ANTIDUMPING AND FEED-IN TARIFFS AS GOOD BUDDIES? MODELING THE EU-CHINA SOLAR PANEL DISPUTE

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

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Abstract

The paper analyzes the interactions between trade and renewable energy policies based on the EU–China Solar Panel dispute which is the most significant antidumping (AD) complaint in Europe. We build a price competition duopoly model with differentiated products and intra-industry trade in photovoltaic equipment. We provide two relevant types of AD duties. The optimal AD which maximizes social domestic welfare always increases with the feed-in tariff (FIT) program set in the home country. The appropriate AD – equalizing the foreign firm's price on the domestic market with the foreign market price – decreases with the FIT program. We show that the optimal FIT increases with the AD duty. Therefore, trade and renewable energy optimal policies may complement one another. When setting AD duties in clean energy sectors, it is important not to ignore the extent to which 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 from EU solar manufacturers, the European Commission (EC) established that solar cells and solar panels imported from China were being sold at a dumped price that was harming EU solar manufacturers.[1] The EC argued that "unfair trade in solar panels does not help the environment and is not compatible with a healthy global solar industry.[2]" In December 2013, a definitive AD duty was imposed on these products. The measure took the form of an ad valorem duty ranging between 27.3 % and 64.9%.[3] This was not an isolated case: the US introduced the same type of trade protective measures during this period.[4] Voituriez and Wang (2015)'s case study shows that China's support policies were not detailed in the EC's investigation and highlights a series of measures such as corporate tax rebates, or loan offer facilities, suggesting implementation of a strategic trade policy.[5]

In March 2017, following investigations and several periods of partial interim reviews, and in a context of China being denied 'market economy status', the EC decided to retain the AD measure. The European authorities considered that "when balancing the likely negative effects on the upstream and downstream industry as well as the consumers against the benefits which Union industry would derive from the measures, 18 months constitute an appropriate mediation between the competing interests.[6]"

The solar panel case has been widely discussed for several reasons. Major trade players including China and the EU, consider the green energy production equipment industry to be a strategic emerging sector in which trade disputes are inevitable (Voituriez and Wang, 2015). Production of photovoltaic equipment experienced substantial growth during the 2000s, and this coincided with a reduction in the price of solar panels, explained in part by the increasing penetration of lower cost Chinese photovoltaic producers (Pillai, 2015). This growth in photovoltaic products was connected also to public policies.[7] In both the EU and China, the ascendancy of the photovoltaic sector has been fostered by green industry policies. However, these policies are uncoordinated. Broadly,[8] China has chosen to subsidize photovoltaic equipment manufacturers (Chen, 2015; Groba and

[1] Chen (2015) and Voituriez and Wang (2015) provide surveys of this dispute. 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] See the EC's notice `http://trade.ec.europa.eu/doclib/press/index.cfm?id=996`.

[3] Council Implementing Regulation (EU) No 1238/2013 of 2 December 2013 imposing a definitive anti-dumping duty and collecting definitively the provisional duty imposed on imports of crystalline silicon photovoltaic modules and key components (i.e. cells) originating in or consigned from the People's Republic of China (OJ L 325, 5.12.2013).

[4] See Hughes and Meckling (2017).

[5] See Carbaugh and St. Brown (2012) for details of China's industrial policy specifically for the renewable energy sector.

[6] European Commission (2017).

[7] See Pérez de Arce and Sauma (2016) for a theoretical presentation of the main common policies, and see Jenner et al. (2012) for an empirical analysis of the determinants of FIT programs use in the EU.

[8] The facts suggest a more nuanced picture. See e.g. Grau et al. (2012) for a comparison of China and Germany.

Cao, 2015) rather than consumers (i.e., renewable electricity producers), whereas the EU has chosen to subsidize consumers[9] rather than producers. As a consequence, in 2011 China was exporting 90% of its solar panel production and experiencing very low domestic consumption. At that time, the EU had the world's largest installed solar generation capacity, constituted 80% of Chinese products. It was the first export market for Chinese solar manufacturers (Chen, 2015) and the market share of European photovoltaic manufacturers fell progressively.[10] This led to the European photovoltaic manufacturers' complaint against unfair competition, and to the EC's AD (and anti-subsidy) investigations.

This solar dispute is the most significant AD complaint ever investigated by the EC. It took place in a context where widespread AD would seem to question the real motivation for this policy (Blonigen and Prusa, 2016; Zanardi, 2006): a response to dumping practices or simply another form of protection.[11] The solar panel case focuses on strategic trade policies but not exclusively.[12] The renewable energy and environmental stakes are obvious. For instance, subsidizing the photovoltaic sector can be seen as a means to manage the positive knowledge externalities from new technologies developed by infant industries (Jaffe et al., 2005). These new technologies are not trivial since they are technologies for carbon abatement. The fight against global warming, and the promotion of energy transition were vulnerable to how the trade dispute was managed. Consequently, in 2012 the EC felt the need during its AD investigation to argue against the claim that use of AD duties would undermine EU green energy objectives.[13] A side benefit of the EU being able to import cheap solar panels has been the adoption of renewable energy equipment and a reduction in global greenhouse gas (GHG) emissions.

Furthermore, AD duties could be seen as interfering with renewable electricity support programs such as FIT. FIT programs guarantee a price for renewable electricity that is higher than the gross market electricity price, allowing green electricity producers to cope with higher fixed production costs. These subsidy programs also benefit upstream firms (solar panel producers) through a 'pass-through effect' (Bougette and Charlier, 2015). An AD policy could counteract this effect. In other words, the interrelation between FIT and AD policies could be questioned. The novelty of the present paper is that it examines and acknowledges the renewable energy and environmental stakes in the EU–China solar panel trade dispute.

The *EU–China* solar panel dispute has provoked considerable comment but few economic studies. The event study literature has shown a particular interest in the case. In this body of work, the AD measures are considered an external shock whose consequences are studied. Huang et al.

[9]The policy takes the form of feed-in tariffs (FITs) for renewable electricity produced from solar panels, low interest rate loans for solar panel installations, etc. FIT programs existed in China but were underdeveloped and were not unified at the national level until 2011 (Chen, 2015).

