Antidumping and Feed-In Tariffs as Good Buddies? Modeling the EU–China Solar Panel Dispute

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Preliminary version

Abstract

Can we inflict antidumping (AD) duties on pollution abatement technologies ignoring their environmental dimension? On December 2015, the Commission imposed AD duties on Chinese solar panels. Based on the dispute that constitutes the most significant AD complaint in Europe, we build a price competition duopoly model with differentiated product and intra-industry trade of photovoltaic equipment. We provide two relevant types of antidumping duties with nice properties integrating the environmental concern. The first duty is found maximizing social domestic welfare and is showed to always increase with the feed-in tariff program set in the domestic country. The second duty is found equalizing the foreign firm's price on the domestic market to the foreign market. On the opposite, this appropriate AD decreases with the feed-in tariff program. When switching to an energy policy on its own, we show that the optimal feed-in tariff increases with the antidumping duty. In other words, trade and environmental optimal policies do complement each other. This clearly indicates that when setting AD duties in sectors related to clean energy products, one should not ignore the other side, i.e. to what extend renewable energy is subsidized.

Keywords: Antidumping, FIT, Solar Panels, Renewable Energy, Trade disputes, EU, China.
JEL Codes: F18, L52, Q42, Q48, Q56.

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1 Introduction

The EU–China solar panel dispute opposes the largest photovoltaic market to the bigger photovoltaic manufacturer. Following a complaint of EU solar manufacturers, the European Commission (EC) established that solar cells and solar panels imported from China were sold at a dumped price, hurting the EU solar manufacturers. [1] In December 2015, the EC imposed AD duties coupled with import quotas on these products. Voituriez and Wang (2015)'s case study simultaneously shows that China's support policies were not detailed in the EC's investigation, but highlights a series of measures[2] suggesting the implementation of a strategic trade policy. In late 2016, the EC proposed to extend its AD duties for two additional years, while more than 120 companies and associations in Europe have been against the extension of these measures.[3]

The solar panel case has been widely discussed for several reasons. Major trade players, among which China and the EU, consider green energy production equipment industries as a strategic emerging sector, so that trade disputes have been likely to occur (Voituriez and Wang, 2015). The production of photovoltaic products experienced a substantial growth during the 2000s. This growth was connected with public policies. In both the EU and China, the rise of the photovoltaic sector has been fostered by green industrial policies. Yet, these policies were not coordinated. Broadly,[4] China authorities have chosen to subsidy photovoltaic equipment manufacturers rather than consumers (i.e., renewable electricity producers), whereas the EU has chosen consumers[5] rather than producers. As a consequence, the EU had the world's largest installed solar generation capacity in 2011 and formed the first export market for Chinese solar manufacturers (Crowley and Song, 2015). The market share of the European photovoltaic manufacturers progressively fell.[6] This situation led to the European photovoltaic manufacturers' complaint against unfair competition, and to the EC's antidumping (and anti-subsidy) investigations.

[1]According to European legislation "an anti-dumping (AD) duty may be applied to any dumped product whose release for free circulation in the Community causes injury" European Commission (2009, art.1).

[2]e.g. corporate tax rebates, loan offer facilities. See Carbaugh and St. Brown (2012) for details on the China's industrial policy specifically in the renewable energy sector.

[3]The Member States have not yet approved the proposal. The final decision will be made in March 2017.

[4]Facts offer a more nuanced picture. See for example Grau et al. (2012) for a comparison between China and Germany.

[5]The policy takes the form of feed-in tariffs (FITs) to renewable electricity produced with solar panels, loans at low interest rates for solar panel installations, etc.

[6]See the data provided by the EC's decision imposing provisional AD duties (European Commission, 2016).

This solar dispute represents the most significant AD complaint the EC has ever investigated. It appears in a context where the widespread use of AD questions the real motive of this policy: a response to dumping practices or simply another form of protection (Blonigen and Prusa, 2003; Zanardi, 2006).[7] However, the AD measures have been imposed for a period of two years. This period ended in December 2015 and given their ongoing review investigations, the measures remain in force. These reviews are not expected to be completed until late-2016. In the end, the EC will have to decide whether to maintain the measures or to remove them.[8]

This dispute concerns strategic trade policies, but not exclusively.[9] The environmental stakes are obvious. For instance, subsidizing the photovoltaic sector can be seen as a means to manage the positive knowledge externalities of new technologies brought by infant industries. In the case of renewable energy sector, these new technologies are not meaningless since they are carbon abatement technologies. The fight against global warming and the energy transition can thus be impacted by the way the trade dispute is managed. Consequently, the EC felt necessary during its AD investigation in 2012 to argue against the claim that the use of AD duties would undermine the EU green energy objectives.[10] A side benefit of the EU being able to import cheap solar panels is that this increases its adoption of renewable energy equipment and this reduces global GHG emissions. Furthermore, AD can be seen as interfering with renewable electricity support programs such as feed-in tariffs (FIT). FIT programs guarantee a price for renewable electricity higher than the gross market electricity price allowing green electricity producers to face higher fixed cost of production. These subsidy programs benefit to the upstream firms (solar panels producers) too by a 'pass-through effect' (Bougette and Charlier, 2015). AD could contradict this effect. Turning things differently, we can also question whether FIT programs could protect the domestic photovoltaic sector from the foreign competition. In a duopoly setting with differentiated products, Bougette and Charlier (2015) show that a FIT program without local content requirement does not necessarily benefit to the foreign solar panels producer. The originality of the paper

[7]For a critique of using AD duties, see Konings and Vandenbussche (2008) among others. Analyzing 4,799 EU producers involved in European AD cases in the mid-1990s, the authors compare the productivity of firms that filed for and obtained AD protection to the productivity of similar firms that neither applied nor obtained protection. They find that the average protected firm is much less productive than a similar firm prior to protection.

