transfer: The case of the Chinese photovoltaic industry." Energy Policy 39(761-770).

. For example, Suntech CEO and founder studied in Australia and worked for an Australian PV company before returning to China to launch Suntech, once China’s largest PV company ibid.


installer SolarCity is entering the manufacturing sector with U.S.-based operations. Only time will tell.

VI. CONCLUSION

The 2011-2012 U.S. antidumping litigation likely diverted trade away from China to other trade partners, including Malaysia and Taiwan, both of whom had a foothold in the U.S. market before 2011 when China burst onto the scene. These shifts may have increased the wholesale import price of solar cells and modules in the U.S. market. Even so, any such effects must be considered in light of the industry as a whole and its rapidly changing landscape.

Future studies should consider an alternative empirical approach to the one used here: an ordinary least squares gravity model that accounts for friction across trade partners. For many applications, gravity models have become a go-to method for evaluating bilateral trade flows (Egger and Nelson 2011, Gómez-Herrera 2013, Chan, Harris et al. 2014). This methodology was explored for this analysis but was not used here given data limitations and a desire to focus in on the most recent period. The short time period considered here likely rendered the results of that analysis unstable; data for many relevant factors like PV installations and demographics generally is available at the annual level only, particularly when evaluating trends across an array of diverse trade partners. A gravity model could capture trade flows between a number of countries, like those between Taiwan and Japan noted above, and could control for some of the many factors at play, changes in GDP, installation rates, and spinoff litigation. In so doing, it would shed light on the question motivating this analysis: to what extent has the U.S. trade dispute shaped not only the U.S. market but also that of the global industry?
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