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

[11]For a critique of the way AD duties are used, see Konings and Vandenbussche (2008) among others.

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

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

(2016) study the effects of European AD law on the stock prices of Chinese photovoltaic sector firms, and compares them to other AD shocks. They show that stock price synchronization and co-movement (and therefore stock-market volatility) were impacted positively by both EU and the US AD legislation on solar panels. Crowley and Song (2015) develop an event study approach to examine the impact of European AD legislation on the stock market performance of Chinese photovoltaic sector firms. They find that it is the larger, export-oriented firms that have been the most affected, and that firms' exposure depends on their ownership structure. According to Crowley and Song (2015), the largest negative effect of European AD duty is felt by privately owned firms, with state owned firms experiencing only limited adverse effects.

From a more general perspective, dumping and AD duties have been studied extensively in both the theoretical and empirical literature (see, e.g., Blonigen and Prusa (2016)'s survey). These works stress several effects of AD actions such as protection effects (Veugelers and Vandenbussche, 1999), collusive effects (Collie and Le, 2010), and substitutes for tariffs (Dinlersoz and Dogan, 2010), or R&D (Gao and Miyagiwa, 2005). Questions related to the dumping determination and measures, and therefore which type of AD duty to choose are debated in the literature (Sykes, 1996; Blonigen and Prusa, 2016). At the same time, the question of an adequate FIT rate is also debated intensively, from both theoretical and empirical viewpoints (Drechsler et al., 2012; Zhang et al., 2016; Farrell et al., 2017). To our knowledge, there are no theoretical works on the interactions between AD duties and renewable energy support programs. Yet, the possibility of interference between trade and energy policies is an original feature of the dispute that needs to be explored.

In this paper, we consider a price competition duopoly model with differentiated products and intra-industry trade in photovoltaic equipment. We derive the conditions for unilateral dumping by the foreign firm. We show that dumping has a positive impact on the environment by allowing domestic consumers to access renewable energy products cheaper; domestic AD measures reverse this effect. After assessing the environmental stakes of these trade policies, we evaluate the interrelation between FIT and AD. We show that if the FIT rate and the AD duty to be implemented are calculated based on welfare maximization, FIT and AD appear to be complementary policies: the optimal FIT rate increases with the AD duty, and vice versa. Therefore, when setting AD duties in sectors related to clean energy products, the other side, i.e. the extent to which renewable energy is subsidized, needs to be considered. If AD duty is chosen to nullify the dumping margin rather than to maximize domestic welfare, the FIT and AD become substitutes. Investigating the reaction of these two policies to dumping we show that an AD duty reacts positively to higher levels of dumping, while for a given AD duty, the FIT rate decreases with higher levels of dumping. Further, we show that when domestic firms' competitiveness decreases due to a rise in marginal costs, the optimal AD duty reacts strategically, but is accompanied by an higher FIT.

The paper is organized as follows. Section 2 presents a unilateral dumping model, and evaluates the impact of dumping on the other country's welfare incorporating the reduction in an externality created by expansion of electricity produced from photovoltaic sources. The properties of an AD duty are presented in this case. Section 3 explores the interrelation between an FIT program and AD duty, and section 4 concludes and discusses some policy implications from the *EU–China* solar panel dispute.

2 A Unilateral Dumping Model

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 representative 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 Firm 1 and the foreign firm labeled Firm 2. Firm 2 is assumed to be in a monopolist position in its own market, and competing *à la Bertrand* with Firm 1 in the domestic firm's market.

First, we characterize the market equilibrium (2.1), and then analyze the impact of unilateral dumping on market characteristics (2.2). Lastly, we analyze the introduction of AD measures (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 the quantity it produces is x_{2j}. In each market, there is a representative consumer with quasilinear preferences that are described by a quadratic utility function. The utility functions of two representative consumers – one in each market – 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). We assume 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 consumers' budgets in country j are written as

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

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

If the respective utilities are maximized subject to the budget constraints, the demand functions in the j^{th} market are:

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

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

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

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 has a cost advantage ($c_2 < c_1$). The foreign country has an intrinsic comparative advantage in producing the differentiated product, as in Bernhofen (1995).[14]

The first order conditions lead to the equilibrium prices $p^\star_{1h}$, $p^\star_{2h}$, and $p^\star_{2f}$. We then find the equilibrium quantities $x^\star_{1h}$, $x^\star_{2h}$, and $x^\star_{2f}$. All equilibrium characteristics are provided in the appendix. To ensure that firms are active at the equilibrium, requires the assumption 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, and a maximum degree of product substitutability.

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

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

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

We assume that electricity produced from fossil fuel is replaced by renewable electricity, and that 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, which for simplicity we define with an additive form:

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

This improvement to the environment concerns both countries. γE is the external benefit related to the domestic country environment ($\gamma > 0$).

[14] In Bernhofen (1995)'s model, dumping also is not reciprocal. If the foreign firm engages in dumping, the domestic firm will reverse dump.

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

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

2.2 The effects of foreign dumping

At the equilibrium, the foreign firm dumps its product in the domestic market when $p^\star_{2f} > p^\star_{2h}$. In other words, the domestic consumer has to pay less than the foreign consumer for the same product 2. When this inequality is resolved, we obtain the following unilateral dumping condition:

$$\alpha_f > \frac{2(\alpha_h(1-\phi_h)(2+\phi_h) + \phi_h(2c_1 + \phi_h c_2))}{(2-\phi_h)(2+\phi_h)}\,. \tag{15}$$

This condition imposes a minimum foreign market size. This lower bound depends on the domestic market's characteristics as well as the marginal costs of both firms. This minimum size decreases in the domestic market's size, and in the degree of product substitutability. However, it increases with the marginal costs of the two firms. In the rest of the paper, we keep the constraint (15) active in order later to justify the domestic AD policy.