[8]See European Commission (2016) and the history of proceedings at http://trade.ec.europa.eu/tdi/case_history.cfm?id=1895\&init=1895

[9]See Curran (2015) for an analysis of this case in terms of political economy.

[10]http://trade.ec.europa.eu/doclib/docs/2012/september/tradoc_149903.pdf

is precisely to tackle these issues where the environmental stakes of the trade dispute is recognized.

The EU–China solar panel dispute has drawn considerable comment, but few studies in the economic literature have been carried out. The event study literature has been especially interested in the case. In these works, the AD measures are considered as an external shock, the consequences of which are studied. Huang et al. (2016) study the effects of the European AD on stock prices of the Chinese firms in the photovoltaic sector and compare them to other AD shocks. They show that the stock price synchronization and co-movement (and therefore stock-market volatility) were positively impacted by both the EU and the US AD on solar panels. Crowley and Song (2015) develop an event study approach on the case, too. These authors examine the impact of the European AD on the stock market performance of the Chinese firms in the photovoltaic sector. They find that larger export-oriented firms have been the most affected, and that firms' exposure depends on the ownership structure. According to Crowley and Song (2015), the larger negative effect of the European AD is found for privately owned firms, whereas state owned firms experienced only limited adverse effects.

From a more general perspective, dumping and AD duties have been extensively studied in both theoretical and empirical literature (see, e.g., Blonigen and Prusa (2003)'s survey). More particularly, several effects from AD actions have been stressed, such as protection effects (Veugelers and Vandenbussche, 1999), collusive effects (Collie and Le, 2010), substitutes for tariffs (Dinlersoz and Dogan, 2010), or R&D (Gao and Miyagiwa, 2005). To our knowledge, no theoretical works study the interactions between AD duties and renewable energy support programs. Yet, the possibility of interferences between the trade policy and the environmental one forms an original feature of the dispute that need to be explored.

In this paper, we consider a price competition duopoly model with differentiated products and intra-industry trade of photovoltaic equipment. Conditions for unilateral dumping from the foreign firm are derived. We show that dumping has a positive impact on the environment allowing domestic consumers to access renewable energy products cheaper. The domestic AD reverses this effect. After having assessed the environmental stakes of these trade policies, we turn to evaluate the trade stakes of the environmental policy. More precisely, we test the capacity of FIT programs in front of dumping to protect domestic solar panels producers. We show that FIT programs may have the same effects as imposing a AD duty, i.e. restoring the domestic firm's situation before dumping. This result clearly indicates that the question of the substituability/complementarity of the two types of policies, as well as the relevance of a policy mix have to be explored. When setting AD duties in sectors related to clean energy products, one should not ignore the other side, i.e. to what extent renewable energy is subsidized. Investigating this issue, we show that AD can react differently to a degradation of the domestic firm's competitiveness when combined with FIT and when facing foreign dumping alone.

The paper is organized as follows. Section 2 presents a model of unilateral dumping and evaluates the impact of such dumping on the other country's welfare incorporating the reduction of an externality created by the expansion of photovoltaic electricity. The economic rationale for AD is then presented in this case. The conditions under which such a policy creates an obstacle to energy transition are in particular discussed. In Section 3, the question of the optimal policy mix between AD and FIT programs, is addressed. Finally, Section 4 concludes and discusses some policy implications in the light of the EU–China solar panel dispute.

2 A Model of Unilateral Dumping

We assume that there are two countries, a domestic (European) and a foreign country (China) denoted respectively h and f. Markets are segmented. In each country, a firm i produces a differentiated product (as in, e.g., Anderson et al. (1995), Clarke and Collie (2003), and Collie and Le (2010)), with the domestic firm labeled as Firm 1 and the foreign firm labeled as Firm 2. Firm 2 is supposed to be monopolist on its own market, while it is competing *à la Bertrand* with Firm 1 on the domestic market.

We first characterize the market equilibrium (2.1). We then analyze the impact of unilateral dumping on market characteristics (2.2). Lastly, we analyze the introduction of AD actions (2.3).

2.1 Market equilibrium

The quantities produced by Firm 1 and the price it sets on the domestic market are denoted x_{1h} and p_{1h}. In the j^{th} market ($j = h, f$), the price set by Firm 2 is denoted p_{2j} and its quantities produced is x_{2j}. In each market, there is a representative consumer with quasilinear preferences that are described by a quadratic utility function. The utility function of the representative consumers in both markets are:

$$U_h = \alpha_h x_{1h} + \alpha_h x_{2h} - \frac{1}{2}\beta\left(x_{1h}^2 + 2\phi_h x_{1h}x_{2h} + x_{2h}^2\right) + z_h, \tag{1}$$

$$U_f = \alpha_f x_{2f} - \frac{1}{2}\beta x_{2f}^2 + z_f \tag{2}$$

where z_j represents the composite good, and α_j, β, and ϕ_h are positive parameters. The two markets $j = h, f$ differ in terms of market size (i.e., α_i, β_i). One assumes that $\alpha_h > \alpha_f$, so that the domestic market offers significant prospects for the foreign firm. Consumers do not necessarily consider the two goods as perfect substitutes: $0 \leq \phi_h \leq 1$. $\phi_h = 1$ means that the two products are perfect substitutes for domestic consumers and $\phi_h = 0$ means the two products are independent. The representative consumer's budgets in country j are written as

