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Renewable Energy, Subsidies, and the WTO: Where has the 'Green' Gone?*

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Abstract

Faced with the energy transition imperative, governments have to decide about public policy to promote renewable electrical energy production and to protect domestic power generation equipment industries. For example, the *Canada – Renewable energy* dispute is over Feed-in tariff (FIT) programs in Ontario that have a local content requirement (LCR). The EU and Japan claimed that FIT programs constitute subsidies that go against the SCM Agreement, and that the LCR is incompatible with the non-discrimination principle of the World Trade Organization (WTO). This paper investigates this issue using an international quality differentiated duopoly model in which power generation equipment producers compete on price. FIT programs including those with a LCR are compared for their impacts on trade, profits, amount of renewable electricity produced, and welfare. When 'quantities' are taken into account, the results confirm discrimination. However, introducing a difference in the quality of the power generation equipment produced on both sides of the border provides more mitigated results. Finally, the results enable discussion of the question of whether environmental protection can be put forward as a reason for subsidizing renewable energy producers in light of the SCM Agreement.

Keywords: Feed-in tariffs, Subsidies, Local content requirement, Industrial policy, *Canada – Renewable energy* dispute, Trade policy.

JEL Codes: F18, L52, Q42, Q48, Q56.

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1 Introduction

Energy transition has important implications for international trade.[1] The equipment required for the generation of renewable energy sources is being produced by newly developed industries (e.g., solar photovoltaic industry) which have emerged to attack the challenges of global warming and higher oil prices. In the context of energy transition, the development of domestic industries to produce equipment for renewable energy export appears strategic. Governments are tempted to design policies to support the development of these sectors. However, specific protection of domestic industries could lead to trade policies that potentially violate the non-discrimination principle which is the cornerstone of World Trade Organization (WTO) international law.

This situation has already arisen as evidenced by seven trade disputes brought to the WTO's Dispute Settlement Body.[2] These trade disputes account for 14.5% of the total of disputes occurring in the period December 2010 (date of the first of the 7 disputes) to December 2013. Around two-thirds of them are disputes between newly industrialized and industrialized countries. The nature of these seven trade disputes is mostly complaints about national programs that provide support for the development of renewable energy and preferential use of domestic over imported rival products.

One reason for the significant share of disputes related to energy is the increasing use of Feed-In Tariff ('FIT') programs in order to develop and sustain renewable energy sources. FIT programs provide guaranteed prices for renewable energy supplied to the grid through long-term contracts. The guaranteed price is set higher than the wholesale market price for energy supplied from non-renewable sources. This guarantee helps offset the higher costs faced by renewable energy producers. By removing the cost disadvantage, the objective of FITs is to foster investment and innovation in renewable energy sectors, and they have emerged as one of the most popular green policies. For instance, Steer (2013) points out that more than 50 developing countries have adopted FIT or renewable energy standards to foster green technologies. In Europe, between 1990 and 2011, 23 EU members implemented FIT schemes to support the development of photovoltaic and onshore wind power (Jenner et al., 2013). Jenner et al. (2013) is the first econometric study of FIT efficacy in Europe. The authors find that European FIT policies have driven solar

[1] Energy transition in the European Union has the following objective of 20% renewable energy in overall European energy consumption by 2020. Renewable energy sources include wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gases, sewage treatment plant gases, and biogas.

[2] In chronological order, these disputes are: *Canada – Renewable Energy* (DS412), *China – Measures concerning wind power equipment* (DS419), *Canada – Feed-In Tariff Program* (DS426), *European Union and a Member State – Certain Measures Concerning the Importation of Biodiesels* (DS443), *India – Certain Measures Relating to Solar Cells and Solar Modules* (DS456), and *European Union – Certain Measures on the Importation and Marketing of Biodiesel and Measures Supporting the Biodiesel Industry* (DS459). For further details, see `http://www.wto.org/english/tratop_e/dispu_e/dispu_status_e.htm`

photovoltaic capacity growth but argue that this effect is overstated by not controlling for country characteristics and specific designs. Smith and Urpelainen (2014), in a study based on 26 industrialized countries from 1979 to 2005, show that FIT schemes have caused large increases in renewable electricity generation. Borenstein (2012) and others criticize the relevancy and efficiency of FITs partly because they believe that they may lead to increased consumption of electricity and act as disincentives for energy efficiency. Therefore, the design of renewable energy programs is of prime importance.

