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Globalizing Solar: Global Supply Chains and Trade Preferences

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Global production is increasingly organized through supply chains made up of firms that specialize in specific stages of production. This raises an important question: how does firms' participation in global supply chains affect their trade preferences? Research shows that multinational corporations (MNCs) tend to prefer open trade, while domestic import-competing firms favor trade protection. We argue that the globalization of production also leads vertically specialized firms—those specializing in specific stages of the production process—to support open trade. Using firm-level data from the solar photovoltaics industry, we show that vertically specialized firms prefer open trade if they have ties to global supply chains. We present evidence that three sets of vertically specialized firms tend to favor open trade: upstream suppliers of inputs to a global supply chain, global manufacturers that import inputs, and downstream users of final products. Our findings suggest that the rise of global value chains shifts the politics of globalization: it expands firm coalitions in favor of open trade. Our findings also matter for an important public-policy concern: climate change. Governments face cross-cutting demands from solar firms over trade policy, dividing the growth coalition supporting clean energy technologies.

Global manufacturing is in the midst of a "second unbundling": global supply chains increasingly organize production through geographically dispersed firms that specialize in specific stages of production (Baldwin 2013, 16).[1] The growth of global supply chains results from technological innovation that lowers the costs of organizing production across firm boundaries (OECD, WTO, and World Bank Group 2014).[2]

A growing body of work examines the economic implications of this change (for example, Antràs 2013; Helpman 2014). But what implications follow for public policy? In particular, how does the participation of firms in global supply chains affect their trade preferences?

Traditionally, scholars have argued that import-competing manufacturers favor trade protection, while multinational corporations (MNCs) and exporting firms prefer open trade (Milner 1988).[3] We propose that the rise of global supply chains expands support for open trade beyond MNCs. It also leads vertically specialized firms—those that specialize in specific stages of the production process—to back open trade. We present evidence that three sets of vertically specialized firms favor open trade: upstream suppliers—firms supplying inputs to a global supply chain; global manufacturers—firms outsourcing production to firms based in the country subject to protectionist demands; and downstream users—firms purchasing inputs.[4] Domestic import-competing manufacturers are thus isolated in preferring trade protection against upstream suppliers, globalized manufacturers, and downstream users that favor open trade. The new economic interdependence of global supply chains further shifts trade politics in favor of open-trade interests.

We draw on firm-level data from the global solar photovoltaics industry. The structure of global supply chains varies—in some, multinational firms organize production, while others are characterized by the presence of vertically specialized firms, lacking an MNC organizing production.

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[1] Baldwin (2013) refers to the emergence of global supply chains as a "second unbundling," with the first characterized by the spatial dispersion of production following the invention of the steam engine.

[2] Scholars use a variety of terms, including Global Supply Chains, Global Production Networks, and Global Value Chains, to refer to the phenomenon characterized by the globalization of productive activities and the increased use of outsourcing within firms' product strategies.

[3] Recent research suggests that MNCs producing through supply chains that incorporate international affiliates also favor open trade. Jensen, Quinn, and Weymouth (2015) find, for example, that MNCs producing through supply chains incorporating international affiliates are less likely to file anti-dumping measures.

[4] The data presented here also suggest that vertically specialized firms also seek to exercise political influence, despite the relatively small size of some firms. Other vertically specialized firms are themselves part of MNCs that are diversified horizontally and are willing to pay the costs of engaging in political activities. This empirical finding contrasts with Gawande and Magee (2012). See the conclusion for further discussion of this point.

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In the solar photovoltaics industry, vertically specialized firms with global ties populate all stages of production, including upstream, manufacturing, and downstream, and research suggests that this is representative of a general type of global supply chain present across industries.[5] Further, innovation in information and communication technologies allowing firms in the solar photovoltaic industry to codify and transfer production-related knowledge is acknowledged to have affected a broad range of industries, enabling firms to retain productive processes within their boundaries or to outsource them to others (Kogut and Zander 1993). Taken together, this means the solar photovoltaics industry is useful for exploring the effects of global supply chains on firms' trade policy preferences (Seawright and Gerring 2008, 301–2).

Our findings matter for a key public-policy challenge: climate change. Solar photovoltaics are an important part of efforts to decarbonize the power sector, which is the largest global contributor to greenhouse gas emissions. At the same time, an increasing number of trade disputes also focus on climate change–related technologies (Lewis 2014).

We proceed in five sections. In the next section, we summarize recent findings on the relationship between firm characteristics and policy preferences in trade politics. In Section 3, we introduce the empirical setting and describe our outcome variable, which focuses on the policy preferences of firms responding to the rise in solar exports from China. We also hypothesize about the trade policy responses of firms given their position in the global supply chains for solar photovoltaics. In Sections 4 and 5, we describe the methods applied to data collection, examine whether data are consistent with the hypotheses, and discuss alternative explanations. In the final section, we discuss the implications of our findings for trade protection, and for the politics of climate change.

Global Supply Chains and Trade Preferences

Data reveal important differences in the characteristics of firms within industries in terms of their engagement in international trade and investment (Hummels, Ishii, and Yi 2001; Melitz and Redding 2012). Studies increasingly examine the implications of this intra-industry heterogeneity for firms' political behavior. Existing work finds that large firms are more likely to engage in lobbying activities and to gain higher levels of protection (Bombardini 2008; Kerr, Lincoln, and Mishra 2014). Evidence also suggests that firms investing internationally through vertical foreign direct investment are less likely to file anti-dumping petitions against countries that host their investments, compared to firms that have no international trade or investment relationships (Jensen, Quinn, and Weymouth 2015). Competition in lobbying is also important to take into account when assessing the extent to which governments focus on private welfare considerations, or on providing benefits to firms or industries (Gawande, Krishna, and Olarreaga 2012).[6]

These results relax the assumption that the policy preferences of firms are either homogeneous within industries, or are distinguished only by differences between domestic firms and MNCs. We nevertheless lack a good understanding of how intra-industry differences between firms shape their trade preferences and policy outcomes. While global supply chains can be anchored by MNCs that engage in vertical FDI, for example, they may also outsource manufacturing processes to vertically specialized third-party firms—with varying degrees of tightness in the linkages with other firms (Gereffi and Fernandez-Stark 2011; OECD, WTO, and World Bank 2014, 20–21).