$$R_h = x_{1h}p_{1h} + x_{2h}p_{2h} + z_h \tag{3}$$

$$R_f = x_{2f}p_{2f} + z_f, \tag{4}$$

When one maximizes respective utilities subject to the budget constraints, demand functions in the j^{th} market are:

$$x_{1h} = \frac{\alpha_h(1-\phi_h) - 2p_{1h} + 2\phi_h p_{2h}}{\beta\left(1-\phi_h^2\right)} \tag{5}$$

$$x_{2h} = \frac{\alpha_h(1-\phi_h) - 2p_{2h} + 2\phi_h p_{1h}}{\beta\left(1-\phi_h^2\right)} \tag{6}$$

$$x_{2f} = \frac{\alpha_f - 2p_{2f}}{\beta} \tag{7}$$

The profit functions for each firm i in country j are:

$$\pi_{1h} = (p_{1h} - c_1)\, x_{1h} \tag{8}$$

$$\pi_{2h} = (p_{2h} - c_2)\, x_{2h} \tag{9}$$

$$\pi_{2f} = (p_{2f} - c_2)\, x_{2f}, \tag{10}$$

The two firms have constant marginal costs c_i $(i = 1, 2)$. Firm 2's marginal cost c_2 may be reduced by the effect of a foreign public policy (e.g., subsidy, easier access to credit, etc.), so that we consider a situation where the foreign firm gained a cost advantage $(c_2 < c_1)$. The foreign country has an intrinsic comparative advantage in producing the differentiated product, as in Bernhofen (1995).[11]

The first order conditions lead to the equilibrium prices $p_{1h}^\star$, $p_{2h}^\star$, and $p_{2f}^\star$. We then find the equilibrium quantities $x_{1h}^\star$, $x_{2h}^\star$, and $x_{2f}^\star$. All equilibrium

[11] In Bernhofen (1995)'s model, dumping is not reciprocal, neither. If the foreign firm engages in dumping, the domestic firm will reverse dump.

characteristics can be found in the Appendix. In order to ensure that firms are active at the equilibrium, one must assume that

$$\alpha_f > 2c_2, \quad c_2 < c_1 < \frac{\alpha_h}{2}, \quad \text{and} \quad \phi_h < \Phi. \tag{11}$$

with Φ defined in the Appendix. These conditions establish a minimum market size for both markets, as well as a maximum degree of products' substituability.

We can now compute consumers' surpluses of the two markets at the equilibrium:

$$CS_h^\star = \frac{\alpha_h(\alpha_h - c_1 - c_2)}{\beta(2-\phi_h)(1+\phi_h)} \quad \text{and} \quad CS_f^\star = \frac{\alpha_f(\alpha_f - 2c_2)}{4\beta}\,, \tag{12}$$

which are strictly positive under the activity constraint (11).

We assume that fossil fueled electricity is replaced by the renewable one. As a consequence, the "environment" is improved by the development of solar panels sales. Therefore, the production of solar panels is responsible for a positive environmental externality, denoted E, that we define for simplicity with an additive form:

$$E = x_{1h} + x_{2h} + x_{2f}\,. \tag{13}$$

This improvement of the environment concerns both countries. However, domestic and foreign countries do not necessarily value this positive externality at the same level. We denote $\gamma_i E$ the external benefit related to the environment for country i ($\gamma_i > 0$).

The domestic welfare W_h is thus represented by the sum of domestic consumer surplus, the domestic firm's profit, and the external benefit.

$$W_h = CS_h + \pi_h + \gamma_h E\,. \tag{14}$$

Global welfare W_g is therefore computed by integrating the foreign country's characteristics

$$W_g = W_h + CS_f + \pi_f + \gamma_f E\,. \tag{15}$$

Equilibrium values are available in the Appendix.

2.2 The effects of foreign dumping

At the equilibrium, the foreign firm dumps its product into the domestic market when $p_{2f}^\star > p_{2h}^\star$. In other words, the domestic consumer has to pay less than the foreign consumer for the same product 2. When one resolves this inequality, we get the following unilateral dumping condition:

$$\alpha_f > \frac{2(\alpha_h(1-\phi_h)(2+\phi_h) + \phi_h(2c_1 + \phi_h c_2))}{(2-\phi_h)(2+\phi_h)}\,. \tag{16}$$

This condition imposes a minimum foreign market's size. This lower bound depends on the domestic market's characteristics, as well as on the marginal costs of both firms. This minimum size decreases in the domestic market's size, and in the degree of products substituability. However, it increases with both marginal costs. In the remaining of the paper, we will keep the constraint (16) active in order to later justify the domestic AD policy.

We can now analyze the effects of foreign firm's dumping policy on the equilibrium market characteristics.

Proposition 1 *The foreign dumping policy has the following effects: i) it decreases the domestic demand for product 1 and Firm 1's profit whereas it increases the domestic demand for dumped product 2; ii) it increases the environmental benefit and the domestic consumers' surplus; iii) it increases the foreign firm's total profit even though the impact on foreign firm's profit realized on the domestic market is ambiguous.*

Note that for given firms and consumers' characteristics c_1, α_h, α_f, and ϕ_h, the foreign government can makes Firm 2's dumping easier by lowering parameter c_2 using subsidy policies. Hence, Proposition 1 shows that this foreign country's strategic policy reaches its objective. Firm 2's total profit increases at the expense of the domestic firm's situation. However, the dumping policy increases the environmental benefit and domestic consumers' surplus, but not to the point of having an overall positive effect on the domestic welfare (see simulations).