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

Proposition 1 *The foreign dumping policy has the following effects: i) decreases domestic demand for Product 1 and Firm 1's profit, and increases domestic demand for the dumped Product 2; ii) increases in the environmental benefit and in the domestic consumers' surplus; iii) increases the foreign firm's profits, i.e., on both the domestic and foreign markets.*

Note that for given firm and consumer characteristics c_1, α_h, α_f, and ϕ_h, the foreign government can make Firm 2's dumping easier by lowering parameter c_2 using subsidy policies. Hence, Proposition 1 shows that this foreign country's strategic policy achieves 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 that it has an overall positive effect on the domestic welfare.

In the next subsection, we study the impact of an AD action introduced by the domestic country to counteract the foreign firm's dumping policy. Ultimately, what is at stake is the impact on the environment and on welfare which allows us to take account of the energy transition context related to the *EU–China* solar panel dispute.

2.3 The use of antidumping duties

In reaction to the foreign dumping, the domestic country can impose an AD duty denoted τ. The AD duty raises Firm 2's overall marginal cost, i.e. $c_2 + \tau$. 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 a policy is to compensate for the negative effects of the foreign Firm 2's dumping policy on Firm 1's domestic profit (Proposition 1). To ensure that both firms are active at the equilibrium under this new market condition and while the foreign firm dumps, the constraints (11) and (15) are revised as follows:

$$\alpha_f > 2c_2\,, \quad \tau < c_1 - c_2\,, \quad c_2 < c_1 < \frac{\alpha_h}{2}\,, \quad \text{and} \quad \phi_h < \Phi(\tau)\,, \tag{16}$$

where $\Phi(\tau)$ 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 size of the domestic market and on the AD duty. The AD duty must have a ceiling value based on the difference between the two marginal costs it is supposed to remedy. Finally, the degree of substitutability 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:

$$\pi_{2h} = (p_{2h} - (c_2 + \tau))\, x_{2h}\,. \tag{17}$$

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

Proposition 2 *Under conditions of activity, dumping and antidumping duties have opposite effects on the equilibrium characteristics.*

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

$$W_d^\star = CS_h^\star + \pi_{1h}^\star + \gamma_h E^\star + \tau\, x_{2h}^\star\,. \tag{18}$$

One important issue is the adequate level of AD duty. Two different scenarios are explored in this article. In the first scenario, the regulator chooses the adequate AD duty, τ^a, in order to equalize 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 only to producers; in the second scenario, the consequences of AD on consumers and on the environment are considered.

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

i) Optimal anti-dumping duty $\tau^\star$ is positive if the environmental benefit γ is sufficiently small.

ii) Optimal anti-dumping duty $\tau^\star$ is decreasing with the environmental benefit γ.

iii) Both adequate anti-dumping duty τ^a and optimal anti-dumping duty $\tau^\star$ are increasing with dumping.

iv) Optimal anti-dumping duty $\tau^\star$ (respectively adequate anti-dumping duty τ^a) is increasing (respectively decreasing) with the domestic producer's marginal cost c_1.

Proposition 3 compares two types of AD policies and offers a normative point of view to the debate over the appropriate AD duty to choose. First, it shows that only with a sufficiently small solar panel external benefit is AD not welfare-damaging. Above a certain threshold, the reduction in environmental quality following AD predominates, and pushes down the domestic welfare. In this situation, $\tau^\star$ should be zero.[15] In contrast (and by definition), τ^a is always positive under the dumping condition (and therefore can be welfare-decreasing). Second, Proposition 3 shows that the strength of the AD is clearly linked to the strength of the dumping, 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. Third, if this gap is wider due to an increase in c_1 rather than because of more dumping, $\tau^\star$ also increases while τ^a decreases. In this latter case, the rise in optimal AD duty is purely strategic, revealing a protectionist AD at the expense of the amount of renewable energy produced. The adequate AD duty behaves differently and takes into consideration that the loss in domestic competitivity obviates the need for AD protection.

Note that τ^a and $\tau^\star$ are affected differently by domestic and foreign solar panel substituability: τ^a always increases in ϕ_h, while $\tau^\star$ may decrease in the same variable (see simulations Figure 4 in the Appendix). The consequences for the amount of renewable energy produced and the environment are straightforward: An increase in the degree of product substitutability is always detrimental to the environment when the AD duty τ^a is applied but this is not necessarily the case for $\tau^\star$.

The intuition from the above result is as follows. When the level of product substitutability ϕ_h increases, the dumping condition (15) is relaxed since the lower bound for α_f decreases with the parameter ϕ_h. This makes dumping easier, and favors the environment (Proposition 1). At the same time, an increase in ϕ_h systematically increases the AD duty τ^a which is not environment-friendly (Proposition 2). The impact on $\tau^\star$ is ambiguous. Ultimately, the net effect of an increase in ϕ_h is negative for the environment when τ^a is applied ($E(\tau^a)$ decreases with ϕ_h), and is ambiguous with $\tau^\star$. In the latter case, the net effect depends especially on γ, the external benefit from solar panel development, as shown by the numerical simulations presented in figures 1 and 2 in the appendix. Furthermore, these figures show that to achieve the highest impact on the environment when developing solar panels, it is necessary to consider using the adequate AD duty if the external benefit is relatively low (figure 1) and the optimal AD duty if the external benefit is relatively high (Figure 2).

[15]Note that as expected, the optimal AD decreases with the solar panel external benefit γ.

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

The analysis focuses on the interrelations between trade (AD) policy and renewable energy policy (FIT). In particular, we investigate the impact of FIT programs, and whether they can be used as complements or substitutes for AD duties. As shown in the previous section, AD duties have a direct impact on the amount of solar technologies bought on the domestic market, and thus, may slow production of renewable energy. One way to prevent this negative effect on the environment would be to subsidize the production of renewable energy through a FIT program. Environment and welfare are the key elements analyzed.