How might differences in firms operating in different stages of the supply chain affect their trade policy preferences? In a vertically integrated MNC, the distributional implications of policies are negotiated within the firm, pitting business units benefiting from a policy change against those likely to lose. A firm that manufactures in both the United States and China, for example, will weigh the benefits of protecting domestic production against the costs it imposes on other business units.

When production is organized through vertically specialized firms participating in global supply chains, on the other hand, policies are negotiated *between* firms. This is an important difference, given that firms are a crucial organizational unit through which political lobbying occurs (Hart 2004). The degree of control that MNCs retain over other firms in the global supply chain also varies. The proliferation of global supply chains thus makes the preferences of vertically specialized firms politically salient, where they have opportunity to influence policy (Mazaheri 2016, 47).

Scholars already know that differences in firms within industries prove consequential when a tariff is applied that increases the cost of inputs for firms operating *downstream* (Gawande, Krishna, and Olarreaga 2012). We propose that vertically specialized suppliers operating in the *upstream* of a global supply chain also oppose policies that reduce demand from geographically dispersed companies operating downstream in global supply chains. Tariffs or other protectionist measures affecting users of their product imply a potential reduction in demand, making them likely to oppose such a measure. We also expect vertically specialized *manufacturing* firms to oppose protectionist measures if they have ties to the targeted country, such as production facilities, supply relationships, sales relationships, or ownership by a party from the trading partner country.

These considerations lead us to expect that the emergence of global supply chains will increase the number and types of firms that oppose trade protectionism. MNCs should oppose tariffs or other protectionist measures targeting countries in which they have manufacturing facilities. We expect them to be joined by three sets of vertically specialized firms: upstream firms that sell to markets subject to protectionist demands, manufacturers that outsource production, and downstream firms that use inputs affected by a protectionist policy.

In the balance of the article, we develop and test our expectations using the empirical setting of the solar photovoltaics sector. We begin with a descriptive section introducing the sector. We then generate hypotheses specific to the sector, and the data and measures used to test them.

Empirical Setting: Solar Photovoltaics

In this article, we test a number of hypotheses associated with the expected effects of global supply chain participation on the trade policy preferences of firms. Our empirical setting focuses on the solar photovoltaics industry.

[5] Gereffi, Humphrey, and Sturgeon (2005) identify five different types of global supply chain, varying by the degree of hierarchy.

[6] Global supply chains are also found to affect the behavior of governments, giving them an incentive to protect the property rights of firms engaging in foreign direct investment (Johns and Wellhausen 2015).

Table 1. Shares of global PV investment, capacity, and module manufacturing

	China	*EU*	*Japan*	*United States*
Global share of capital investment in PV in 2013	16.66% (US$16.26 bn)	20.76% ($20.26 bn)	27.3% ($26.6 bn)	16% ($15.78 bn)
Share of global PV capacity in 2013	13.26% (19.1 GW)	51.39% (74 GW)	10% (14.4 GW)	8.6% (12.4 GW)
Module production capacity in 2013	45 GW	6 GW	3.4 GW	1.6 GW

Source: Mehta 2013, The Pew Charitable Trust 2014.

Solar photovoltaics specifically, and renewable energy generally, are an important new area of economic activity. Around the time of the dispute, global investment in renewable energy in 2013 stood at US$249 billion, accounting for 15 percent of global energy investment (REN21 2014). Governments invested 15 percent of fiscal spending implemented in response to the global financial crisis in climate change–related industries, notably renewable energy (Robins, Clover, and Singh 2009).

The solar photovoltaics industry has also grown rapidly. Renewable power capacity increased to approximately 138 gigawatts (GW) in 2013, and 98 percent of that capacity was installed since 1994 (REN21 2014, 47). Global revenues in solar manufacturing increased from US$2.5 billion in 2000 to $91.3 billion in 2013 (Pernick, Wilder, and Belcher 2014). The solar industry created approximately 140,000 jobs in the United States in 2012, 110,000 in the EU in 2014, and 210,000 jobs in Japan in 2013 (Solar Foundation 2014, 5; EY Belgium 2015, 19; Japan Photovoltaic Energy Association 2014, 16).

There has also been a change in the geography of production. Manufacturers in Europe, the United States, and Japan experienced a rapid increase in import competition from Chinese-based manufacturing of modules, the key power-generating unit of a solar panel (REN21 2014, 48). Firms in the United States, Europe (predominantly Germany), and Japan represented 90 percent of global module production in 2005. By 2012, Chinese manufacturers captured 60 percent of the global module market (European Photovoltaic Industry Association 2013). Cross-border trade in solar goods also increased significantly: in 2006–2008, the solar industry had a trade intensity of 60 to 90 percent, compared to a trade intensity of 10 percent in the market for wind technology (Kirkegaard et al. 2010, 26).

The increase in Chinese solar photovoltaics module production coincided with a fall in firm profitability: from the first quarter of 2011 to the end of the third quarter of 2012, 26 module producers became insolvent, exited the market, or closed manufacturing plants (Mehta 2013, 40–41). Other firms concentrated on market niches less affected by Chinese import competition. A number of firms also chose to lobby policymakers for protection against Chinese module imports. Firms, and the industry groups that represented them, could thus support or oppose demands for measures to protect against rising Chinese photovoltaics production, or could remain neutral.