In the next subsection, we study the impact of an AD action introduced by the domestic country to countervail the foreign firm's dumping policy. What is at stake is eventually the impact of the environment and welfare, which allows to take into account the energy transition context linked to the EU–China solar panel dispute.

2.3 The use of antidumping duties

In reaction to the foreign dumping, the domestic country may impose an AD duty τ. AD is conceived as raising Firm 2's overall marginal cost: $c_2 + \tau$. Therefore, the AD law is seen as creating a barrier to trade of τ per unit exchanged as in Bernhofen (1995). The objective of such policy is to compensate the negative effects of the foreign Firm 2's dumping policy on Firm 1's domestic profit (Proposition 1). In order to ensure that both firms are active at the equilibrium under this new market condition while the foreign firm dumps, the constraints

(11) and (16) can modified as the following:

$$\alpha_f > 2c_2\,, \quad \tau < c_1 - c_2\,, \quad c_2 < c_1 < \frac{\alpha_h}{2}\,, \quad \text{and} \quad \phi_h < \Delta\,, \tag{17}$$

where Δ value is reported in the Appendix (and corresponds to the value of Φ computed with $c_2 + \tau$ rather than with c_2 only). These conditions imply a minimum size for the foreign market depending on the domestic market size and on the AD duty. This latter must have for floor value the difference between the two marginal costs it is supposed to remedy. A ceiling value constrains the AD duty, too. It is positively linked with the domestic market size and negatively with the foreign marginal cost. Finally, the degree of substituability has to be sufficiently weak. The maximum degree of substitution increases in the domestic market size and in the domestic marginal cost, but decreases in the AD duty and in the foreign marginal cost.

With the AD duty, the foreign firm's profit on the domestic market becomes:

$$\pi_{2h} = (p_{2h} - (c_2 + \tau))\, x_{2h}\,. \tag{18}$$

The foreign firm's profit function on the domestic market clearly indicates that introducing the AD duty $\tau > 0$ – modeled as a transportation cost in line with Bernhofen (1995)'s paper – contradicts the decrease of c_2 caused by foreign country's subsidies. Therefore, the effects of dumping and AD duties are opposite one another, as Proposition 2 states.

Proposition 2 *Under conditions (17) (i.e. when both firms are active), dumping and antidumping duties have opposite effects on the equilibrium characteristics.*

In other words, the introduction of AD policy always harms consumers and the environment, whereas it protects the domestic firm. Note that AD duties generate tax revenue ($\tau\, x_{2h}$) that should be integrated in the new domestic welfare. Thus, domestic welfare at equilibrium is therefore computed as:

$$W_d^\star = SC_h^\star + \pi_{1h}^\star + \gamma_h E^\star + \tau\, x_{2h}^\star\,. \tag{19}$$

An important issue is the AD duty adequate level. Two different scenarios are explored in this article. In the first scenario, the regulator chooses the adequate AD duty, τ^a, in order to nullify the difference in the prices p_{2h} and p_{2f} observed in the domestic and foreign markets for the foreign good. In the second scenario, the regulator chooses the AD duty τ^* maximizing domestic welfare. In the first scenario, attention is paid to producers only, whereas in the second, the consequences of AD on consumers and on environment are also considered.

Proposition 3 *There exists an unique adequate antidumping duty, τ^a nullifying the difference in prices for the foreign good observed on the domestic and foreign markets, and an unique optimal antidumping duty, $\tau^\star$ that maximizes domestic welfare.*

i) τ^a is always smaller than the difference in the domestic and foreign marginal costs $c_1 - c_2$ and positive in conditions of dumping. When foreign and domestic products are strong substitutes, τ^a must be strong, too.

ii) Both τ^a and $\tau^\star$ are positive functions of dumping.

iii) $\tau^\star$ (respectively τ^a) is a positive (respectively negative) function of c_1, the marginal cost of the domestic producer.

Proposition 3 compares two types of AD policies and gives a normative point of view on the debate over the appropriate AD duty to choose. First, it shows that the strength of AD is clearly linked to the dumping's one, whatever the scenario explored. When the gap between c_1 and c_2 increases because of the reduction in c_2, both $\tau^\star$ and τ^a increase since the foreign dumping is stronger. Second, when this gap is higher because of an increase in c_1 rather than because of a stronger dumping, $\tau^\star$ increases too, whereas τ^a decreases. Therefore, in this latter case, the rise of the optimal AD duty is purely strategic, revealing a protectionist AD. The adequate AD duty behaves differently considering that the loss of domestic intrinsic competitivity obviates the need for AD protection.

3 Feed-in Tariffs and Antidumping as Complements or Substitutes?

The analysis focuses on comparing different policy tools available to countervail the foreign firm's dumping policy. In particular, we want to investigate the impact of FIT programs and study whether they can be used as complement or substitute for AD duties. As showed in the previous section, the AD duties directly impact the amount of solar technologies bought on the domestic market and thus may slow down the production of renewable energy. One means to prevent this negative effect on the environment would be to subsidize the production of renewable energy through FIT programs. This would benefit to the upstream firms too by a 'pass-through effect' (Bougette and Charlier, 2015). Environment and welfare are thus the key elements to be analyzed. The study of different scenarios (FIT and AD chosen simultaneously or sequentially) will then allow us to shed light on the EU–China solar panel dispute.