Let g denote the difference between the guaranteed price from the FIT 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 a 'unit of solar panels' so that 1 unit produces exactly 1 kw/h. Therefore, an easy way to introduce FIT in solar panels market is to consider that it raises parameter α_h. Hence, demand for solar panels on the domestic market becomes

$$x_{1h} = \frac{(\alpha_h + g)(1-\phi_h) - 2p_{1h} + 2\phi_h p_{2h}}{\beta\,(1-\phi_h^2)} \tag{19}$$

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

Since FIT programs are financed by public money, it is necessary to introduce the social cost of public funding ($\lambda > 0$) in the welfare computation. Therefore, the cost of FIT programs can be written as $g\ (1+\lambda)\,(x_{1h} + x_{2h})$, and the domestic welfare expression (14) under FIT becomes:

$$W_h - g\ (1+\lambda)\,(x_{1h} + x_{2h})\ . \tag{21}$$

We now turn to the situation where both AD and FIT programs are implemented. The results refer to both firms active at the equilibrium. The conditions (16) are modified as follows:

$$\alpha_f > 2c_2\,, \quad \tau < c_1 - c_2\,, \quad c_2 < c_1 < \frac{\alpha_h}{2}\,, \quad \text{and} \quad \phi_h < \Phi(\tau, g)\,, \tag{22}$$

where $\Phi(\tau, g)$ value is reported in the appendix.

We consider the realistic case where separate agencies decide the levels of the FIT and AD duty. First, all the characteristics at the equilibrium are computed. For a given AD duty, the previously discussed positive effects of FIT 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. The two types of AD discussed earlier are considered: τ^* maximizing the domestic welfare, and τ^a nullifying the dumping margin. Under conditions (22) the following new proposition and corollary hold.

Proposition 4 *For a given antidumping duty, τ, there exists a unique FIT rate $g^*(\tau)$ that maximizes domestic welfare.*

i) The optimal FIT rate is increasing in the AD duty.

ii) The optimal FIT rate is increasing in the environmental benefit γ, and in the two firms' marginal costs c_1 and c_2.

Corollary 1 *FIT and AD policies are complementary (resp. substitutes) when the optimal (resp. adequate) AD duty is used.*

Proposition 4 and corollary 1 show the clear link between the AD trade policy on the one hand, and the FIT energy policy on the other hand. The two policies can be considered complementary if $\tau^\star$ is chosen. In this case, a generous FIT allows the imposition of a higher AD duty. Alternatively, it might be considered that a high AD duty should be compensated by a high FIT to counter the negative effect of the former on the environment, and on the domestic welfare more generally. However, if τ^a is chosen, the complementarity disappears and the two policies should be considered substitutes: a high FIT rate (raising p_{2h}^*) lowers the adequate AD duty (depicted in figure 3 in the appendix).

Proposition 4 explores the sensitivity of the optimal FIT rate computed for a given AD duty to the same variables, and in each case shows a positive link. When the degradation of the domestic country's competitiveness is due to the rise in the domestic firm's marginal cost c_1, the optimal FIT increases as the optimal AD duty $\tau^\star$ but in contrast to τ^a (see Proposition 3). When this reduction in competitiveness is due to a decrease in the foreign marginal cost c_2, the domestic country should weaken its FIT policy (which is less important in this context), and should ease its AD policy, whatever the AD chosen τ^* or τ^a (see Proposition 3).

By definition, the AD duty τ^a is not affected by the marginal environmental benefit γ in contrast to $\tau^\star$ and $g^\star$. As expected, $g^\star$ is increasing in γ while $\tau^\star$ is decreasing in γ (see figure 5 in the appendix).

Finally, note that if AD and FIT were to be decided jointly by a single agency or two agencies operating in a network, an optimal AD and FIT pair that maximized domestic welfare would exist. This result is interesting in substance since it shows that since FIT and AD on solar panels interact, they should be decided jointly (see figure 6 in the appendix for a numerical illustration). However, its practical implication is limited since in practice, two different agencies are involved in determining the FIT rate and the AD duty.

4 Discussion

Can we inflict AD duties on pollution abatement technologies and ignore their environmental dimension? The paper addresses this issue with the help of a model applied to the *EU–China solar panels* dispute. This study shows that one of the main features of this case 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. Yet, in order to decide the level of AD, the EC's investigation focused as expected, on dumping practice (such as in Proposition 1) and evaluated the normal price for solar panels, leaving 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"[16] acknowledges this shortcoming. Our results show 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 discussed widely by the media, and Proposition 2 formally states this result. However, these results were derived in the static context chosen for the model. It does not include the dynamic effects of both dumping and AD duty might have via the incentives to invest in R&D which could mitigate these conclusions.

More interesting in the static context selected, we explore the issue of the interrelation between energy and trade policies. In its decision to maintain AD duty on solar panels, the EC points that "there has been a boom in solar installation demand in the years 2010 to 2013 driven, in certain Members States, by a mismatch between FIT set at a level of a fair module price and the overall level of prices driven by unfairly dumped Chinese modules" (European Commission, 2017). This "mismatch" clearly expresses the interference that Chinese dumping might impose in setting the FIT. Therefore, once the AD duty is decided, how FIT and AD duty interact should be investigated too. We explored this issue by addressing two related points: the debated question over the appropriate AD duty,[17] and the original question about the links between AD duty and FIT.

On the first point, Proposition 3 provides two types of relevant AD duties. The first equalizes the foreign firm's prices on the domestic and foreign markets. We describe it as the *appropriate* AD duty. The second maximizes domestic social welfare, i.e., the *optimal* AD duty. Both types of AD behave in the same way if foreign dumping increases. However, in the case of reduced domestic competitiveness, only the optimal AD reacts strategically, with associated negative consequences for the environment.

On the second point, Proposition 4 shows that both AD duty variants considered act in opposite directions to a rise in the FIT: the optimal AD duty also rises while the appropriate AD duty decreases. Therefore, depending on the type of AD duty chosen, environmental policy (i.e. the FIT) and trade policy (i.e. the AD duty) can be seen as complements or substitutes. When these policies are complementary, they have contradictory effects on renewable energy production and on the environment: a rise in the FIT is beneficial to the environment but an accompanying increase in AD duty is detrimental to the environment. This contradictory effect disappears if the appropriate AD duty is chosen. The indirect effect of FIT leads to a rise in the price of foreign

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

[17] See, e.g., Sykes (1996).

solar panels in the domestic market, and thus, automatically diminishes dumping and the need for an appropriate AD duty.