In *Canada – Renewable Energy* (DS412 and DS426), Japan and the European Union complain about the FIT program implemented by the Canadian Province of Ontario which guarantees the purchase price (i.e. at higher than the wholesale market price) of wind and solar electricity production.[3] The FIT program was implemented in 2009 to diversify Ontario's supply-mix and to help replace the generation capacities that would be lost by 2014 due to closure of coal-fired facilities in Ontario. According to the plaintiffs, these programs make the award of a contract allowing guaranteed prices for renewable electricity subject to a Local Content Requirement (LCR) in the production facilities. More precisely, to qualify for the FIT rate, 50% to 60% of power generation equipment should be manufactured in the Province of Ontario. The complaints focus on two issues: *i)* breach of the non-discrimination principle, and *ii)* creation of subsidies restricting competition. First, by benefiting only electricity producers whose facilities meet the criterion of national content, the LCR policy treats imported and domestic power generation equipment asymmetrically, and goes against the GATT 1994 Agreement principle of national treatment.[4] Second, by guaranteeing a purchase price for electricity produced from renewable sources higher than the wholesale price, the FIT program constitutes a subsidy within the meaning of the Agreement on Subsidies and Countervailing Measures (SCM Agreement).[5]

Most of the economic literature on FIT programs is empirical and investigates the impact of this policy in several countries, or assesses the efficiency of some specific designs.[6] However, Edenhofer et al. (2013)'s survey on the economics of renewable energy sources calls for analysis of policy instruments tackling the welfare issue. From this per-

[3]See Cosbey and Mavroidis (2014) for a legal overview of the case.

[4]Despite the controversial nature of LCRs, they have been used in both developing and developed countries. Governments offering benefits for use of locally-produced goods in their renewable energy programs include among others Brazil, China, Croatia, Greece, India, Italy, Spain, Turkey, Ukraine (Wu and Salzman, 2013). For an analysis of the LCRs in India's National Solar Mission, see Sahoo and Shrimali (2013).

[5]See Rubini (2012) for a discussion of the legal uncertainty surrounding the treatment of subsidies within the WTO.

[6]See, e.g., Chua et al. (2011) for Malaysia; Huang and Wu (2011) for Taiwan; Pirnia et al. (2011) and Yatchew and Baziliauskas (2011) for Ontario; Mabee et al. (2012) for Ontario and Germany, and Antonelli and Desideri (2014) for Italy. Although they find some design and implementation issues, most studies point to the positive effects of the FIT program on the development of renewable energy production.

spective, our study is the first to present a theoretical model that allows comparing FIT programs with and without LCR. We show that FIT programs without LCR are beneficial to power generation equipment suppliers and increase the total amount of renewable energy produced. The impact on domestic welfare is ambiguous and depends mostly on the social cost of public funds. Upstream suppliers largely capture the FIT as a subsidy, and even the foreign supplier may benefit from the program. Furthermore, results confirm discrimination with LCR but, under certain conditions, the foreign supplier may also gain. Interestingly, we show that the total amount of renewable energy produced may decrease under a FIT program with LCR, in contradiction with the energy transition objective. Our results shed light on the *Canada – Renewable Energy* dispute ruling and broader open research questions at the intersection of trade, energy, industry policy, and the environment.

The rest of the paper is organized as follows. Section 2 presents the benchmark model. Section 3 investigates the effects of FIT schemes within this framework. Section 4 introduces the LCR into FITs. Section 5 discusses the results and offers some concluding remarks and policy implications.

2 The Model

We consider a standard vertical product differentiation duopoly model in which two manufacturers – domestic and foreign – produce renewable energy power generation equipment. Take the example of solar panels that convert sunlight to electricity. Pillai and McLaughlin (2013) provide an analysis of the solar module industry and show that it is a far from perfectly competitive industry. Section 2.1 presents the two markets involved in the model (an upstream manufacturing duopoly and the renewable electricity market) and the regulator's objective. Section 2.2 resolves the unregulated equilibrium that constitutes our benchmark model for the analysis of the FIT programs in succeeding sections.

2.1 The power generation equipment and electricity markets

Power generation equipment differs only in quality. There are two rival technologies in the solar industry – crystalline silicon modules, and thin film modules – which result in a different marginal product.[7] Equipment purchasers are renewable energy producers. The domestic renewable energy supply consists of numerous individual small producers. These producers take the electricity price and the price of power generation equipment as given. Also, an impartial regulator aims at increasing domestic supply of electricity produced from renewable energy sources.

