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

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Abstract

The paper aims at analyzing the interactions between trade and renewable energy policies based on the EU–China Solar Panel dispute that constitutes the most significant antidumping (AD) complaint in Europe. To do so, we build a price competition duopoly model with differentiated products and intra-industry trade of photovoltaic equipment. We provide two relevant types of AD duties. The optimal AD maximizing 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 to the foreign market one – decreases with the FIT program. Furthermore, we show that the optimal FIT increases with the AD duty. Trade and renewable energy optimal policies do therefore complement each other. When setting AD duties in clean energy sectors, 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] 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 anti-dumping duty was imposed on these products. The measures took the form of an ad valorem duty ranging between 27.3 % and 64.9%.[3] The case was not isolated since the US took the same type of trade protective measures during this period.[4] 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[5] suggesting the implementation of a strategic trade policy.

In March 2017, following investigations, several periods of partial interim reviews, and in the context where the 'market economy status' was denied to China, the EC decided that the anti-dumping measures should be maintained. 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, 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. During this period, the reduction in the price of solar panels is observed too, and is partly explained by the increasing penetration of Chinese lower cost photovoltaic producers (Pillai, 2015). This growth was connected with public policies.[7] 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,[8] China authorities have chosen to subsidy photovoltaic equipment manufacturers (Chen,

[1] Chen (2015) and Voituriez and Wang (2015) survey the 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] Among others, 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.

[6] European Commission (2017).

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

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

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

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, 2016; Zanardi, 2006).[11] The solar panel case concerns 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 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, in 2012 the EC felt necessary during its AD investigation to argue against the claim that the use of AD duties would undermine the EU green energy objectives.[13] A side benefit of the EU being able to import cheap solar panels is the adoption of renewable energy equipment and the reduction of global GHG emissions.

Furthermore, AD duties 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 actually this effect. Turning things differently, one can also question the interrelation between FIT and AD policies. The originality of the paper is precisely to tackle these issues where the renewable energy and environmental stakes of the trade dispute are 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

Germany.

[9]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. FIT programs existed in China but were underdeveloped and 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 using AD duties, 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`

of which are studied. Huang et al. (2016) study the effects of the European AD on stock prices of 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 (2016)'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). Interestingly, the question of the dumping determination and measure, and therefore of the right AD duty to choose is debated in the literature (Sykes, 1996; Blonigen and Prusa, 2016). At the same time, the question of the adequate FIT rate is an intensely debated issue too, from both a theoretical and empirical points of view (Drechsler et al., 2012; Zhang et al., 2016; Farrell et al., 2017). To our knowledge, no theoretical works study the interactions between AD duties and renewable energy support programs. Yet, the possibility of interferences between trade and energy policies 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 interrelation between FIT and AD. We show that when welfare maximization is used to calculate the FIT rate and the AD duty that should be implemented, FIT and AD appear as complementary policies: the optimal FIT rate increases in the AD duty and vice versa. Therefore, 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. Besides, when AD duty is chosen to nullify the dumping margin rather than to maximize the domestic welfare, FIT and AD are no longer complementary but become substitute. Investigating the reaction of the two policies to dumping we show that AD duty reacts positively to a higher dumping, whereas for a given AD, the FIT rate decreases in the same context. Furthermore, when the degradation of the domestic firm's competitiveness is due to a rise of its marginal cost, we show that both optimal FIT and optimal AD react strategically.

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 properties of AD are then presented in this case. In Section 3, the interrelation between the FIT program and AD is explored. 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 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 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 quantity 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 functions of two representative consumers in both markets are:

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

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

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 consumers' budgets in country j are written as

$$R_h = x_{1h} p_{1h} + x_{2h} p_{2h} + z_h \quad (3)$$

$$R_f = x_{2f} p_{2f} + z_f, \quad (4)$$

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

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

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

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

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 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).[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 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:

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

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

We assume that 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. We denote γE the external benefit related to the environment for the domestic country $(\gamma > 0)$.