We also propose an *optimal* FIT rate that takes account of a given AD duty. The FIT rate increases with the AD duty revealing complementarity between the two policies. The results of this work clearly question the relevance of setting one policy independently of the other. From a more practical point of view, if the EC wants to use AD duties as a trade protection instrument against Chinese products, both DG TRADE and the energy regulatory bodies should interact, and should set AD duty levels as a function of the range of European FIT rates. This paper constitutes an attempt to prompt discussion of this issue, and to provide some theoretical propositions.

An alternative to an AD duty would be to subsidize the domestic solar panel producer in response to the foreign subsidy. We can show that this subsidy s would decrease the domestic marginal cost c_1. Clearly, this subsidy increases the equilibrium quantity of domestic product sold and the domestic profit, and decreases the domestic price. Thus, it favors the environment unambiguously. However, an optimal subsidy rate exists since the subsidy program would have the following weight in the domestic welfare: $s_1 x_{1h}(1+\lambda)$. The choice between AD duty and subsidy should be driven by a comparison of the welfare under these two different policies. However, neither policy systematically outperforms the other on this criterion. The simulations in the appendix figure 7 and figure 8 show that for a high value of the marginal external benefit *gamma* the domestic regulator should always prefer an optimal AD duty τ^* (i.e. whatever the extent of the dumping), whereas if γ becomes small, the regulator should choose the AD duty to counter low levels of dumping, or the subsidy to penalize high levels of dumping.

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Appendix

Unilateral dumping equilibrium characteristics

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

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

We can deduce Firm 1's and Firm 2's demands at the equilibrium.

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

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

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

It can be shown that the upper bound Φ is increasing in the size of the domestic market ($\partial\Phi/\partial\alpha_h > 0$), and in the foreign firm's marginal cost ($\partial\Phi/\partial c_2 > 0$), and is decreasing in the domestic firm's marginal cost ($\partial\Phi/\partial c_1 < 0$).

We can compute the equilibrium profits as:

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

$E^{\star}$, the environmental externality at equilibrium, can be written 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 foreign Firm 2 to dump its product in the domestic market. The following derivatives of the different equilibrium characteristics with respect to c_2 and their respective signs computed under the unilateral foreign dumping constraint (15) demonstrate Proposition 1.

$$\frac{\partial x_{1h}^{\star}}{\partial c_2} > 0, \quad \frac{\partial \pi_{1h}^{\star}}{\partial c_2} > 0, \quad \frac{\partial x_{2h}^{\star}}{\partial c_2} < 0, \quad \frac{\partial E^{\star}}{\partial c_2} < 0, \quad \frac{\partial CS_h^{\star}}{\partial c_2} < 0, \quad \frac{\partial \pi_{2h}^{\star}}{\partial c_2} < 0, \quad \frac{\partial \pi_{2f}^{\star}}{\partial c_2} < 0.$$

Equilibrium characteristics under AD

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

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

The value of the upper bound $\Phi(\tau)$ for ϕ in expression (16) has the form:

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

and the dumping condition is revised as:

$$\alpha_f>2c_2\,,\quad \tau<c_1-c_2\,,\quad c_2<c_1<\frac{\alpha_h}{2}\,,\quad \text{and}\quad \phi_h<\Phi(\tau)\,.$$

Equilibrium profits with AD duty are given by:

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

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

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

$E^{\star}$, 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 derivations of different equilibrium characteristics with respect to the AD duty τ and their respective signs (computed under the unilateral dumping constraint (16)) demonstrate Proposition 2.

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

Proof of Proposition 3

Under the foreign dumping condition, the adequate AD duty that equalizes p_{2h} and p_{2f} is given by the expression

$$\tau^a = \frac{1}{8}[4(\alpha_f - \alpha_h) + 2\phi_h(\alpha_h - 2c_1) + \phi_h^2(2\alpha_h - \alpha_f - 2c_2)]\,. \tag{23}$$

τ^a is positive if by definition the dumping condition holds and also $0 < \tau^a \leq c_1 - c_2$ with $0 < \phi_h \leq \Phi$, or $\underline{\tau}^a < \tau^a \leq c_1 - c_2$ with $\phi_h < \Phi < 1$, where

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

Regarding the optimal AD duty, requires us to know the domestic welfare at equilibrium (18). Let us find $\tau^\star$ that maximizes the domestic welfare. The maximization program is the following:

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

The first order conditions give 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:

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

i) The non-negativity constraint ($\tau^\star > 0$) leads to the upper bound parameter $\bar{\gamma}$ as follows:

$$\bar{\gamma} = \frac{\phi_h(\phi_h^2 c_1 - \alpha_h(\phi_h^2 + \phi_h - 2)) - c_2(\phi_h^4 - 8\phi_h^2 + 8)}{(\phi_h + 2)(\phi_h^2 - 3\phi_h + 2)}\,.$$

ii) The derivation $\frac{\partial \tau^\star}{\partial \gamma}$ is always positive under the dumping conditions, showing that optimal anti-dumping duty $\tau^\star$ is always decreasing with the environmental benefit.

iii) To show that the higher the level of foreign dumping, the higher must be the optimal AD duty requires compution of the derivation of $\tau^\star$ with respect to Firm 2's marginal cost c_2, which yields:

$$\frac{\partial \tau^\star}{\partial c_2} = \frac{1}{2}\left(\frac{\phi_h^2}{\phi_h^4 - 7\phi_h^2 + 8} - 1\right) < 0\,.$$

By definition, the product differentiation parameter ϕ_h varies 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 imposes a negative sign on the whole derivation. In other words, when c_2 decreases (i.e. the foreign firm dumps), the optimal AD duty must increase.