[7]For further details on solar technologies, see, e.g., Sahoo and Shrimali (2013).

Power generation equipment producers. We assume that power generation equipment is produced by two– domestic and foreign– firms competing in the domestic market. The two manufacturers differ in output quality and production costs. The costs of producing power generation equipment are assumed to be a quadratic function of the power generation equipment quality (the power generation equipments marginal product Γ) and actual demand Q: $c_i(\Gamma_i, Q_i)$ for $i = d, f$ where $c_i^{'}(\Gamma) > 0$, $c_i^{'}(Q) > 0$, $c_i^{''}(\Gamma) > 0$, and $c_i^{''}(Q) > 0$ (see, e.g., Moorthy (1988)). Whenever necessary, we will use the following form for the cost function

$$c_i(\Gamma_i, Q_i) = a\,\Gamma_i^2\,Q_i^2\,, \quad \text{for} \quad i = d, f \quad \text{with} \quad a > 0\,. \tag{1}$$

Power generation equipment producers d and f compete on price *à la Bertrand* in the market.[8] Prices are denoted k_d and k_f ($k_i > 0$ with $i = d,\ f$).

Renewable electricity producers. In the domestic economy, a continuum of potential renewable electricity producers is considered. The size of each generating facility is assumed to be fixed (normalized to 1 unit of power generation equipment). The production from each generating facility depends on two elements: the marginal product of power generation equipment Γ (which is positive $\Gamma \in]0,\ \infty[$) and an exogenous parameter θ denoting the difficulty involved in producing electricity due to natural conditions (e.g., low wind speeds, sunshine hours, etc.).

Electricity producers are heterogeneous on θ which is uniformly distributed on $[0, 1]$. The electricity production of a given plant is therefore assumed to decrease with θ. The marginal revenue of one producer running a generating facility using equipment with marginal product Γ is $p\,(1-\theta)\,\Gamma$, where p is the given price of the electricity sold ($p > 0$). One unit of power generation equipment costs k. Other costs of production (variable cost) are assumed to be negligible. Under these assumptions, the (marginal) profit of a generating facility is given by the expression:

$$p\,(1-\theta)\,\Gamma - k\,. \tag{2}$$

A producer's willingness-to-pay for one unit of power generation equipment with a marginal product Γ is $p\,(1-\theta)\,\Gamma$. This willingness-to-pay increases in Γ and decreases in θ. Given p, θ, (Γ_d, k_d), and (Γ_f, k_f), a renewable electricity producer can choose among producing one unit of electricity using power generation equipment d, producing one unit of electricity using power generation equipment f, or not producing.

Two critical levels θ_d and θ_f can be defined equating the profit of producing electricity

[8] Cournot competition is also a possible option though less realistic.

to zero:[9]

$$\theta_i = 1 - \frac{k_i}{p\Gamma_i} \quad \text{for} \quad i = d, f\,. \tag{3}$$

Using power generation equipment $i = d, f$ is profitable as soon as $\theta \leq \theta_i$.[10]

The marginal electricity producer is indifferent about power generation equipment quality Γ_d at price k_d and power generation equipment quality Γ_f at price k_f when the electricity price is p is such that:

$$\widetilde{\theta} = 1 - \frac{k_d - k_f}{p\left(\Gamma_d - \Gamma_f\right)}\,. \tag{4}$$

Throughout the rest of the paper we suppose that $\Gamma_d > \Gamma_f$. This assumption avoids the situation where a domestic subsidy is given to the less efficient technology under a FIT program with LCR.[11] When the domestic power generation equipment is more efficient than the foreign equipment ($\Gamma_d > \Gamma_f$), producers for which θ is smaller than $\widetilde{\theta}$ prefer the domestic power generation equipment and those for which θ is bigger than $\widetilde{\theta}$ prefer the foreign power generation equipment. Note that $\widetilde{\theta}$ can be outside of $[0, 1]$.

A result on the position of $\widetilde{\theta}$, θ_d and θ_f can be stated and will be useful to analyze the structure of demand for the two types of power generation equipment.