The supply chain for solar photovoltaics is divided into the manufacture of raw materials and machine tools; wafer, cell, and module manufacturing; and system integration and project development (see Table 2).[7] In the early phase of the solar industry, the supply chain tended to be located in the same country or region, and was often owned by vertically integrated firms. Over time, however, firms shifted manufacturing facilities internationally. Many firms also specialized in a limited number of segments, rather than integrating vertically through the supply chain. As a result, production is now governed by multiple supply chains made up of vertically specialized, and some integrated, firms, spanning across multiple countries.

We expect these changes to affect the trade preferences of firms in the solar photovoltaic industry. We hypothesize that two aspects of a firm's characteristics will influence its position toward trade protection: (i) the existence of ties to firms in China; and (ii) the stage of the supply chain in which the firm specializes.

Upstream Segment

For vertically specialized upstream suppliers, a rise in Chinese solar photovoltaic manufacturing increases demand for their products. Firms producing polysilicon, which is the raw material used in solar wafer production, can be expected to benefit from a rise in short-run demand. Similarly, the emergence of Chinese solar photovoltaic module production should increase demand for machine tool manufacturers that produce the equipment used in the production of modules. We thus expect upstream suppliers specialized in the manufacture of these products to benefit from an increase in module manufacturing capacity in China. Indeed, we expect them to oppose barriers to imports that may reduce demand regardless of whether they have affiliates based in China.

Upstream suppliers should oppose import barriers for a second reason: if the costs of solar photovoltaic power increase relative to other sources of electricity generation, then demand for their products will decrease even as imports are substituted for domestic products. Upstream suppliers that are vertically specialized in the production of polysilicon or machine tools should thus oppose the imposition of import barriers.

H1: *Vertically specialized upstream suppliers should oppose the imposition of trade barriers.*

Manufacturing Segment

We expect the position of solar photovoltaic module manufacturers toward trade barriers to differ, depending on how they are incorporated into global supply chains. Module manufacturers that have no ties to manufacturing in China should strongly prefer import protection: solar modules are largely undifferentiated, meaning Chinese module producers are direct competitors for these firms. We expect firms that are integrated over wafer, cell, and module production, and those that specialize in module production alone, to adopt this position.

H2: *Module manufacturers without China ties should support the imposition of trade barriers.*

[7]The value chain for thin-film silicon—a smaller share of the market—differs in the upstream.

Table 2. The solar photovoltaic supply chain

Upstream		*Manufacturing*			*Downstream*
Raw materials	Equipment	Wafers	Cells	Modules	Systems integration/ project development

We expect firms that own module production in China, on the other hand, to oppose measures that reduce the competitiveness of their products relative to domestic producers. If a vertically specialized module producer imports cells from China, for example, a tariff or like measure will reduce the competitiveness of its products. Similarly, trade barriers will reduce the competitiveness of module manufacturers outsourcing production to Original Equipment Manufacturers (OEMs).[8] We thus expect both firms manufacturing in China, and using third-party suppliers, to oppose the imposition of import barriers.

H3: *Module manufacturers with China ties should oppose the imposition of trade barriers.*

Downstream Segment

Finally, we expect downstream firms that install solar photovoltaic systems, and that develop projects, to oppose policies that increase the costs of their inputs. Trade sanctions imposed on Chinese module manufacturers, for example, should hurt firms using these materials as inputs. Indeed, downstream firms that purchase from non-Chinese module manufacturers should also oppose trade barriers that restrict supply, increasing module prices if not imported from China. We thus expect vertically specialized downstream users, like upstream suppliers, to oppose trade barriers.

H4: *Downstream users should oppose the imposition of trade barriers, regardless of whether they have ties to solar photovoltaics production in China.*

Summary

Considering the presence of ties to firms in the trading partner country ("domestic" vs. "globalized") and the stage of the supply chain in which the firm specializes ("upstream—manufacturing—downstream"), we state four hypotheses regarding firms' expected positions toward restraining imports from China. These are summarized in Table 3.

We thus hypothesize an association between ties with the trading partner, vertical specialization, and the positions firms adopted toward import barriers in the solar photovoltaic industry. Firms that manufacture modules domestically, and lack ties with the trading partner, should favor protection. Upstream suppliers should oppose trade barriers, along with globalized manufacturers with production facilities or supply contracts with China, and downstream users. The primary effect of globalization and vertical specialization is thus to increase the number and types of firms supporting trade openness and opposing any proposed introduction of barriers to trade.

Table 3. Expectations for firm preferences in global PV industry

		Extent of ties with trading partner	
		Domestic	*Globalized*
Segment of Specialization	*Upstream*	H_1: oppose	
	Manufacturing	H_2: support	H_3: oppose
	Downstream	H_4: oppose	

Empirical Section

In the rest of the article, we test these hypotheses. We focus on three major photovoltaic markets: Europe, the United States, and Japan. In addition to being important solar photovoltaics markets globally, each experienced a substantial increase in imports from China. This makes them useful as cases through which to examine how firms' characteristics, and their ties to China, affected trade preferences.

Data and Methods

Our hypotheses focus on the association between the characteristics of firms operating in the global solar photovoltaics market and their preferences toward trade barriers to imports of Chinese photovoltaic modules. Two kinds of data are used to test the hypotheses.