FIT programs in domestic country ensure renewable electricity producers a higher price than the wholesale market price. Let g denote the difference between the guaranteed price and the market price for a kw/h. We assume that the higher price for green electricity raises renewable electricity producers' willingness-to-pay for solar panels by an amount exactly equal to the difference g. We define the 'unit of solar panels' so that one unit produces exactly one kw/h. Therefore an easy way to introduce FITs in solar panels market is to consider that it raises parameter α_h. Hence, the demands for solar panels on the domestic market are

$$x_{1h} = \frac{(\alpha_h + g)(1-\phi_h) - 2p_{1h} + 2\phi_h p_{2h}}{\beta\,(1-\phi_h^2)} \tag{20}$$

$$x_{2h} = \frac{(\alpha_h + g)(1-\phi_h) - 2p_{2h} + 2\phi_h p_{1h}}{\beta\,(1-\phi_h^2)} \tag{21}$$

Since FIT programs are financed with public funds, it is necessary to introduce the social cost of public funds λ ($\lambda > 0$) when one comes to welfare computation. The cost of the FIT program can be therefore written as $g\ (1+\lambda)\,(x_{1h} + x_{2h})$, and the domestic welfare expression (14) under FIT turns into:

$$W_h - g\ (1+\lambda)\,(x_{1h} + x_{2h})\ . \tag{22}$$

We can now turn to the situation where both AD and FIT programs are implemented. To do so, we first consider the situation where FIT and AD would be decided jointly by an unique agency or two communicating agencies. We then turn to the (realistic) situation where FIT and AD are decided separately by different agencies. The results are found when both firms are active at the equilibrium. For this the conditions (**??**) are modified as the following:

$$\alpha_f > 2c_2\,, \quad \tau < c_1 - c_2\,, \quad c_2 < c_1 < \frac{\alpha_h}{2}\,, \quad \text{and} \quad \phi_h < E\,, \tag{23}$$

where E value is reported in the Appendix.

We first assume that the two agencies communicate and decide jointly of an optimal pair of AD and FIT that maximizes domestic welfare. We can show that this optimal pair of tariffs exists.

Proposition 4 *There exists a unique optimal pair of antidumping duty and FIT rate maximizing domestic welfare.*

This proposition is interesting in substance since it shows that, as FIT and AD on solar panels interact, they should be decided jointly. However, its practical implication is limited since in reality two different agencies are involved in the FIT rate and AD duty determination. For this reason we consider the case where separate agencies decide the level of FIT and AD.

All the characteristics at the equilibrium for this latter case are computed first. For a given AD duty, the positive effects of FIT previously discussed on the demand for solar panels, on the domestic consumers' surplus, on the domestic solar panel producers' profits, and on the environmental benefit can be shown, too. The two king of AD levels discussed earlier are considered: τ^* maximizing the domestic welfare and τ^a nullifying the difference in the foreign price and domestic price for the foreign good. Under conditions (23) the following proposition hold:

Proposition 5 *i) For a given FIT, g, there exists a unique antidumping duty τ^* maximizing domestic welfare, and an unique antidumping duty τ^a pushing the foreign good's price on the domestic market to its foreign level.*

ii) For a given antidumping duty, τ, there exists a unique FIT rate $g^*(\tau)$ maximizing domestic welfare.

iii) The duties τ^* and τ^a respectively increases and decreases in the FIT rate (or in α_h), but both increase in α_f.

iv) The optimal FIT rate is increasing in τ, c_1, and c_2, but decreases in α_f.

v) The optimal FIT rate is increasing in the environmental benefit γ, whereas the optimal AD is decreasing in this variable.

This Proposition 5 clearly states the link existing between the AD trade policy on the one hand, and the FIT energy policy on the other hand. The two policies can be seen as complementary when τ^* is chosen. In this case, a generous FIT allows imposing higher AD duties. In another way, one can consider that an important AD duty has to be compensated by a high FIT to counter the negative effect of the former on domestic welfare. However, if τ^a is chosen, the complementarity disappears and the two policies should be considered as substitutes: the stringency of the one, lessens the other one.

Then, the proposition 5 explores the sensibility of the optimal FIT rate calculated for a given AD duty to the domestic and foreign marginal costs and shows a positive link. When the degradation of the domestic country's competitiveness is due to the raise of the domestic firm's marginal cost c_1, the optimal FIT increases strategically, as the optimal AD duty τ^*, but contrary to τ^a (see Proposition 3). When this competitiveness degradation is due to the decrease of the foreign marginal cost c_2, the domestic country should weaken its FIT policy because of its increasing cost and ease its AD policy, whatever the AD chosen τ^* or τ^a (see Proposition 3).

In the following simulation, we illustrate the relationship between the degree of product substituability and the level of AD that maximizes domestic welfare. One may observe that the more differentiated products are, the higher AD needed but when domestic and foreign products become highly substitute to one another, the agency should decrease the optimal AD.

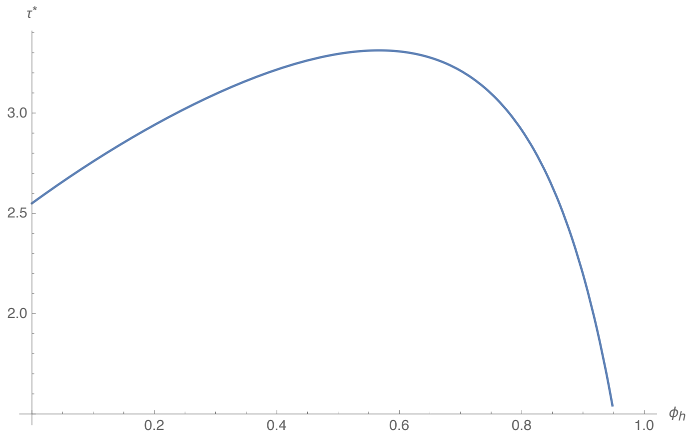

Figure 1: Product substituability and welfare maximizing AD duty ($c_2 = 0.5$, $\alpha_f = 5$, $\lambda = 1.2$, $\beta = 1$, $c_1 = 2$, $\gamma = 23$, $\alpha_h = 16$, and $g = 13$)