To show that the adequate anti-dumping duty τ^a is also increasing with the dumping, the derivation of τ^a with respect to c_2 is always negative ($\frac{\partial \tau^a}{\partial c_2} = -\frac{\phi_h^2}{4} < 0$).

iv) With respect to c_1, the following derivations can be computed with their respective signs.

$$\frac{\partial \tau^\star}{\partial c_1} = \frac{\phi_h^3}{2(\phi_h^4 - 7\phi_h^2 + 8)} > 0 \quad \text{and} \quad \frac{\partial \tau^a}{\partial c_1} = -\frac{\phi_h}{2} < 0\,.$$

Proof of Proposition 4

i) We now solve the following program $\max_g\{W_d^\star\}$. Second order conditions are satisfied. Thus, the optimal FIT rate for a given AD has the following form:

$$\begin{aligned} g^\star(\tau) \quad = \quad & \frac{1}{(2+\phi_h)(\phi_h - 4\lambda(2-\phi_h)-3)}(\phi_h^2(\alpha_h + c_1(2\alpha - 1) + c_2 \\ & -2\lambda(\alpha_h - c_2 - \tau) + 2(\tau+\gamma)) + \phi_h(\alpha_h - 2(c_2+\tau)) \\ & -2(\alpha_h - 4(\alpha_d\lambda + c_2(2+4\lambda) + 4(\lambda(c_1+\tau)+\tau+\gamma)))) \end{aligned} \tag{25}$$

ii) The signs of the following derivations are not ambiguous under the activity and dumping constraints:

$$\frac{\partial g^\star}{\partial \gamma} > 0\,, \quad \frac{\partial g^\star}{\partial c_1} > 0\,, \quad \text{and} \quad \frac{\partial g^\star}{\partial c_2} > 0\,.$$

Proof of Corollary 1

To do this, we first compute the derivation of the adequate AD duty with respect to the FIT rate g.

$$\frac{\partial \tau^a}{\partial g} = \frac{1}{4}\left(\phi_h^2 + \phi_h - 2\right) < 0\,.$$

The higher the FIT rate, the lower the adequate AD duty. We then compute the derivation of τ^* given in (24) with respect to $\alpha - h$

$$\frac{\partial \tau^*}{\partial \alpha_h} = \frac{\phi_h\left(-\phi_h^2 - \phi_h + 2\right)}{2\left(\phi_h^4 - 7\phi_h^2 + 8\right)} > 0\,.$$

The higher the FIT rate, the higher the optimal AD duty.

Numerical simulations

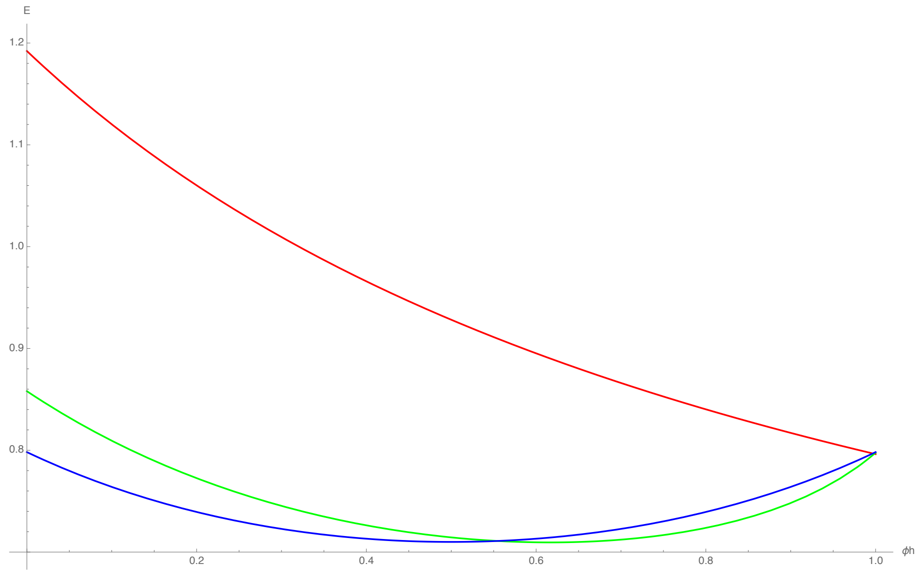

Figure 1: The evolution of the environment as a function of domestic product substitutability

(Red: Adequate AD; Green: Optimal AD; Blue: No AD)

($\alpha_h = 67$, $\alpha_f = 35/43$, $\beta = 84$, $c_1 = 1/4$, $c_2 = 22/405$, $\gamma = 10$)

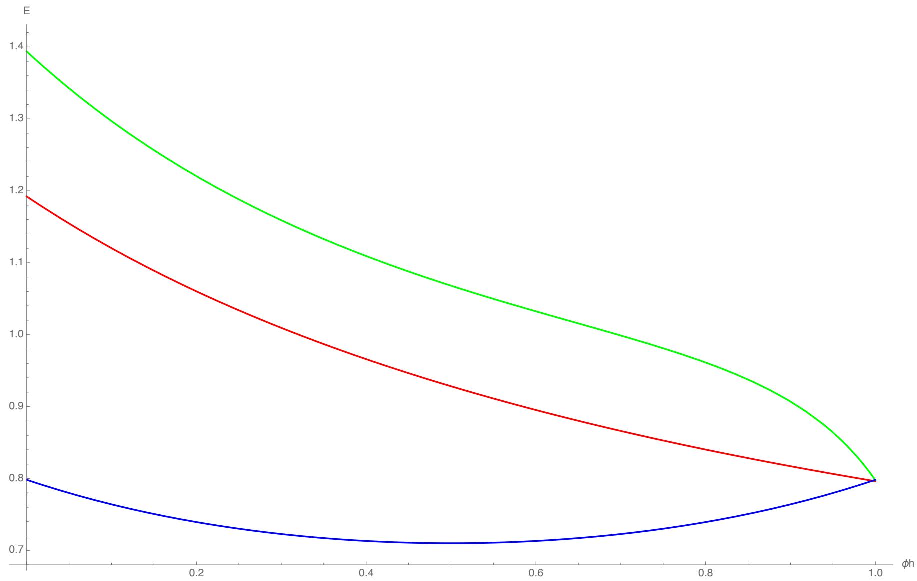

Figure 2: The evolution of the environment as a function of domestic product substitutability

(Red: Adequate AD; Green: Optimal AD; Blue: No AD)

($\alpha_h = 67$, $\alpha_f = 35/43$, $\beta = 84$, $c_1 = 1/4$, $c_2 = 22/405$, $\gamma = 100$)