The first is the type of firms' vertical specialization, and the extent of their ties to solar photovoltaics production in China. We used GTM Research's global database of solar photovoltaic manufacturers, combined with membership lists from the major industry associations headquartered in each country or region, to identify relevant firms and their characteristics. We then used the GTM database, corporate websites, and industry journals to identify firms as upstream suppliers, manufacturers, or downstream users, depending on the stages of the supply chain each participated in, from silicon and equipment, to wafers, cells, and modules, to systems integration and project development. In addition, we drew on the GTM database, corporate websites, and industry journals, to code whether firms had ties to Chinese module production, in the form of sales to China, supply purchase agreements, production facilities in China, or Chinese ownership. In Table 3, we refer to firms that have any of the above ties as "globalized," whereas we code firms that do not have any such ties to China as "domestic." We also used the database to ensure that large firms were included in the analysis. For upstream suppliers and downstream users, we examined firms that were listed as members of politically active industry associations to identify the characteristics of firm members.[9]

[8]On OEMs, see Sturgeon (2001). The intensity of preferences for vertically integrated firms should be weaker than vertically specialized firms that are in direct competition with photovoltaic module manufacturers with a presence in China, because the losses of the division producing modules should be balanced against the fall in input prices for downstream divisions within the firm that benefit from falling module prices. Lack of data on preference intensity makes it impossible to test this against data, however.

[9]We also coded firms as "pure play" or "diversified" to be able to account for horizontal diversification as an alternative explanation for non-protectionist preferences.

Table 4. Dependent variable—firm preferences

Firm preference	*Indicator*
Support protection	1. Written documentation of support for increasing trade barriers against rise in PV imports from China, including press releases (self-reporting) and articles in major newspapers or industry magazines (third-party reporting). 2. Statement of support for increasing trade barriers against rise in PV imports from China by firm or industry association representative in on-the-record interview. 3. Two independent third-party interview statements that a firm supported increasing trade barriers against rise in PV imports from China. 4. Membership of industry organization that adopts position in support of increasing trade barriers against rise in PV imports from China.
Oppose protection	1. Written documentation of opposition to increasing trade barriers against rise in PV imports from China, including press releases (self-reporting) and articles in major newspapers or industry magazines (third-party reporting). 2. Statement of opposition to increasing trade barriers against rise in PV imports from China by firm or industry association representative in on-the-record interview. 3. Two independent third-party interview statements that a firm opposed increasing trade barriers against rise in PV imports from China. 4. Membership of industry organization that adopts position against increasing trade barriers against rise in PV imports from China.
Indifferent	1. Explicit statement of neutrality toward increasing trade barriers against rise in PV imports from China.

Note: For firms in the manufacturing segment, we coded cases where no information on firm preferences was available as missing data.

The second type of data is the trade preferences of firms. We used three sources of data to identify firms' trade preferences. First, we used primary documents in which firms state a position toward the use of barriers to trade against China imports. Second, we used member lists from associations in each market, coupled with formal statements by those associations. This assumes that members agree to the position taken by the association of which they are members, which is reasonable given that a number of the associations were created specifically to lobby for a given trade policy position. Third, we conducted interviews—summarized in the supplementary material—with market participants in the European, US, and Japanese markets. We carried out a total of 37 interviews across the three markets with senior representatives of firms and industry associations. Standards for evidence when identifying firms' trade preferences are shown in Table 4 above. In cases where direct statements by market participants were unavailable, we used third-party statements about observed firm preferences. Taken together, evidence collected for the manufacturing sector represents 89 percent of total module production capacity at year-end 2012 for the European market, 93 percent for the United States, and 100 percent for Japan.

Upstream Segment—Firm Characteristics and Preferences

In this section, we assess hypothesis 1, which focuses on the policy preferences of upstream firms. This segment of the market consists of polysilicon producers and manufacturers of machine tools used in solar photovoltaic manufacturing. We expect firms operating in this segment of the market to oppose the imposition of trade barriers, regardless of whether they have ties to solar photovoltaic module production in China.

The evidence is largely consistent with expectations. Semiconductor Equipment and Materials International (SEMI) is a US-headquartered industry body of manufacturers in the micro- and nano-electronic industries. SEMI represents the interests of 180 toolmakers and polysilicon producers operating in the solar industry. Of these firms, all but seven firms manufactured some kind of production equipment or intermediate product for the solar wafer, cell, and module industry. A statement from the organization noted its opposition to the imposition of trade barriers on module imports from China, noting that "SEMI continues to strongly advocate for policies that promote the deployment of solar PV as an answer to energy challenges. The findings of these cases may lead to significant price increases on solar PV systems. This poses a serious challenge to the continued adoption of solar PV in the United States, where price is the single greatest factor in deployment of this technology" (SEMI 2012). Individual manufacturers in the United States also expressed opposition to import barriers. Applied Materials, for example, is a toolmaker that exports machines for crystalline silicon photovoltaic cell production to China, and opposed US trade measures early in the case (Mufson 2011; Schwartz 2011).

This was also the case in the European market. The major industry association representing the upstream sector in Germany—in this case toolmakers—is the Verband Deutscher Maschinen- und Anlagenbau (VDMA) PV, the photovoltaics branch of the German Engineering Association. Data show that 50 of the 53 members of VDMA PV produced some kind of machinery for the production of solar wafers, cells, and modules, and the organization notes that 100 member countries operate in solar photovoltaics.[10] Like their US counterparts, upstream equipment producers in Europe sold products to China; the European Commission examined a sample of eight upstream producers in Europe, finding that on average firms sold 20 percent of their solar-related products to the EU, 50 percent to China, and 30 percent to other third countries. The VDMA itself notes that "business with East Asia has proven to be the motor for growth during the last years" (Wessendorf 2013). The Executive Director of VDMA, Hannes Hesse, recorded the organization's opposition to trade sanctions, stating that the organization wanted "to avoid a useless trade conflict with one of the most important target markets of the machinery industry," and that the "Commission has chosen the wrong way by implementing protective measures. Strengthening free trade would have been the better alternative" (Wessendorf 2013).