4 Discussion

One of the main features of the *EU – China solar panels* dispute is that both dumping and AD duties affect the environment and the development of green energy, i.e. the path to a successful energy transition. To decide the level of AD, the European Commission's investigation focused, as expected, on dumping practice (such as in Proposition 1) and evaluated the normal price for solar panels, putting aside the environmental consequences of dumping and AD duties. The EC's press release entitled "Why the EU's investigation into solar panel imports from China does not harm European climate goals"[12] may acknowledge this pitfall. This paper shows that the negative effects of AD duties should not be disregarded (Proposition 2). In other words, the rise in the price of solar panels that such a trade policy implies may hamper the development of solar energy production in Europe. This has been largely discussed on media,

[12]http://trade.ec.europa.eu/doclib/docs/2012/september/tradoc_149903.pdf

and Proposition 2 establishes formally this result. To go further in exploring the case originality, Proposition 3 provides two types of relevant AD duties. The first AD is the one that makes the foreign firm's prices on domestic and foreign markets equal. We name it the *appropriate* AD duty. The second relevant AD is the one that maximizes domestic social welfare, i.e. the *optimal* AD. Both variants of AD vary in opposite direction when the FIT rises: the optimal AD rises, too, while the appropriate AD decreases. We also provide an *optimal* FIT rate that takes into account a given AD duty. The FIT rate increases with the AD duty showing complementarity between the two policies. Of course, AD duties cannot be the objective of the energy policy *per se*, but the results of Proposition 5 clearly questions the relevance of setting one policy independently from the other. For a more practical point of view, when the EC wants to use AD duties as a trade defense instrument against the Chinese products, both DG TRADE and energy regulatory bodies should interact; setting the level of AD duties in function of the range of European FIT rates. This paper constitutes an attempt to start such a discussion and provide theoretical propositions.

One alternative to AD duties would be to use high-quality standards in solar technologies, no matter where the latter are produced. In addition to quality standards, one could ask also for sustainability standards for any product used to produce electricity in the EU. This would allow European solar manufacturers to compete through quality instead of aggressive prices. In this context, this alternative instrument needs further investigation to fully understand its impact on market characteristics.

Appendix

Unilateral dumping equilibrium characteristics

First order conditions from profits maximization of (8)–(10) give rise to the following three prices at the equilibrium.

$$\begin{aligned}
p^\star_{1h} &= \frac{\alpha_h(1-\phi_h)(2+\phi_h)+4c_1+2\phi_h c_2}{2(2-\phi_h)(2+\phi_h)} \\
p^\star_{2h} &= \frac{\alpha_h(1-\phi_h)(2+\phi_h)+2\phi_h c_1+4c_2}{2(2-\phi_h)(2+\phi_h)} \\
p^\star_{2f} &= \frac{1}{4}(\alpha_f-2c_2)
\end{aligned}$$

We therefore deduce demands of Firm 1 and Firm 2 at the equilibrium.

$$\begin{aligned}
x^\star_{1h} &= \frac{\alpha_h(1-\alpha_h)(2+\alpha_h)-2c_1(2-\phi_h^2)+2\phi_h c_2}{\beta(2-\phi_h)(1-\phi_h)(1+\phi_h)(2+\phi_h)} \\
x^\star_{2h} &= \frac{\alpha_h(1-\alpha_h)(2+\alpha_h)+2\phi_h c_1-2c_2(2-\phi_h^2)}{\beta(2-\phi_h)(1-\phi_h)(1+\phi_h)(2+\phi_h)} \\
x^\star_{2f} &= \frac{\alpha_f+2c_2}{2\beta}
\end{aligned}$$

The value of the upper bound Φ for ϕ in expression (11) has the following form:

$$\Phi = \frac{1}{2(2c_1-\alpha_h)}\left(\alpha_h-2c_2+\sqrt{9\alpha_h^2-32c_1(\alpha_h-c_1)-4c_2(\alpha_h-c_2)}\right).$$

We can calculate that this limit for products substituability is increasing in the domestic market size ($\partial\Phi/\partial\alpha_h > 0$), and in the marginal cost of the foreign firm ($\partial\Phi/\partial c_2 > 0$), whereas it is decreasing in the domestic firm's marginal cost ($\partial\Phi/\partial c_1 < 0$).

We can compute equilibrium profits, which yields to:

$$\begin{aligned}
\pi^\star_{1h} &= \frac{\left(\alpha_h(1-\phi_h)(2+\phi_h)-2c_1(2-\phi_h^2)+2\phi_h c_2\right)^2}{2\beta(1-\phi_h^2)(4-\phi_h^2)^2}, \\
\pi^\star_{2h} &= \frac{\left(\alpha_h(1-\phi_h)(2+\phi_h)+2\phi_h c_1-2c_2(2-\phi_h^2)\right)^2}{2\beta(1-\phi_h^2)(4-\phi_h^2)^2}, \\
\pi^\star_{2f} &= \frac{(\alpha_f-2c_2)^2}{8\beta}.
\end{aligned}$$

$E^\star$, the environmental externality at equilibrium, may be written such as:

$$E^\star = \frac{4\alpha_h+\alpha_f(2-\phi_h)(1+\phi_h)+4c_1+2c_2+(\phi_h^2-\phi_h-4)}{2\beta(2-\phi_h)(1+\phi_h)}.$$