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

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

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

2.2 The effects of foreign dumping

At the equilibrium, the foreign firm dumps its product into 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 one resolves this inequality, we get the following unilateral dumping condition:

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

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 (15) 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) a decrease in the domestic demand for Product 1 and Firm 1's profit and an increase of the domestic demand for the dumped Product 2; ii) an increase in the environmental benefit and in the domestic consumers' surplus; iii) an increase in the foreign firm's profits, i.e. both on the domestic and foreign markets.*

Note that for given firms and consumers' 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 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.

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 on 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 denoted τ. The AD is conceived as rising 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 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 (15) are revised as the following:

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

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. 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:

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

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 activity conditions, 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 expression of domestic welfare. Thus, domestic welfare at equilibrium is computed as:

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

An 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 to producers only, whereas in the second, the consequences of AD on consumers and on the environment are also 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 gives a normative point of view on the debate over the appropriate AD duty to choose. First, it shows that AD is not welfare-damaging only with a sufficiently small solar panels' external benefit. Above a certain threshold, the reduction of the environment following AD predominates and pushes down the domestic welfare. In this situation $\tau^\star$ should be zero.[15] On the contrary (and by definition), τ^a is always positive under the dumping condition (and can therefore be welfare-decreasing). Second, Proposition 3 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. Third, 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, at the expense of the amount of renewable energy produced. The adequate AD duty behaves differently considering that the loss of domestic intrinsic competitivity obviates the need for AD protection.

Note that τ^a and $\tau^\star$ are impacted differently by domestic and foreign solar panels' substituability: τ^a always increases in ϕ_h, whereas $\tau^\star$ may decrease in the same variable (see simulations Figure 4 in the Appendix). The consequences on the amount of renewable energy and environment are straightforward: An increase in the degree of products' substituability is always detrimental to the environment when the AD duty τ^a is used, whereas it is not necessarily the case when using $\tau^\star$.

The intuition of the result above is the following. When the degree of products' substituability ϕ_h increases, the dumping condition (15) is relaxed since the lower bound for α_f decreases with 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. In the end, the net effect of an increase of ϕ_h is negative for the environment when τ^a is used ($E(\tau^a)$ decreases with ϕ_h), and is ambiguous with $\tau^\star$. In the latter case, the net effect depends especially on γ, the external benefit of solar panels development, as shown by the numerical simulations presented in Figures 1 and 2 in the Appendix. Furthermore, these figures show that in order to get the highest impact on the environment when developing solar panels, one should consider the use of the adequate AD duty when the external benefit is relatively low (Figure 1) and of the optimal AD duty when the external benefit is relatively strong (Figure 2).

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

3 Feed-in Tariffs and Antidumping Duties as Complement or Substitute?

The analysis focuses on the interrelations between trade policy (AD) and renewable energy policy (FIT). In particular, we 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. Environment and welfare are the key elements to be 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 the 'unit of solar panels' so that one unit produces exactly one kw/h. Therefore an easy way to introduce FIT in solar panels market is to consider that it raises parameter α_h. Hence, the demands for solar panels on the domestic market become

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

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

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

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

We can now turn to the situation where both AD and FIT programs are implemented. The results are found when both firms are active at the equilibrium. To do so, the conditions (16) are modified as the following:

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

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

We consider the realistic case where separate agencies decide the level of FIT and AD. All the characteristics at the equilibrium 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 types of AD levels discussed earlier are considered: τ^* maximizing the domestic welfare and τ^a nullifying the dumping margin. Under conditions (22) the new following proposition and corollary hold.

Proposition 4 *For a given antidumping duty, τ, there exists a unique FIT rate $g^*(\tau)$ maximizing 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. substitute) when optimal (resp. adequate) AD duty is used.*

Proposition 4 and Corollary 1 clearly state the link existing between the AD trade policy on the one hand, and the FIT energy policy on the other hand. The two policies may be seen as complementary when $\tau^\star$ 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 the environment, and more generally on the domestic welfare. However, if τ^a is chosen, the complementarity disappears and the two policies should be considered as substitute: a high FIT rate (raising p^*_{2h}) lowers the adequate AD duty (illustration is given in Figure 3 in the Appendix).