Lemma 1 *If the marginal product of power generation equipment d is higher, $\Gamma_d > \Gamma_f$, then θ_f is greater than θ_d when $\theta_d > \widetilde{\theta}$, whereas θ_f is smaller than θ_d when $\theta_d < \widetilde{\theta}$.*

The proof is given in the Appendix ■

The structure of the demand for power generation equipment in the domestic market can now be specified when $\Gamma_d > \Gamma_f$. The following settings can emerge: *i)* no power generation equipment is purchased because the electricity production is not profitable, *ii)* either domestic or foreign power generation equipment is produced (monopoly cases), *iii)* both types of power generation equipment are purchased, with the critical values for θ ordered as follows: $0 < \widetilde{\theta} < \theta_d < \theta_f$. In the rest of the paper we consider only this duopoly case as illustrated in Fig. 1.

The demands for power generation equipment are therefore $Q_d = \widetilde{\theta}$ and $Q_f = \theta_f - \widetilde{\theta}$. Note that in this market setting θ_f denotes renewable electricity market coverage. Because $\theta_i < 1$ $(i = d, f)$, the market is never fully covered.

[9] Note that these critical values are always smaller than 1 and can be negative.

[10] Insufficient rate of return is therefore the only reason for non-adoption.

[11] This assumption is not necessarily realistic. However, it allows working with a scenario where the FIT program with LCR should not be automatically rejected. See Sections 4 and 5 for a discussion.

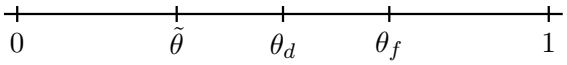

Figure 1: The duopoly market structure

The regulator. An impartial regulator aims at maximizing total *domestic* welfare. In the domestic economy, we consider that the production of renewable energy compared to fossil fuels or nuclear generations is small.[12] Renewable generation is assumed (realistically) to cost more than non-renewable generation. Furthermore, the structure of demand for renewable energy power generation equipment above shows that there are always potential electricity producers that choose not to produce at all. In this context, and because of the objective to initiate energy transition, the regulator aims to foster renewable electricity supply in the market.

The domestic market electricity price is exogenous and given. This price may be insufficient to incite sufficient numbers of renewable electricity producers to enter the market. The regulator aiming at developing the offer of renewable energy in the market in order to maximize domestic welfare, can offer a higher price, $p_g > p$, implementing a FIT program (see Sections 3 and 4). The difference between the guaranteed price and the market price, $p_g - p$, can therefore be considered a subsidy.

We assume that an increase in the amount of renewable energy decreases the production of fossil electricity. Unlike fossil fuel generation, renewable energy is assumed to imply no external costs. As a consequence, developing renewable electricity (i.e., reducing non-renewable generation) with the subsidy $p_g - p$ always decreases the external cost of non-renewable energy. In the model, this relation is considered assuming that the external cost of fossil generation of electricity is negatively linked to the total purchase of the power generation equipment used in the production of green electricity (*cf infra*). Since θ_f denotes renewable electricity market coverage in the duopoly situation, the external cost is formalized as γ/θ_f, where $\gamma > 0$ is a scale factor.[13] Note however, that this subsidy should not be considered a policy aimed primarily at reducing pollution. Consequently, the subsidy (or the choice of p_g) is not modified by taking account of the marginal cost of pollution abatement. Finally, subsidizing renewable energy development requires public funds, and therefore its social marginal cost must be considered.

[12]This assumption is quite realistic, since for instance conventional fossil-fuel and nuclear generators provided 87% of U.S. electricity in 2011 (Schmalensee, 2013).

[13]Therefore, it is a decreasing function of the renewable electricity market coverage.

2.2 Unregulated equilibrium

The domestic and foreign firms compete on price *à la Bertrand*. They determine power generation equipment prices and produce the output that meets electricity producers' demands.

Demands. When $0 < \widetilde{\theta} < \theta_d < \theta_f$, both firms producing power generation equipment have positive demands and form a duopoly:

$$D_d(k_d, k_f) = \widetilde{\theta} = 1 - \frac{k_d - k_f}{p(\Gamma_d - \Gamma_f)}, \tag{5}$$

$$D_f(k_d, k_f) = \theta_f - \widetilde{\theta} = \frac{k_d\Gamma_f - k_f\Gamma_d}{p\Gamma_f(\Gamma_d - \Gamma_f)}. \tag{6}$$

Profits. Using expressions (1), (5), and (6), the two profit functions are given by:

$$\Pi_d(k_d, k_f) = k_d D_d(k_d, k_f) - c(\Gamma_d, D_d), \tag{7}$$

$$\Pi_f(k_d, k_f) = k_f D_f(k_d, k_f) - c(\Gamma_d, D_f). \tag{8}$$

The two firms compete on price choosing k_d and k_f non-cooperatively, anticipating the competitors price. Since each profit function $\Pi_i(k) = \Pi_i(k_i, k_j)$, for $i = d, f$, $j = d, f$, $i \neq j$, is continuous in k and is concave in k_i for each value of k_j, an equilibrium point exists.