This extends to polysilicon. In the United States, the two major vertically specialized polysilicon

[10]Representative of trade association, telephone interview with author, July 8, 2014.

producers—Hemlock Semiconductor and REC Silicon—both rejected tariffs (Kaften 2012; Lynch-Morin 2012).[11] The Chief Executive Officer of REC Silicon, for example, argued that tariffs were "not in the best interest of American solar manufacturing, the American solar industry, or American solar consumers" (Kaften 2012). Firms operating in this market segment and headquartered in Europe showed the same preference. Evidence shows that Wacker Chemie AG, Europe's largest polysilicon producer, lobbied against tariffs (Peel and Chaffin 2013).[12] In Japan, the major Japanese producer Tokuyama produced polysilicon in China, in addition to in Japan and Malaysia (Tokuyama Corporation 2014, 25). Given the lack of support for manufacturers for trade protection, they were not required to state their opposition to import barriers, but there is no evidence that the firm sought protection.

Manufacturing Segment—Firm Characteristics and Preferences

In this section, we assess hypotheses 2 and 3, which focus on the manufacturing segment of the solar supply chain. Our expectations are that module manufacturers without China ties should support the imposition of trade barriers. We expect manufacturers with China ties, on the other hand, to oppose the imposition of trade barriers, regardless of whether they are vertically integrated or specialized.

Evidence shows that manufacturing firms largely behaved as expected, although a number of firms adopted positions inconsistent with expectations. In total, five of six US manufacturers for which data are available had preferences consistent with expectations. In the United States, the Coalition of American Solar Manufacturers (CASM) was created in October as an ad hoc industry alliance supporting the imposition of trade sanctions (SolarWorld 2011). It initially represented seven US cell and panel manufacturers, spearheaded by SolarWorld America (Mufson 2011). Key supporters included both vertically integrated firms such as SolarWorld, and non-integrated firms such as Helios. Data show that firms of both types did not have China ties. In the United States, Suniva, a vertically integrated manufacturer, on the other hand, lobbied against the imposition of trade barriers. Suniva had cell manufacturing facilities in the United States and exported products to China, giving it an interest in open trade (Ashley 2010; Wesoff 2014).[13]

Support for protection by vertically integrated and non-integrated firms without China ties was mirrored in the European market. EU ProSun was an alliance brokered by SolarWorld after the lobbying of other manufacturers (Beetz 2012). It claimed to represent the majority of EU solar industrial production. According to Milan Nitzschke, head of the group, 25 firms participated in the complaint, 5 of which were based in Germany (Pauly and Amann 2013). SolarWorld was integrated over cells, modules, and partially downstream segments, but did not have any China ties (SolarWorld 2015). Sovello also supported tariffs, and was a manufacturer without any trade ties to Chinese firms (Pauly and Amann 2013). Calyxo, a German module manufacturer, was non-integrated, did not have any China ties, and welcomed the decision to establish a floor on prices of imports of China (Calyxo 2013). Solarfabrik, in contrast, opposed trade measures, and had a strategic alliance and supply agreement for cells with Chinese manufacturer JA Solar since 2008 (JA Solar 2010; Neidlein 2013). Of the EU-based manufacturers recorded in the database of manufacturers, which records the largest firms in terms of production capacity, the position of seven firms was consistent with expectations, while five firms adopted positions inconsistent with expectations.[14]

In Japan there was no lobbying from module manufacturing firms to implement barriers to trade, in contrast to the European and US markets.[15] Of nine firms operating in the solar sector with some manufacturing capabilities in Japan, just two firms were vertically specialized in module manufacturing and lacked some form of firm ties with China, and of these only Sanyo/Panasonic was a major manufacturer (Mehta 2013). In contrast, seven firms were either headquartered, had a sales office, directly operated manufacturing facilities, or outsourced production to an OEM based in China. There were thus only a small subset of firms that were both located in Japan and were directly competing with Chinese manufacturers.

The Japanese government did not record any demands from firms or industry to push for protection from the rise in imports.[16] Interviews with manufacturing firms, and the industry association, suggested they did not support protectionism.[17] The record of all press conferences between February and June 2014 with the Minister of Economy, Trade, and Industry, which has regulatory competence over many energy-related laws, and who heads the ministry responsible for designing and implementing Japan's renewables policy, also shows no evidence of ministerial concern about rising imports from China. While weaker than a direct statement of firm preferences in response to a demand for protection, the absence of support for trade protection is not inconsistent with hypotheses 2 and 3.

Downstream Segment—Firm Preferences and Characteristics

In this section, we assess the evidence regarding hypothesis 4. We expect downstream users to oppose the imposition of trade barriers, regardless of whether they have ties to solar photovoltaics manufacturing located in China. Firms with ties to China through supply contracts with Chinese module manufacturers would be harmed by trade sanctions. Given that solar modules are largely undifferentiated, additional supply from Chinese producers should also reduce the price of modules, increasing margins for developers and installers. Indeed, US imports of Chinese

[11]Executive at a company involved in dispute, telephone interview with author, August 18, 2014. Although we expect them to hold this trade policy preference regardless of whether they have sales in China, it is also worth noting that both firms sold polysilicon to Chinese customers (Ma 2013).

[12]Author's phone interview with representative of trade association, April 10, 2014.

[13]Author's phone interview with executive at company involved in the solar trade case, 2014.

[14]A number of firms also remained neutral during the EU trade case. We discuss these in the next section.

[15]Inoue Yasumi of Japan Photovoltaic Energy Association (2014) interview by author, Tokyo, Japan, November 5, 2014; Director, Renewable Energy Division, Ministry of Economy, Trade and Industry, Tokyo, Japan, interview with authors, November 5, 2014.

[16]Director, Renewable Energy Division, Ministry of Economy, Trade and Industry, interview with authors, Tokyo, Japan, November 5, 2014.