The properties on the sensibility of τ^* and τ^a to c_1, c_2, and γ, found in Proposition 3, hold when FIT is implemented together with AD. Proposition 4 explores the sensibility of the optimal FIT rate computed for a given AD duty to the same variables and shows in each case 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 $\tau^\star$, 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 (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 impacted by the marginal environmental benefit γ contrary to $\tau^\star$ and $g^\star$. As expected, $g^\star$ is increasing in γ whereas $\tau^\star$ is decreasing in the same variable (illustration is given in Figure 5 in the Appendix).

Note finally, that if AD and FIT were to be decided jointly by a single agency or two agencies operating in a network, an optimal pair of AD and FIT that maximizes domestic welfare would exist. This result is interesting in substance since it shows that, as 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 the determination of the FIT rate and the AD duty.

4 Discussion

Can we inflict AD duties on pollution abatement technologies ignoring their environmental dimension? The paper addresses this issue with the help of a model highlighting the *EU–China solar panels* dispute. The present work 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, 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"[16] may acknowledge this pitfall. 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 largely discussed on media, and Proposition 2 establishes formally this result. However, these results are derived in the static context chosen for the model. Dynamic effects that both dumping and AD may have through the incentives to invest in R&D are absent and may 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 of maintaining AD 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 may have with the setting of FIT. As soon as AD is decided, the question of the interaction of FIT and AD should be questioned, too. We explore this issue, addressing two related points: the debated[17] question over the right AD to choose, and the original one over the links existing between AD and FIT.

On the first point, 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 types of AD behave the same way when the foreign dumping is exacerbated. However, facing the loss of domestic competitivity, only the optimal AD reacts strategically, with negative associated consequences on the environment.

On the second point, Proposition 4 shows that both variants of AD considered vary in opposite directions when the FIT rises: the optimal AD rises, too, while the appropriate AD decreases. Therefore, depending on the type of AD chosen, environmental policy (i.e. the FIT) and trade policy (i.e. the AD) should be seen as complementary or substitute. When complementary, the two

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

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

policies have contradictory effects on the renewable energy production and environment: a rise in the FIT is beneficial, whereas the accompanying increase in AD is detrimental to the environment. This contradiction disappears when appropriate AD is chosen. The indirect effect of FIT leads to the rise in the foreign solar panels price on the domestic market. It thus diminishes dumping and mechanically the need for an appropriate AD.

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, protecting domestic solar panels producers from foreign competition cannot be the objective of the energy policy *per se*,[18] but the results of this work clearly question 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 provides theoretical propositions.

An alternative to AD duties would be to subsidize the domestic solar panel producer in response to the foreign subsidy. We can show that such a subsidy s would decrease the domestic marginal cost c_1. This subsidy clearly increases the equilibrium quantity of domestic product sold, the domestic profit, and decreases the domestic price. It thus unambiguously favors the environment. 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 and subsidy should be driven by the comparison of welfare under these two different policies. However, none of the two policies outperforms systematically the other on this criteria. The simulations from Figure 7 and Figure 8 in the Appendix show that for a high value of the marginal external benefit of solar panels γ the domestic regulator should always prefer an optimal AD τ^* (i.e. whatever the size of the dumping), whereas when γ becomes small, the regulator should choose instead the AD duty to face a low dumping, and the subsidy in front of a strong dumping.

[18] If a "local content requirement" was associated with FIT, this idea would be disputable.