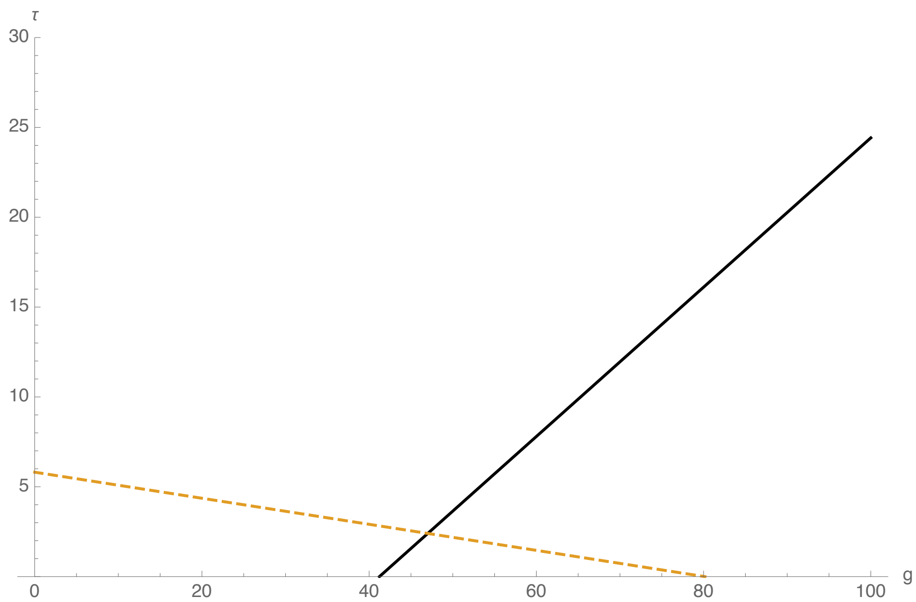

Figure 3: The evolution of the AD duty as a function of the FIT rate

(Plain: Optimal AD; Dashed: Adequate AD)

($\alpha_h = 84$, $\alpha_f = 202/3$, $\beta = 29$, $c_1 = 139/6$, $c_2 = 67/3$, $\lambda = 1.2$, and $\gamma = 100$)

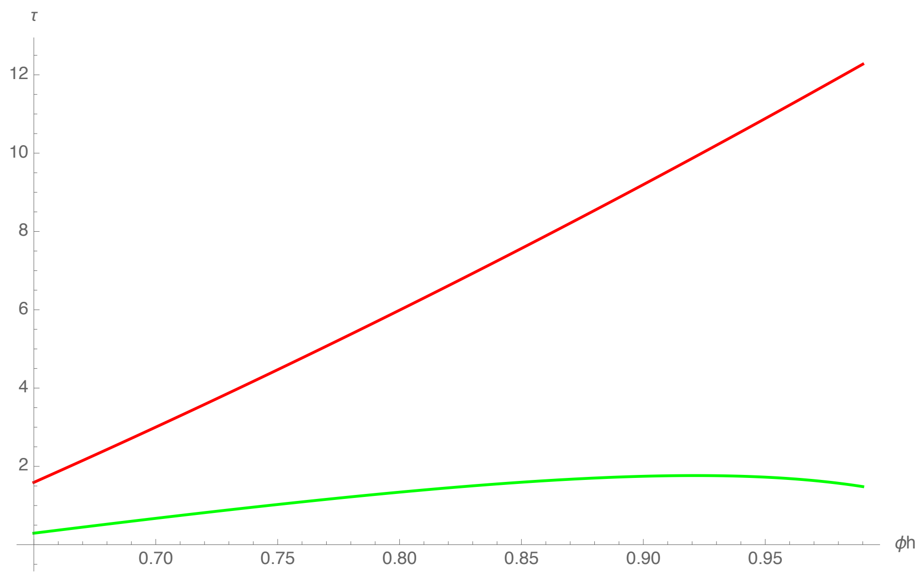

Figure 4: The evolution of the AD duty as a function of domestic product substitutability

(Red: adequate; Green: optimal))

($\alpha_h = 67$, $\alpha_f = 87/2$, $\beta = 84$, $c_1 = 27/4$, $c_2 = 5/4$, and $\tau = 11/2$, and $\gamma = 10$)

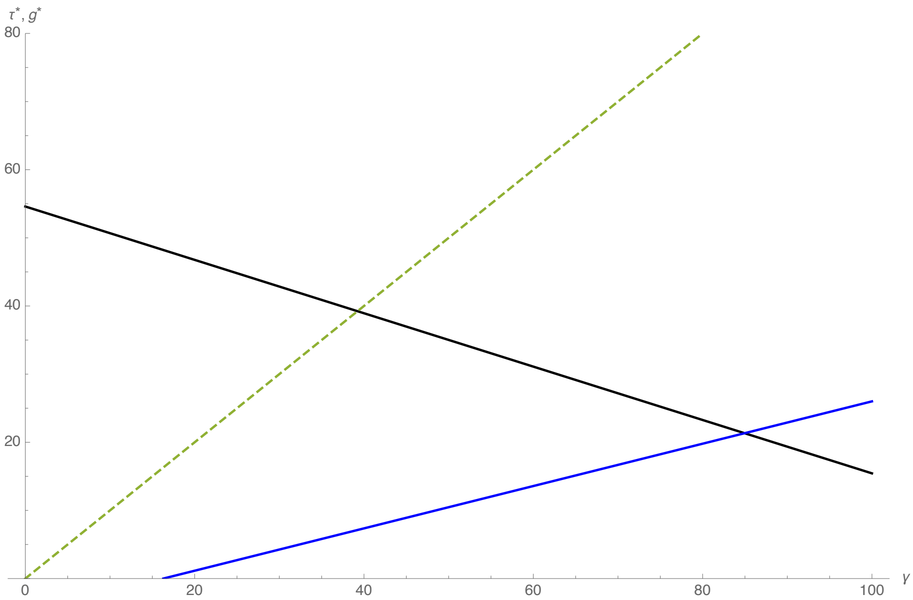

Figure 5: The evolution of the AD duty and FIT rate as a function of the environment

(Black: AD; Blue: FIT, Dashed: γ)

($\alpha_h = 84$, $\alpha_f = 202/3$, $\beta = 29$, $c_1 = 139/6$, $c_2 = 67/3$, and $\lambda = 1.2$)