[17]Representative of Solar Photovoltaic Division, Sharp Inc., interview with authors, Nara, Japan, November 7, 2014; Kyocera, Kyoto, Japan, interview with authors, November 6, 2014; Representative of Sun-Edison, interview with authors, Tokyo, Japan, March 12, 2014; Japan Photovoltaic Industry Association, Tokyo, Japan, interview with authors, November 11, 2014.

photovoltaic solar modules totaling $2.65 billion suggest that US project developers and installers did use Chinese modules (Pew Charitable Trust 2013, 12).

The data are largely consistent with expectations. Downstream developers and installers are predominantly vertically specialized firms. An alliance representing project developers and installers, and some Chinese importers, was created in the United States in November 2011 under the title the Coalition for Affordable Solar Energy (CASE) (Stuart 2011). Data show that 44 of 94 firms were downstream installers and project developers.[18] CASE opposed the imposition of trade measures against imports. CASE president and SunEdison cofounder Jigar Shah noted that the "decision will increase solar electricity prices in the U.S. precisely at the moment solar power is becoming competitive with fossil fuel generated electricity" (Solar Server 2012). In ITC hearings, Sheldon Kimber, Chief Operating Officer of Recurrent Energy, noted that "Recurrent is one of North America's leading solar project developers," and that "The antidumping and countervailing duties being considered in these investigations, instead of supporting the U.S. solar energy industry, in fact, threaten it" (International Trade Commission 2011, 154, 157).

In Europe the Alliance for Affordable Solar Energy (AFASE) was founded in March 2012, and merged with the Sustainable Energy Trade Initiative (SETI), a public-private group promoting free trade in clean technologies, in October 2013. AFASE had small developers among its supporters, and included Chinese manufacturers Trina, Yingli, and Suntech (Beetz 2012).[19] Data show that AFASE represented a substantial number of downstream firms: 151 of the sample of 265 firms, or 57 percent out of a total AFASE membership of 856 if we extrapolate to the population, participate in the downstream segment of the market. AFASE was also clearly opposed to the imposition of trade measures in response to the anti-dumping and anti-subsidy investigations, as expected. An open letter to the EU trade commissioner on AFASE letterhead and signed by 1,024 company representatives notes that the "imposition of anti-dumping and/or countervailing duties will severely hamper the growth of solar energy in the EU to the detriment of the entire EU solar PV value chain" (AFASE 2013a). A position paper released by the organization noted that any decision to impose duties on imports from China would harm the European solar industry, contradict policies stimulating renewable energy, and fail to help firms adjust to the problem of oversupply (AFASE 2013b, 1–2). This is consistent with expectations, given the membership of the organization.

Japanese downstream firms did not create a distinct industry association, in contrast to the US and European markets. This is unsurprising given there was no evidence of an attempt by domestic module manufacturers to implement protectionist measures against rising imports. Aggregate data suggest that developers were taking advantage of imports, however, as in the US and European cases. In FY2012, 1.4 GW of non-Japanese produced modules were sold within the Japanese market, from a total market of 3.8 GW (36.8 percent) (Japan Photovoltaic Energy Association 2014). The lack of demand for protection from developers in the Japan market is not inconsistent with expectations.

Summary of Evidence

The data summarized above show that firms in the solar photovoltaics industry had different preferences toward the imposition of trade barriers against Chinese module imports, and these differences were largely consistent with expectations. In Europe and the United States, upstream polysilicon and equipment manufacturers, and downstream project developers and installers, largely opposed trade sanctions. Consistent with expectations, domestically focused module manufacturers lacking ties with China supported the imposition of trade sanctions, while firms with some form of ties with China opposed such measures. Data on the characteristics of manufacturers in Japan show that firms enjoying significant market share had ties with China by either outsourcing manufacturing, or owning module production facilities there. Although weaker evidence, it is unsurprising that these firms did not lobby for protectionist measures, in contrast to some US and European firms.

Did firms' trade preferences match expectations overall? In the upstream segment, industry associations in the United States and Europe representing 360 upstream firms adopted the expected position by opposing trade sanctions; see Table 5. No association was created in Japan specifically to represent the interests of upstream firms; however, as noted above, interviews with the industry association confirm that there was no request from the association membership to implement protection. Data from Japanese firms operating in the upstream in the US market also show that many chose to join an industry organization opposing the imposition of trade barriers in the US market.

In the manufacturing segment, the preferences of 12 out of 18 US- and EU-based firms matched expectations. These include both vertically specialized and vertically integrated manufacturers. In the Japanese case, while there was no attempt to pursue import barriers against Chinese manufacturing, interviews with major manufacturers Sharp and Kyocera confirm that they did not engage in lobbying for trade protection. US- and EU-based industry associations with majority membership of 532

Table 5. Summary of firm preferences (n = 910 firms)

		Extent of ties with trading partner	
		Domestic	*Globalized*
Segment of Specialization	*Upstream*	360 (360)	
	Manufacturing	10 (11)	2 (7)
	Downstream	532 (532)	

Note: Table shows number of firms in the sample that match expectations, categorized by type. The total number of firms of a given type in the sample is shown in parenthesis. We exclude Japanese firms from the table because of the lack of a statement from the Japan Photovoltaic Industry Association meeting the standard for evidence noted in Table 4. Data is calculated from the GTM manufacturers database (Mehta 2013), membership lists from VDMA (EU), SEMI and CASE (US), and expected number of firms of each type calculated from EU AFASE membership sample. Details on data collection and calculations are in the supplementary materials, as is a table that recalculates the results including firms operating in the Japan market.

[18]Other firms in the organization were upstream (11 firms), manufacturers (8 firms), and 31 firms for which there was no data available, or which were consultants.

[19]Representative of solar lobby group, telephone interview with author, April 10, 2014.

downstream firms opposed trade barriers, which also matches expectations.