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:

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

One can show that the upper bound Φ is increasing in the size of domestic market ($\partial\Phi/\partial\alpha_h > 0$), and in the foreign firm's marginal cost ($\partial\Phi/\partial c_2 > 0$), 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:

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

$E^\star$, 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 foreign Firm 2 to dump its product on 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.

$$
\frac{\partial x^\star_{1h}}{\partial c_2} > 0\,,\quad \frac{\partial \pi^\star_{1h}}{\partial c_2} > 0\,,\quad \frac{\partial x^\star_{2h}}{\partial c_2} < 0\,,\quad \frac{\partial E^\star}{\partial c_2} < 0\,,\quad \frac{\partial CS^\star_h}{\partial c_2} < 0\,,\quad \frac{\partial \pi^\star_{2h}}{\partial c_2} < 0\,,\quad \frac{\partial \pi^\star_{2f}}{\partial c_2} < 0\,.
$$

Equilibrium characteristics under AD

With the introduction of parameter τ as the AD duty, the equilibrium characteristics have the new following 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 following 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 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 domestic consumer surplus from eq. (12) is impacted 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 derivatives 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, one needs 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 FOCs 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:

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

i) The nonnegativity constraint ($\tau^\star > 0$) leads to upper bound parameter $\bar{\gamma}$ as follows

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

ii) The derivative $\frac{\partial \tau^\star}{\partial \gamma}$ 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 foreign dumping, the higher optimal 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:

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

By definition, 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 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.

To show that the adequate anti-dumping duty τ^a is also increasing with the dumping, the derivative 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, one can compute the following derivatives 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 derivatives 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 so, we compute first the derivative 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.

We then compute the derivative 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.

Numerical simulations

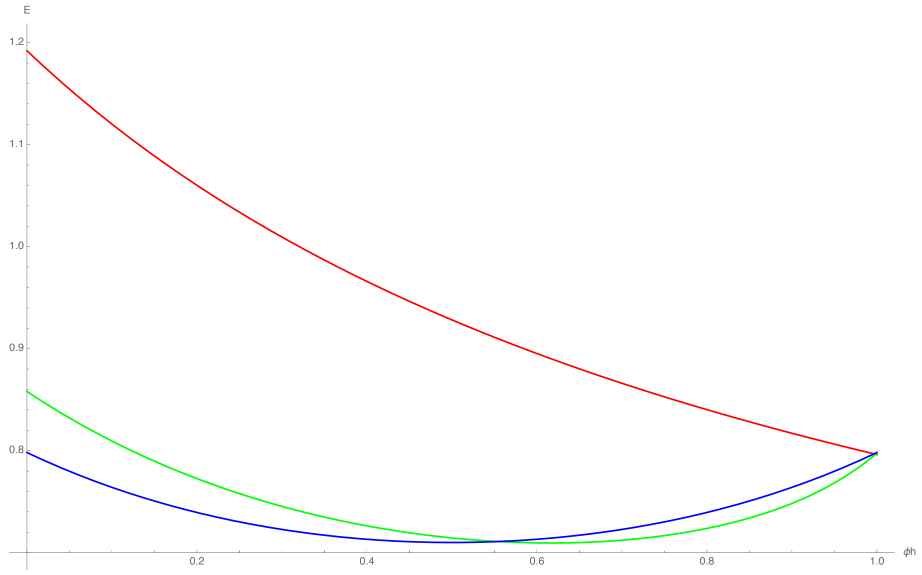

Figure 1: The evolution of the environment in function of domestic products substituability