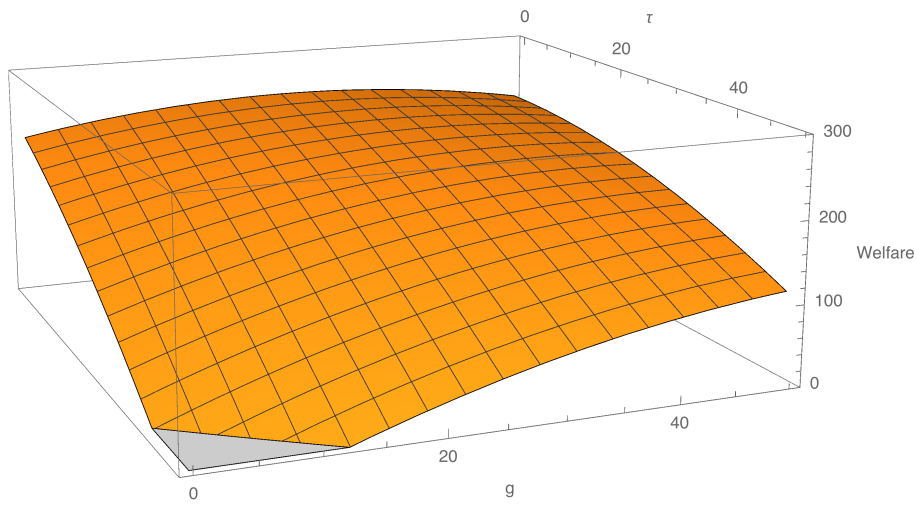

Figure 6: The evolution of the domestic welfare as a function of the FIT rate and the AD duty

($\alpha_h = 84$, $\alpha_f = 202/3$, $\beta = 29$, $c_1 = 139/6$, $c_2 = 67/3$, $\lambda = 1.2$, and $\gamma = 100$)

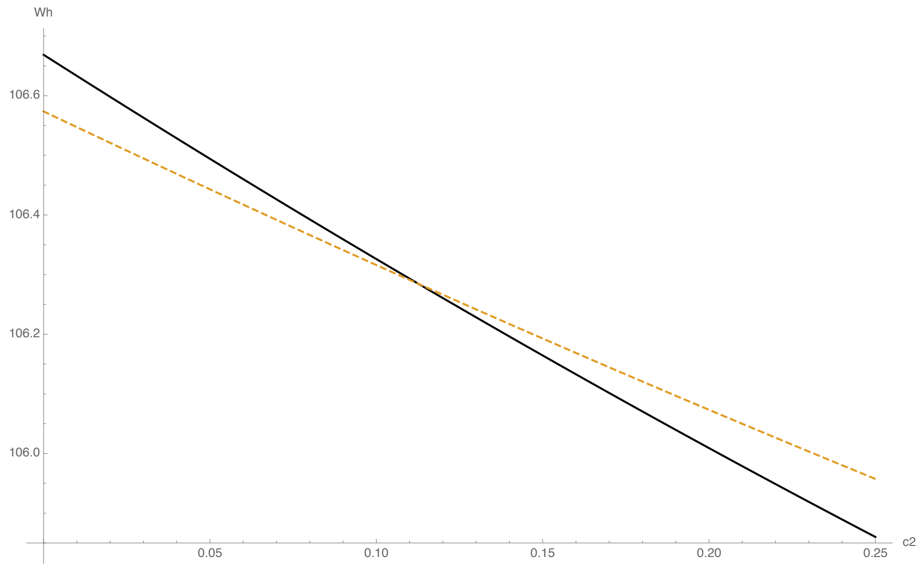

Figure 7: The evolution of the domestic welfare as a function of dumping with AD duty or subsidy

(Dashed: AD; Plain: subsidy)

($\alpha_h = 67$, $\alpha_f = 35/43$, $\beta = 84$, $c_1 = 1/4$, $c_2 = 43781/43869$, $\lambda = 1.2$, and $\gamma = 1$)

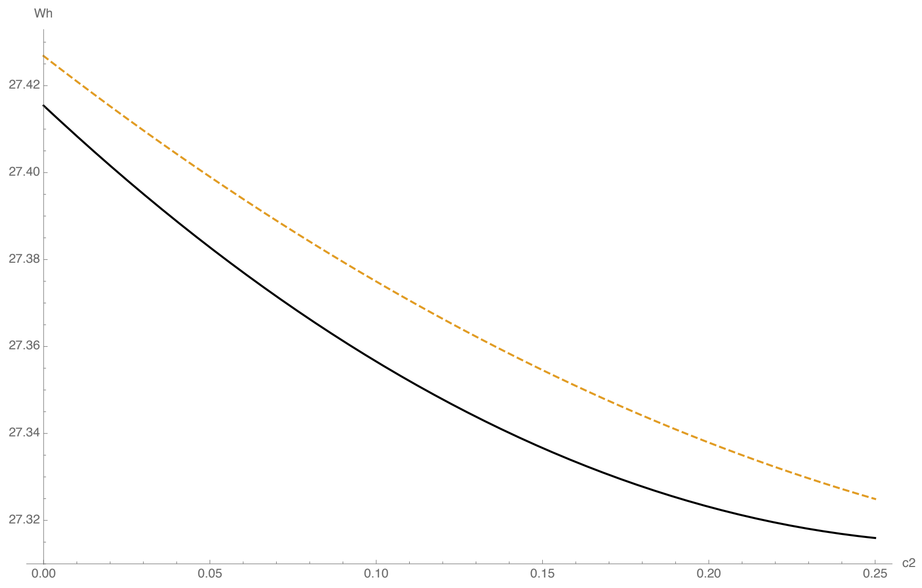

Figure 8: The evolution of the domestic welfare as a function of dumping with AD duty or subsidy

(Dashed: AD; Plain: subsidy)

($\alpha_h = 67$, $\alpha_f = 35/43$, $\beta = 84$, $c_1 = 1/4$, $c_2 = 43781/43869$, $\lambda = 1.2$, and $\gamma = 10$)

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