Proof of Proposition 1

Remember that reducing c_2 allows Firm 2 to dump its product on the domestic market. The following derivatives of different equilibrium characteristics with respect to c_2 and their respective signs (computed under the unilateral dumping constraint (16)) demonstrate Proposition 1.

$$\frac{\partial x_{1h}^\star}{\partial c_2} > 0\,, \quad \frac{\partial \pi_{1h}^\star}{\partial c_2} > 0\,, \quad \frac{\partial E^\star}{\partial c_2} < 0\,, \quad \frac{\partial CS_h^\star}{\partial c_2} < 0\,, \quad \frac{\partial \pi_f^\star}{\partial c_2} < 0\,,$$

where $\pi_f^\star$ amounts to the total Firm 2's profit at equilibrium. Finally, the derivative of Firm 2's profit on the domestic market $\frac{\partial \pi_{2h}^\star}{\partial c_2}$ has ambiguous sign. It may be positive or negative under different constraints.

Equilibrium characteristics under AD

With the introduction of parameter τ as the AD duty, the equilibrium characteristics have the new following form:

$$\begin{aligned}
p_{1h}^\star &= \frac{\alpha_h(1-\phi_h)(2+\phi_h) + 4c_1 + 2\phi_h(c_2+\tau)}{2(2-\phi_h)(2+\phi_h)} \\
p_{2h}^\star &= \frac{\alpha_h(1-\phi_h)(2+\phi_h) + 2(\phi_h c_1 + 2\tau) + 4c_2}{2(2-\phi_h)(2+\phi_h)} \\
p_{2f}^\star &= \frac{1}{4}(\alpha_f + 2c_2) \\
x_{1h}^\star &= \frac{\alpha_h(1-\phi_h)(2+\phi_h) - 2c_1(2-\phi_h^2) + 2\phi_h(c_2+\tau)}{\beta(1-\phi_h)(2-\phi_h)(1+\phi_h)(2+\phi_h)} \\
x_{2h}^\star &= \frac{\alpha_h(1-\phi_h)(2+\phi_h) + 2(\phi_h c_1 - \tau(2-\phi_h^2)) - 2c_2(2-\phi_h^2)}{\beta(1-\phi_h)(2-\phi_h)(1+\phi_h)(2+\phi_h)} \\
x_{2f}^\star &= \frac{\alpha_f - 2c_2}{2\beta}
\end{aligned}$$

The value of the upper bound Δ for ϕ in expression (17) has the following form,

$$\Delta = \frac{1}{2(2c_1-\alpha_h)}\left(\alpha_h - 2(c_2+\tau) + \sqrt{9\alpha_h^2 - 32c_1(\alpha_h - c_1) - 4c_2(\alpha_h - (c_2+\tau))}\right)\,.$$

and the dumping condition is revised as:

$$\alpha_f > 2c_2\,, \quad \tau < c_1 - c_2\,, \quad c_2 < c_1 < \frac{\alpha_h}{2}\,, \quad \text{and} \quad \phi_h < \Delta\,,$$

Equilibrium profits with AD are given by:

$$\begin{aligned}
\pi_{1h}^{\star} &= \frac{\left(\alpha_h(\alpha^2+\alpha_h-2)-2c_1(2-\phi_h^2)-2\phi_h(c_2+\tau)\right)^2}{2\beta(4-\phi_h^2)^2(1-\phi_h^2)} \\
\pi_{2h}^{\star} &= \frac{\left(\alpha_h^2(2c_2-\alpha_h+2\tau)+\alpha_h(2-\phi_h)+2\phi_h c_1-4(c_2+\tau)\right)^2}{2\beta(4-\phi_h^2)^2(1-\phi_h^2)} \\
\pi_{2f}^{\star} &= \frac{\left(\alpha_f-2c_2\right)^2}{8\beta}\,.
\end{aligned}$$

Only domestic consumer surplus from eq. (12) is impacted by the AD duty

$$SC_h^{\star} = \frac{\alpha_h(\alpha_h-(c_1+c_2+\tau))}{\beta(2-\phi_h)(1+\phi_h)}\,.$$

$E^{\star}$, the environmental externality at equilibrium, becomes

$$E^{\star} = \frac{4\alpha_h+\alpha_f(1-\phi_h)(2-\phi_h)-4(c_1+\tau)-c_2(\phi_h^2-\phi_h-4)}{2\beta(2-\phi_h)(1+\phi_h)}$$

Proof of Proposition 2

Given the results from Proposition 1, the following derivatives of different equilibrium characteristics with respect to AD duty τ and their respective signs (computed under the unilateral dumping constraint (17) demonstrate Proposition 2.

$$\frac{\partial x_{1h}^{\star}}{\partial\tau}>0\,,\quad \frac{\partial x_{2h}^{\star}}{\partial\tau}>0\,,\quad \frac{\partial \pi_{1h}^{\star}}{\partial\tau}>0\,,\quad \frac{\partial \pi_{2h}^{\star}}{\partial\tau}<0\,,\quad \frac{\partial \pi_{2f}^{\star}}{\partial\tau}>0,\quad \frac{\partial \pi_{2}^{\star}}{\partial\tau}<0,$$
$$\frac{\partial E^{\star}}{\partial\tau}<0\,,\quad \text{and} \quad \frac{\partial SC_h^{\star}}{\partial\tau}<0\,.$$

Proof of Proposition 3

The AD duty nullifying the difference in p_{2h} and p_{2f} is given by:

$$\tau^a = \frac{1}{8}[4(\alpha_f-\alpha_h)+2\phi_h(\alpha_h-2c_1)+\phi_h^2(2\alpha_h-\alpha_f-2c_2)]$$