Data thus suggest that aside from a number of outliers discussed below, an explanation focusing on the form of vertical specialization, and the presence of China ties, helps explain the policy preferences of firms in the solar industry vis-à-vis Chinese solar imports. Lobbying coalitions opposing trade protection centered on the downstream and upstream firms, allied with manufacturing firms that had some form of ties with China. Supporters of trade sanctions, on the other hand, were overwhelmingly firms that were vertically specialized in manufacturing and did not have ties with Chinese module production. The rise of vertical specialization in the solar photovoltaics industry thus increased the number of firms opposed to import protection. This suggests that—in addition to the globalization of manufacturing—vertical specialization is an important factor that shapes the preferences of firms toward protectionism.

Other Explanatory Factors

The data also show a number of firms with preferences that are not consistent with expectations. In this section, we summarize three additional explanatory factors identified from the data. We use inductive methods, identified as useful for developing new explanations for outcomes that do not meet expectations derived from existing theory (George and Bennett 2005).

Examining the characteristics of manufacturing firms that behaved contrary to expectations offers the first potential explanation for this outcome: in the manufacturing segment, six domestic manufacturers remained neutral, despite lacking links with China. The data show, however, that these firms were in the process of takeover by a foreign firm. One possibility is that these firms remained neutral because they lacked the resources to engage in lobbying. It is also plausible, however, that uncertainty about the future managements' policy preferences may have led firms to adopt a neutral stance. The German module manufacturer Sunways is a case in point, being taken over by the Chinese firm SDK Solar and adopting a neutral position.[20]

A second explanation lies in the potential effect of ideological factors on the formation of firms' trade preferences. CASM was an ad hoc industry alliance made up of manufacturers created in October 2011 to lobby for trade sanctions, as noted in the previous section. By November 2014, however, CASM had incorporated a number of downstream firms that stated their support for protectionist measures in order to protect US manufacturing. A solar installer from New Jersey, Amped on Solar, argued, for example, that "From day one, our mission has included supporting American jobs and the American economy. Unfair practices by off-shore manufacturers and US companies who support those products has made it difficult for us to remain competitive." A representative of Energy Solar of California noted: "I was buying Chinese for the low price and quality. American made have come down and I would rather pay a little more to support the US economy. My customers seem to agree." SolarWorks International of Oregon stated: "We need to protect and grow jobs here in the U.S.A. and the people of the United States need to buy American-made products" (Coalition for American Solar Manufacturing 2015). Many of the firms for which management made such statements were small in size, as measured by numbers of employees, suggesting that the individual preferences of owners or senior management may have influenced the position of the firm toward trade protection more than the potential economic benefits of open trade.

We do not believe this factor was significant across the full sample of firms, however. Theoretically, we expect that firms influenced by some form of nationalist sentiment should support the implementation of barriers to imports. One inference from the fact that firms overwhelmingly supported open trade is thus that this is not likely to be a substantial factor explaining firm preferences.

A third possibility is that firms with business units outside solar photovoltaics with ties to China may have perceived the costs and benefits of supporting trade sanctions differently. Bosch Solar Energy, for example, opposed tariffs, although its solar business would have benefited from their imposition (Stromstra 2012). Bosch is a diversified industrial conglomerate, however, and other divisions with China ties could plausibly have faced retaliation. This is also the case for a number of Japanese solar photovoltaics manufacturers, and upstream firms selling equipment to semiconductor manufacturers in addition to solar photovoltaics.

The possibility that horizontal diversification might affect firms' trade preferences has not been a sustained focus of research to date. Theoretically, it is plausible that horizontally diversified firms would oppose trade sanctions because of the fear or threat of retaliation in other business units. Indeed, there is some justification for concern about retaliation: the Chinese government imposed retaliatory tariffs on polysilicon manufacturers from the United States, for example, although it did not expand these measures to industries unrelated to the solar photovoltaics sector.

How large is the potential effect of horizontal diversification? A large number of firms in the upstream segment—mainly machine tool and other equipment manufacturers—were horizontally diversified. A smaller but still significant number had some business ties with China through a manufacturing facility or sales office. Interview data suggest that the distributive effects of trade sanctions were nevertheless an important factor in shaping upstream firms' preferences. The head of VDMA PV, the trade association representing upstream firms in the European Union, for example, identified the impact of the proposed trade sanctions on the solar industry as the most important factor determining the group's opposition to trade protection.[21] The Japanese Photovoltaic Energy Association (JPEA) noted horizontal diversification as a rationale for the decision by a number of its members to sell their solar photovoltaic business unit, noting that Honda, NEC, and Hitachi had each exited the business as a result of the rise of imports from China.[22] Sharp similarly noted that their preferences in both Europe and Japan were determined by their view that they could not compete with Chinese module manufacturers, and that a more effective strategy was to focus on other segments of the supply chain, and outsource module production. A

[20]Former Head of Communications, telephone interview with author, September 25, 2014.

[21]Head of VDMA PV trade association, telephone interview with author, July 8, 2014.

[22]Yasumi Inoue, Director of Public Infrastructure Division, Japan Photovoltaic Energy Association (JPEA), interview with author, Tokyo, Japan, November 4, 2014.

senior executive at a major European solar firm noted that the potential effect of European policy on their solar module business determined their support for trade protection, despite the fact that the firm had solar-related FDI in China.[23] Taken together, this suggests that horizontally diversified firms tended to determine their preferences based on the distributional effects of trade sanctions in the solar photovoltaics industry, rather than possible implications of the imposition of sanctions for other business lines.

Conclusion

In this article, we examined the effect of firms' participation in global supply chains on their trade preferences. We focused on the solar photovoltaics industry. We documented variation in intra-industry heterogeneity in firm preferences, and proposed that this difference in firm preferences stems from their incorporation into global supply chains across two dimensions: the stage of the supply chain firms participate in, and the extent to which they are tied to supply chains that incorporate Chinese production.