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

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

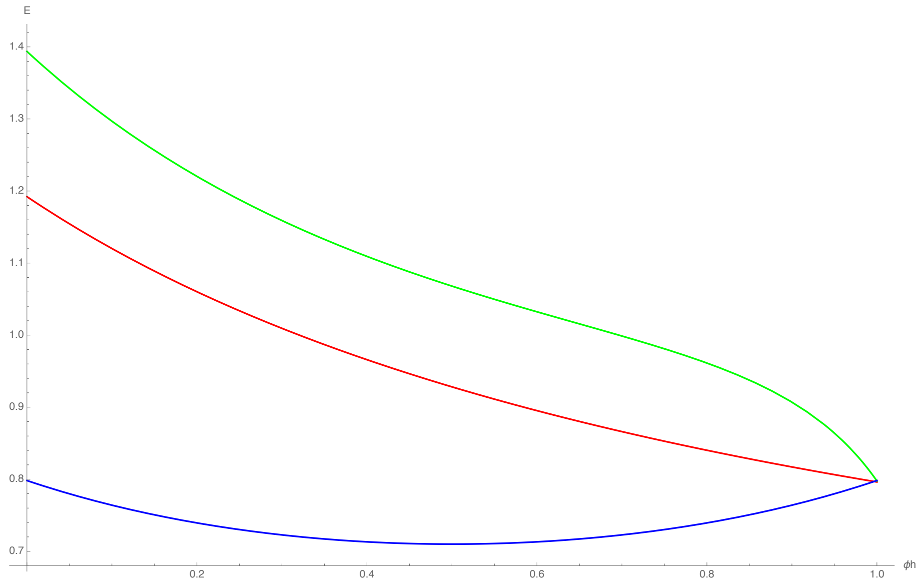

Figure 2: The evolution of the environment in function of domestic products substituability

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

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

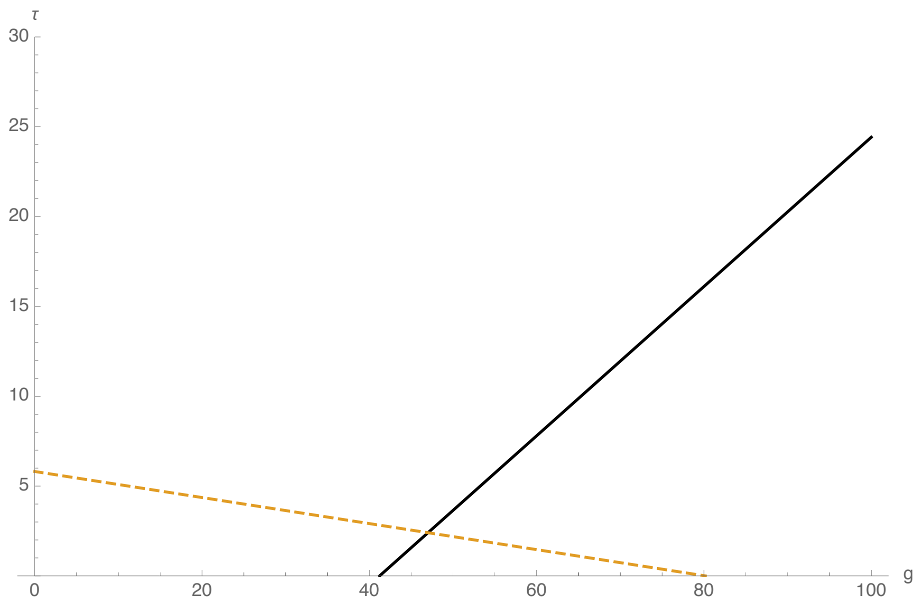

Figure 3: The evolution of the AD duty in function of the FIT rate

(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 $\gamma = 100$)

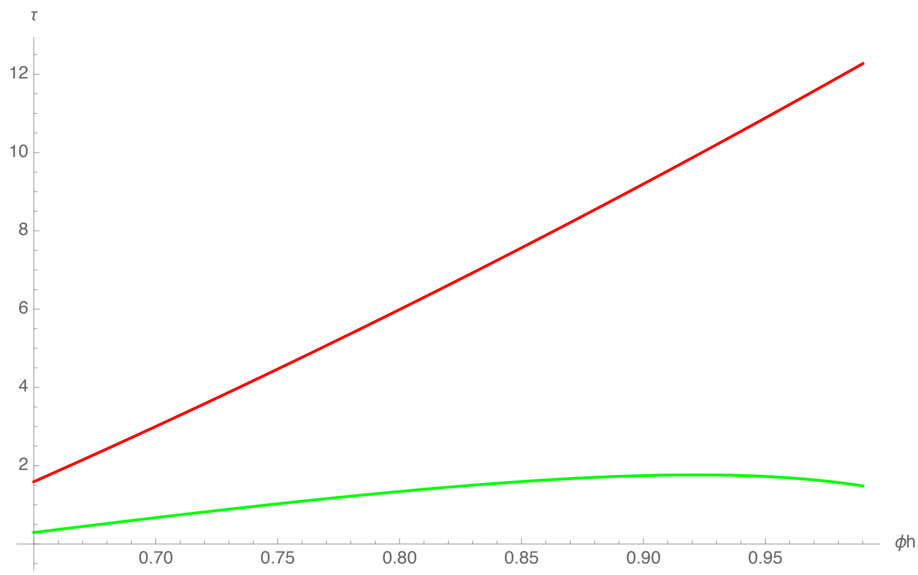

Figure 4: The evolution of the AD duty in function of domestic products' substituability