The maximization of the two profits functions gives the following best-response price functions:

$$k_d(k_f) = \frac{(\Gamma_d(2a\Gamma_d + p) - p\Gamma_f)(p(\Gamma_d - \Gamma_f) + k_f)}{2\Gamma_d(a\Gamma_d + p) - 2p\Gamma_f},$$

$$k_f(k_d) = \frac{\Gamma_f(\Gamma_d(2a\Gamma_f + p) - p\Gamma_f)}{2\Gamma_d(\Gamma_d(a\Gamma_f + p) - p\Gamma_f)} k_d.$$

where power generation equipment prices are strategic complements (best-reaction function slopes are positive), as illustrated in Fig. B.1. Solving $k_d(k_f)$ and $k_d(k_f)$ gives the (unique) unregulated Nash equilibrium, (k_d^*, k_f^*). The resulting equilibrium quantities $D_d^* = \tilde{\theta}^*$ and $D_f^* = \theta_f^* - \tilde{\theta}^*$ are derived using demand functions (5) and (6). Note that, as expected, both firms are active in the domestic market.

Let us illustrate these results by choosing the following parameter values that comply with the duopoly setting: $a = 10$, $\Gamma_d = 50$, $\Gamma_f = 35$, and $p = 10$. Plotting the respective best-response price functions, we find the equilibrium level to be (k_d^*, k_f^*), i.e. $k_d^* \approx 461.50$ and $k_f^* \approx 317.34$ (Fig. B.1 in the Appendix).

Finally, equilibrium profits are easily computed using (7) and (8). Equilibrium results are therefore functions of all the exogenous variables: p, Γ_d, Γ_f, and the cost parameter a. For the sake of clarity the equations for the exposition equilibrium are not included here.[14]

[14] Expressions are available upon authors' request.

Surplus of the electricity producers. Two types of electricity producers can be distinguished, those that use domestic power generation equipment at price k_d and those that use foreign power generation equipment at price k_f. One can therefore compute the total surplus of electricity producers as follows

$$CS = \int_0^{\tilde{\theta}^*} (p\,(1-\theta)\Gamma_d - k_d)d\theta + \int_{\tilde{\theta}^*}^{\theta_f^*} (p\,(1-\theta)\Gamma_f - k_f)d\theta\,, \tag{9}$$

with power generation equipment prices at their equilibrium value (k_d^*, k_f^*). Note that, as expected, the total surplus CS is an increasing function of the electricity price p.

Total amount of renewable energy. One can compute the total amount of renewable energy, denoted kw, produced at equilibrium (i.e., with $\widetilde{\theta}$ and θ_f calculated with k_d^* and k_f^*):

$$\begin{aligned} kw &= kw_d + kw_f \\ &= \int_0^{\widetilde{\theta}} (1-\theta)\Gamma_d d\theta + \int_{\widetilde{\theta}}^{\theta_f} (1-\theta)\Gamma_f d\theta\,. \end{aligned} \tag{10}$$

Unsurprisingly, like the consumer surplus CS, kw grows with the market electricity price p.

Domestic welfare. Total domestic welfare W_d is computed as the sum of the domestic power generation equipment producer's profits and the electricity producers surplus, minus the external cost of fossil generation of electricity referred to at the end of Section 2.1:

$$W_d = \Pi_d + CS - \frac{\gamma}{\theta_f}\,. \tag{11}$$

It is straightforward to show that domestic welfare at equilibrium grows with the electricity price p and both types of power generation equipment quality, Γ_d and Γ_f. However, in Section 3 we show that if the increase in the electricity price is due to the FIT program and if one considers the Social Marginal Cost of Public Funds (SMCF),[15] domestic welfare may decrease with the guaranteed price.