τ^a is positive (implying that dumping exists and is corrected by AD) if the conditions of dumping hold, and $0<\tau^a\leq c_1-c_2$ with $0<\phi_h\leq\Phi$, or $\underline{\tau}^a<\tau^a\leq c_1-c_2$ with $\phi_h<\Phi<1$, where:

$$\underline{\tau}^a = \frac{4c_1-2(\alpha_h+c_2\phi_h+c_1\phi_h^2)+\alpha_h(\phi_h+\phi_h^2)}{2\phi_h}.$$

Domestic welfare at equilibrium refers to (19). Let us find $\tau^{\star}$ that maximizes the domestic welfare. The maximization program is the following

$$\max_{\tau}\{W_d^{\star}\}\,.$$

The first-order condition gives the following optimal $\tau^\star$.

$$\tau^\star = \frac{\phi_h\left(\alpha_h(1-\phi_h)(2+\phi_h)+\phi_h^2 c_1\right)-\gamma_h(2+\phi_h)^2(2-\alpha_h)-c_2(\phi_h^2-8\phi_h^2+8)}{2(\phi_h^4-7\phi_h^2+8)}\,. \tag{24}$$

The second-order condition is satisfied, ensuring that $\tau^\star$ corresponds to a maximum:

$$\frac{\partial^2 W_d^\star}{\partial \tau^2} = \frac{4(3\phi_h^2-4)}{\beta(4-\phi_h^2)^2(1-\phi_h^2)} < 0\,. \tag{25}$$

To show that the higher foreign dumping, the higher AD must be, one needs to compute the derivative of $\tau^\star$ with respect to Firm 2's marginal cost c_2, which yields to:

$$\frac{\partial \tau^\star}{\partial c_2} = \frac{1}{2}\left(\frac{\phi_h^2}{\phi_h^4-7\phi_h^2+8}-1\right)\,. \tag{26}$$

By definition, product differentiation parameter ϕ_h is between 0 and 1. Therefore, the ratio $\frac{\phi_h^2}{\phi_h^4-7\phi_h^2+8}$ is between 0 and 1, which gives the whole derivative a negative sign. In other words, when c_2 decreases (i.e. the foreign firm dumps), the optimal AD duty must increase.

Proof of Proposition 4

Proposition 4 results from the following maximization program.

$$\max_{g,\tau}\{W_d^\star\}\,,$$

where $W_d^\star$ corresponds to expression (19). We show that there exists a unique equilibrium pair of $(g^\star, \tau^\star)$. The second-order condition are ensured so that the optimal pair corresponds to a maximum of domestic welfare.

Proof of Proposition 5

The value of the upper bound E for ϕ in conditions (23) has the following form:

$$E = \frac{1}{2(2c_1-\alpha_h-g)}\left(\alpha_h+g-2(c_2+\tau)+\sqrt{9(\alpha_h^2+g^2)-32c_1(\alpha_h+g-c_1)-4c_2(\alpha_h+g-(c_2+2\tau))-4(\right.$$

We run the welfare maximization process with the integration of the AD duty denoted τ. Remember that τ impacts positively Firm 2's marginal cost. Following the maximization program

$$\max_{\tau}\{W_d^\star\}\,,$$

the optimal AD duty becomes

$$\begin{aligned}\tau^\star \quad = \quad & \frac{1}{2\,(\phi_h^4 - 7\phi_h^2 + 8)}(g(\phi_h^2 + \phi_h - 2)(\lambda(\phi_h^2 - 4) - \phi_h(1 - \phi_h) - 4) \\ & -8\gamma_h - c_2(\phi_h^2 - 8\phi_h^2 + 8) + \phi_h(\phi_h(c_1\phi_h - \gamma_h(\phi_h^2 + \phi_h - 6) \\ & -\phi_h(\phi_h^2 + \phi_h - 2) + 4\gamma_h)))\end{aligned}$$

The second order condition ensures that $g^\star$ corresponds to a domestic welfare maximum.

$$\frac{\partial^2 W_d^\star}{\partial g^2} = \frac{4\left(\phi_h^4 - 7\phi_h^2 + 8\right)}{\beta(4 - \phi_h^2)^2(\phi_h^2 - 1)} < 0\,.$$

To show that the optimal AD duty always increases with the FIT, one needs to compute the derivative of $\tau^\star$ with respect to g and show its positive sign.

$$\frac{\partial \tau^\star}{\partial g} = \frac{(\phi_h^2 + \phi_h - 2)(-4 - \phi_h(1 - \phi_h) - \lambda(4 - \phi_h^2))}{2(\phi_h^4 - 7\phi_h^2 + 8)} > 0\,. \tag{27}$$

We can compute the appropriate AD duty nullifying the difference between the domestic and foreign prices for the foreign good. We denote it $\tau^a(g)$.

$$\tau^a(g) = \frac{1}{8}\left(\phi_h^2(2(\alpha_h + g) - \alpha_f - 2c_2) + 2\phi_h(\alpha_h + g - 2c_1) - 4(\alpha_h + g - \alpha_f)\right)$$

Finally, the optimal FIT rate for a given AD can be calculated as:

$$g^\star(\tau) = \frac{\phi_h^2(\alpha_h + c_1(2\alpha - 1) + c_2 - 2\lambda(\alpha_h - c_2 - \tau) + 2(\tau + \gamma)) + \phi_h(\alpha_h - 2(c_2 + \tau)) - 2(\alpha_h - 4(\alpha_d\lambda + c_2(2}{(2 + \phi_h)(\phi_h - 4\lambda(2 - \phi_h) - 3)}$$

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