(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 $\gamma = 10$)

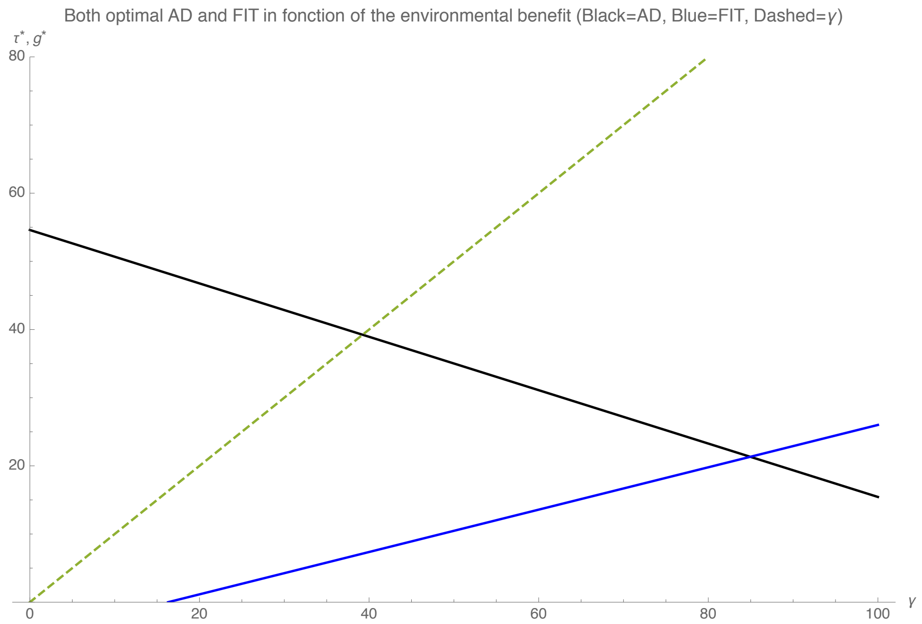

Figure 5: The evolution of the AD duty and FIT rate in function of the environment (Black: AD; Blue: FIT, Dashed: γ)

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

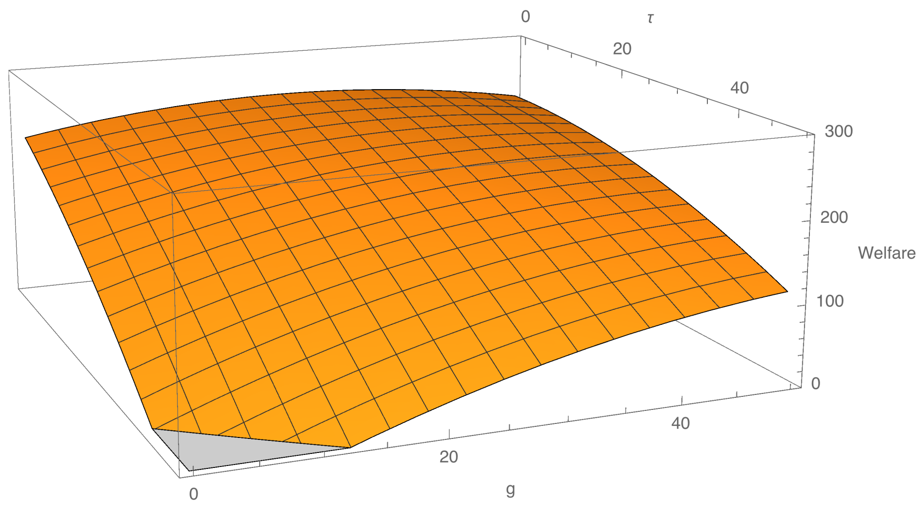

Figure 6: The evolution of the domestic welfare in function of the FIT rate and the AD duty