The data suggest that the globalization of supply chains shifted the preferences of upstream suppliers, manufacturing firms outsourcing to third-party manufacturers, and vertically specialized firms operating in the downstream. Taken together, our findings suggest that the number of firms with preferences for open trade increased. This left domestic import-competing manufacturers isolated.

We think that the processes we identify likely extend to other sectors. The forces that enable the unbundling of manufacturing processes operate across many industries (Humphrey and Schmitz 2000). Global supply chains that incorporate vertically specialized firms have emerged across a range of industries as technological innovation reduces the costs of coordinating the production of standardized products across borders (Baldwin 2013; Gereffi et al. 2005; Milberg and Winkler 2014). Studies show that production in electronics, automobiles and motorcycles, and apparel and footwear is now organized through global supply chains populated not just by MNCs, but also vertically specialized firms. Global supply chains became a key feature of production of both motor vehicles and apparel in the 1960s and 1970s; electronics followed in the 1990s and 2000s. Indeed, motor vehicles and electronics show the highest share of contemporary trade in intermediate products (Cattaneo, Gereffi, and Staritz 2010; Sturgeon and Memedovic 2011). Global supply chains also characterize the production of other renewable energy technologies, such as wind turbines (Nahm 2015).

All of this matters for understanding the politics of globalization. Work on the politics of trade focuses predominantly on the global linkages of MNCs. Scholars justify this focus by pointing to the fact that MNCs tend to be larger and more productive than other firms (Jensen, Dennis, and Stephen 2015, 917). While MNCs remain central to international trade and investment, the rise of vertically specialized firms that operate within global supply chains may expand political conflict over the distributional effects of protectionism beyond MNCs and their affiliates. The case of the solar photovoltaic industry suggests that, under certain conditions, vertically specialized firms that participate in global supply chains engage meaningfully in political bargaining over trade policy. This may depend on the presence of large firms that can shoulder the costs of engaging in political activities. It is also possible that large foreign firms may lower the cost of collective action among small, vertically specialized firms. For example, the presence of politically active China-based module manufacturers in the United States and Europe may have reduced the costs of collective action for smaller, vertically specialized downstream firms in these markets. It may turn out that the proliferation of heterogeneous—but politically influential—firms makes it more likely that smaller firms will also engage meaningfully in political lobbying.

A second question relates to the effect of intra-industry heterogeneity on policymakers' incentives. Gawande, Krishna, and Olarreaga (2012, 116) note that intra-industry divisions matter when estimating the degree to which policymakers pay attention to general welfare, or to private firm interests. In the case of solar photovoltaics, however, firms that supported and opposed trade remedies appealed to the welfare gains they argued would result from adoption of their preferred policies. It is also noteworthy that policymakers in both Europe and the United States were willing to impose trade remedies against China-based firms *despite* divisions within the industry. This raises the possibility that, despite a numeric increase in the number of firms supporting open trade, intra-industry divisions increased the importance of policymakers' preferences relative to those of firms. This, in turn, enabled policymakers to adopt policies unencumbered by the influence of firm lobbying.

We suggest two major avenues for future research. First, the solar photovoltaics industry, as we stressed earlier, provided a useful case for analysis because its production is substantially organized through global supply chains. This enabled us to examine their effect on firms' trade preferences. However, the distribution of firm type across the three segments—upstream, manufacturing, and downstream—is likely product specific. Moreover, vertically specialized firms can be horizontally diversified. They can also be large and globalized in their own right.

We believe this makes it important to collect data on the characteristics of firms participating in global supply chains across different industries. A number of studies identify an important role of lead firms, for example, which coordinate the activities of other firms in the global supply chains through affiliates and outsourcing. In such cases, we might expect that vertically specialized firms' preferences match those of the lead firm—which mirrors what we see with MNCs. In other industries—including solar photovoltaics—global supply chains appear to lack a strong lead firm that coordinates production. These kinds of differences in structure likely shape the political behavior of firms. We need a better understanding of how and why.

First, we should expect the importance of differences in firm characteristics to vary with respect to the distributive effects of specific policies. In the case of tariffs, we observe the divide in policy preferences discussed here. By contrast, intra-industry divisions are likely to prove less important in the case of a feed-in tariff—which provides a direct subsidy to installers of solar photovoltaics panels. A feed-in tariff increases demand for the products of all segments in the solar photovoltaic supply chain. Firms across all three segments are likely to support a feed-in tariff. We should, thus, also study how intra-industry heterogeneity effects the way firms respond to policy proposals with different distributive consequences. Doing so will further help us understand the conditions under which global supply chains lead to variation in firm preferences.

[23]Representative of solar firm, telephone interview with author, October 10, 2014.

Finally, what do our findings mean for climate policy? Many governments are meeting the dual challenge of promoting economic growth and mitigating climate change by supporting green industrial policies (Hughes 2012; Meckling et al. 2015). Interest-group theories of regulation suggest that these policies rest on "Baptist-and-bootlegger" coalitions, bringing together environmental groups with firms—and other special-interest groups—that gain materially from the enactment of climate change–related environmental policies (Desombre 1995; Yandle and Buck 2002). Our data show, however, that different trade-policy preferences split the coalition of firms in support of the growth of the solar photovoltaics industry. Prior studies show that competitive lobbying affects renewable energy policy outcomes (Cheon and Urpelainen 2013). Our study suggests that such competition may weaken the influence of coalitions that underpin public policy used to spur the growth of green industries. This introduces new sources of trade-offs for governments seeking to protect manufacturing while addressing climate change.

Supplemental Information

Supplemental Information is available at the *International Studies Quarterly* data archive.

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