In the following two sections we investigate the impact of a FIT program explored in two variants, i.e. applied to both types (domestic and foreign), and one type (i.e.,

[15]SMCF measures "the loss incurred by society in raising additional revenues to finance government spending" (Dahlby, 2008, pp.1). In practice, for instance, Beaud (2008) provides general equilibrium estimations of λ around 1.20 in France. In other words, 1 euro of spending by the French Government actually costs 1.20 euro.

LCR) of power generation equipment sold in the domestic market. We compare both situations to the benchmark setting in Section 2 and make different propositions relative to market characteristics such as power generation equipment prices, consumer surplus, and welfare.[16] If analytical solutions become intractable, we will use numerical simulations to illustrate some properties and comparative statics results.

3 The Use of Unconditional Feed-in Tariffs

The market price for electricity is often considered insufficient to fully amortize the specific power generation equipment used in renewable electricity generation. Therefore, guaranteeing a certain price level for renewable electricity promotes the production of this type of electricity. Numerous countries have implemented such policies in the energy transition context (Antonelli and Desideri, 2014, e.g.). There is no consensus in the economic literature. Country specificities such as economic and solar radiation conditions, and the design of the schemes will affect investment in renewable energy sources.

In the analysis below, we focus on two types of FIT schemes. In the first, the price is ensured irrespective of the power generation equipment used for electricity generation (most frequent scheme, used, e.g., in France and Germany). In the second, the guaranteed price is conditional on the 'local content' of the electricity generation, i.e. on the use of the domestic power generation equipment. This is a LCR exemplified by the WTO dispute between Canada versus Japan and EU mentioned earlier. For example, under Ontario's FIT program, government pays high fixed prices for electricity produced with renewable energy sources but only if producers use a certain level of locally-produced components. This section investigates the effects of unconditional FITs. The introduction of a LCR in this scheme is analyzed in the next section.

3.1 Feed-in tariff equilibrium

In order to promote renewable electricity generation, a guaranteed price p_g above the market price p, $p_g > p$, is set by the regulator. Under the chosen policy, the (marginal) profit of a generating facility becomes:

$$p_g\,(1-\theta)\,\Gamma - k\,. \tag{12}$$

The critical values for θ therefore change by substituting p for p_g. Thus, demand for both types of power generation equipment is expressed as:

[16] One could consider the benchmark as the situation where no power generation equipment (and no renewable energy) is produced because of lack of profitability. However, this setting might excessively favor the FIT programs in the comparison.

$$
\begin{aligned}
D_{dg}\left(k_d, k_f\right) &= \widetilde{\theta}_g = 1 - \frac{k_d - k_f}{p_g\left(\Gamma_d - \Gamma_f\right)}, \\
D_{fg}\left(k_d, k_f\right) &= \theta_f - \widetilde{\theta} = \frac{k_d\Gamma_f - k_f\Gamma_d}{p_g\Gamma_f\left(\Gamma_d - \Gamma_f\right)}.
\end{aligned}
$$

Equilibrium prices on the power generation equipment market are affected by these changes in demand.

Proposition 1 *Following unconditional feed-in tariffs, the prices of both national and foreign power generation equipment producers rise at the equilibrium level.*

The proof is given in the Appendix ■

The intuition behind Proposition 1 is straightforward: since the guaranteed price is higher than the market price for electricity, electricity producers have a higher willingness to pay for both types of power generation equipment. This situation allows power generation equipment producers to increase their prices. This result is illustrated using the same parameter values as before, in order to simulate the effect of a FIT of $p_g = 15$ (market price remains at $p = 10$). In line with Proposition 1, both equilibrium power generation equipment prices appear higher, $k^*_{d,g} \approx 667.463$ and $k^*_{f,g} \approx 455.057$ (see Fig. B.2 in the Appendix).

Proposition 2 *Guaranteeing a price for renewable electricity higher than the market price for electricity has the following three effects: i) an increase in market coverage θ_f, ii) an increase in demand for the domestic power generation equipment, and iii) an increase in demand for the foreign power generation equipment but only if the market electricity price and the gap between the prices of the domestic and the foreign power generation equipment are not too high:*

$$
p < 2a\,\psi\left(\Gamma_d, \Gamma_f\right) \quad \textit{and} \quad k^*_d - k^*_f < 2a\,\varphi\left(\Gamma_d, \Gamma_f\right),
$$

where $\varphi\left(\Gamma_d, \Gamma_f\right)$ and $\psi\left(\Gamma_d, \Gamma_f\right)$ are two positive functions of Γ_d and Γ_f.