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

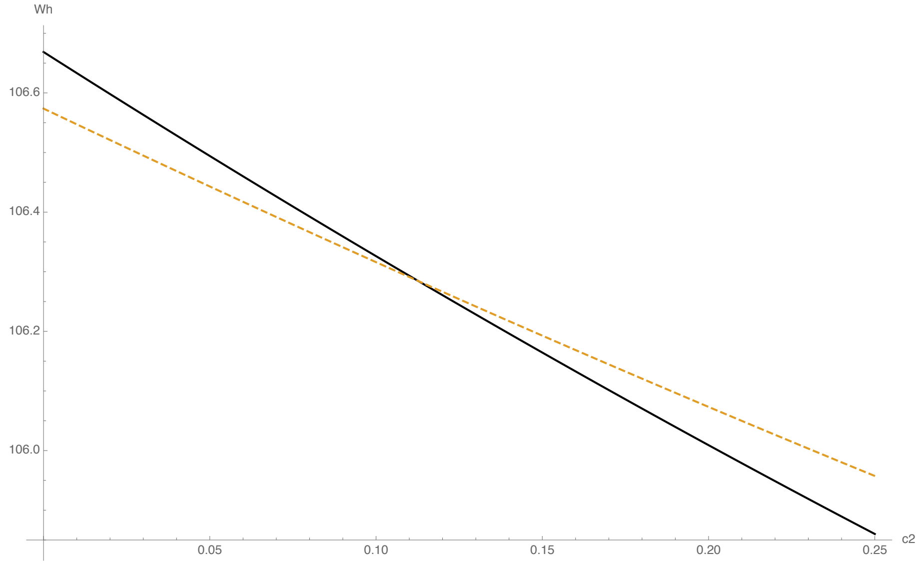

Figure 7: The evolution of the domestic welfare in function of dumping with AD or subsidy (Dashed: AD; Plain: subsidy)

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

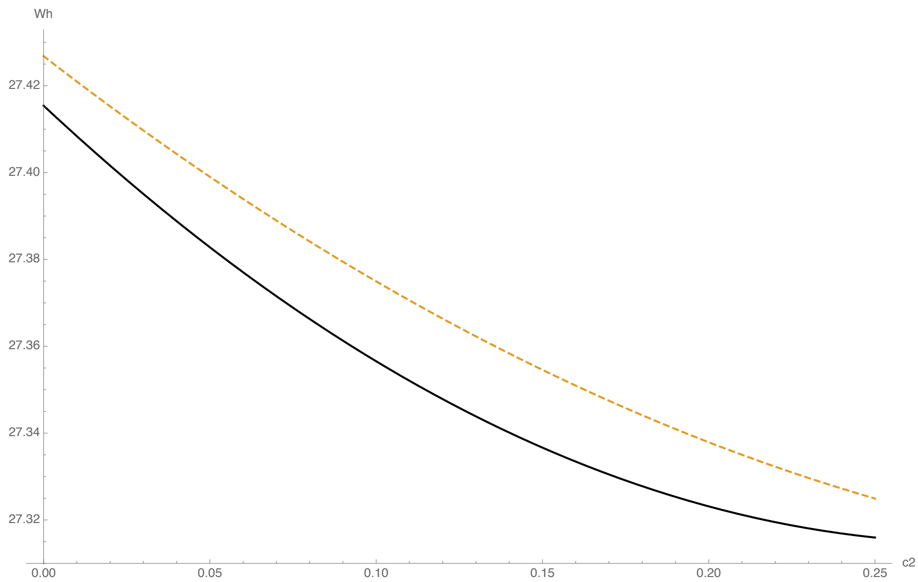

Figure 8: The evolution of the domestic welfare in function of dumping with AD or subsidy (Dashed: AD; Plain: subsidy)

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

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