The proof is given in the Appendix ■

The intuition behind Proposition 2 is as follows. Because the guaranteed price p_g is higher than p, some electricity producers using foreign power generation equipment under p will find it profitable to use domestic rather than foreign power generation equipment (increase of $\widetilde{\theta}$ with p), while others will find market entry attractive using the foreign power

generation equipment (the rise of θ_f with p). Therefore, the demand for foreign generation power equipment increases in p only if the existing producers switching to domestic power generation equipment are less numerous than the producers entering the electricity market and running their installations using the foreign power generation equipment. Proposition 2 states that this result holds only if two conditions are met simultaneously. First, the difference in power generation equipment prices cannot be larger than a threshold which depends on the power generation equipment qualities. This condition reveals that the gap between domestic and foreign power generation equipment qualities cannot be too large.[17] Second, the FIT p_g cannot be too high, in order to avoid a situation where the producers that would use foreign power generation equipment under p but domestic power generation equipment under p_g become too numerous.

We denote kw_g as the total amount of renewable energy the FIT program. kw_g is computed as in the expression (10) with $\widetilde{\theta}$ and θ_f calculated using the new equilibrium prices.

Corollary 1 *The production of renewable energy in the domestic country increases under a FIT scheme.*

The proof is given in the Appendix ■

The rise in renewable energy production under a guaranteed price results from the increase in market coverage (increase of θ_f) and from the fact that under a guaranteed price more producers choose the more efficient power generation equipment (increase of $\widetilde{\theta}$).

3.2 Surplus and domestic welfare

The results of a guaranteed price for renewable energy can also be assessed in relation to profits and welfare. We can show that whatever the parameter values under duopoly constraints, the power generation equipment producers' profits and the electricity producers' surpluses rise following implementation of an unconditional FIT.

Proposition 3 *Under a FIT program, power generation equipment producers' profits and electricity producers' profits rise.*

[17] Remember that the conditions to maintain a duopoly (i.e., $0 < \widetilde{\theta} < \theta_d < \theta_f$) are such that a positive difference in power generation equipment quality ($\Gamma_d > \Gamma_f$) must be translated into a positive difference in power generation equipment prices at equilibrium ($k_d^* > k_f^*$). An important gap between k_d^* and k_f^* therefore, reveals an important difference in the power generation equipment qualities.

The proof is given in the Appendix ■

The intuition behind Proposition 3 is straightforward. First, guaranteeing a price p_g higher than the market price for electricity p increases the profits of both power generation equipment producers since the profit functions are strictly increasing in p. Second, the electricity producers fall into two categories: those using domestic power generation equipment located in the segment $\left[0;\widetilde{\theta}\right]$, and those using foreign power generation equipment found in the segment $\left[\widetilde{\theta};\theta_f\right]$. Implementing a FIT program pushes up $\widetilde{\theta}$ and θ_f. The rise in $\widetilde{\theta}$ means that at least one producer θ finds it more profitable to use domestic than foreign power generation equipment. As a consequence, the profit of each producer under this θ increases under a FIT program. The rise of θ_f means that at least one producer θ finds it profitable to enter the market and produce using the foreign power generation equipment. As a consequence, the profit of each producer using foreign power generation equipment under this θ increases under a FIT program. These two effects imply that electricity producers' total profits increase when a guaranteed price higher than the market price is proposed.

This first series of results suggests a positive effect of the FIT program. However, the impact of the guaranteed price on total domestic welfare is a major disadvantage. Since the implementation of a FIT program needs public funds, welfare (11) can be expressed as follows:

$$W_{d,g} = \Pi_d + CS - \frac{\gamma}{\theta_f} - \lambda k w_g (p_g - p)\,, \tag{13}$$

where $\lambda > 1$ stands for the SMCF and kw_g corresponds to the new expression from (10).

Proposition 4 *Domestic welfare may decrease under the FIT program.*

Corollary 2 *There does not exist any p_g that maximizes domestic welfare.*

The proofs are given in the Appendix ■

Proposition 4 and Corollary 2 question the economic rationale of the FIT program especially when domestic welfare is decreasing. These results highlight one of the main inconveniences attached to subsidizing renewable electricity generation in order to reduce fossil fuel generation.[18] In effect, some electricity producers would produce in the absence of a subsidy and would receive a subsidy under a FIT program. Therefore, in this model public funds are expended without any increase in the supply of renewable electricity, since producers are assumed to use only one unit of power generation equipment. Furthermore, the external cost economy becomes ever less important as renewable electricity market

[18] See Jaffe et al. (2005) and Fischer and Newell (2008).

coverage increases while the marginal social cost of public funds remains constant. These results show that welfare maximization does not resolve the question of where to set p_g. Note that the target of maximizing renewable energy production to fix p_g does not help since the production of renewable energy is increasing with the electricity price (Corollary 1 and Fig. B.4 in Appendix). Thus, political motivations are central in deciding about implementation of this type of regulatory scheme.

A numerical simulation of the effects of a FIT is given in Table 1.

Characteristics	**Benchmark**	**Unconditional FIT**
k_d	461.502	667.463
k_f	317.344	455.057
D_d	0.0389453	0.0559718
D_f	0.0543583	0.0772527
Π_d	9.10042	19.032
Π_f	8.78026	18.0472
CS_d	1.12013	3.4449
CS_f	0.517094	1.5666
kw_d	1.90935	2.72027
kw_f	1.77674	2.44807
W	0.0199535	-9.3043

Table 1: Simulation of the effects of a FIT Program
($a = 2.34$, $\Gamma_d = 50$, $\Gamma_f = 35$, $\gamma = 1$, $\lambda = 1$, $p = 10$, and $p_g = 15$)

The values chosen for the parameters a, Γ_d, Γ_f, γ and λ, illustrate the results demonstrated in Propositions 1-2: increases in power generation equipment prices, profits, and renewable electricity produced following implementation of an unconditional FIT program.

Note that there is no international competition issue involved in this policy since the profits of both competing power generation equipment producers' increase under the FIT scheme. Another perspective is offered if FIT schemes are conditional on a LCR.

4 Feed-in Tariffs with LCR

In a conditional FIT program, benefiting from a guaranteed price depends on a LCR. Specifically, the electricity price p_g is ensured only for renewable electricity producers using domestic power generation equipment, while the producers using foreign power generation equipment obtain the market electricity price p.

Therefore, the critical values for θ change compared to their values in the benchmark scenario. p is substituted for p_g only if it refers to the domestic power generation equip-

ment producer. Under the assumption of a duopoly setting,[19] both demands for power generation equipment result in the following expressions:

$$\begin{aligned} D_{d,cg}\left(k_d, k_f\right) &= \widetilde{\theta}_g = 1 - \frac{k_d - k_f}{p_g \Gamma_d - p\Gamma_f}, \\ D_{f,cg}\left(k_d, k_f\right) &= \theta_f - \widetilde{\theta}_g = \frac{k_d - k_f}{p_g \Gamma_d - p\Gamma_f} - \frac{k_f}{p\Gamma_f}. \end{aligned}$$

We can then deduce equilibrium power generation equipment prices $k^*_{d,cg}$ and $k^*_{f,cg}$. The demands for power generation equipment at equilibrium are denoted $D^*_{d,cg}$ and $D^*_{f,cg}$.

Proposition 5 *Under the conditional FIT program, the price of the domestic power generation equipment always increases compared to the unregulated equilibrium, while the change in the price of the foreign good is ambiguous.*

The proof is given in the Appendix ■

Proposition 5 highlights the fact that the producer of domestic power generation equipment always charges higher prices under a conditional FIT scheme. In contrast, the LCR disadvantages the foreign producer in the domestic market. Maintaining a duopoly setting, in some circumstances may require a reduction in $k^*_{f,cg}$ compared to the unregulated case. The simulations below show that $k^*_{f,cg}$ is more inclined to decrease when LCR is used (see Fig. B.3 in the Appendix).

Proposition 6 *Compared to the unconditional FIT scheme, introducing a LCR has two opposite effects. First it increases demand for the domestic power generation equipment only if two conditions are satisfied, $p < a\kappa\left(\Gamma_d, \Gamma_f\right)$ and $p_g < \xi\left(a, \Gamma_d, \Gamma_f\right)$, where $\kappa\left(\Gamma_d, \Gamma_f\right)$ and $\xi\left(a, \Gamma_d, \Gamma_f\right)$ are positive functions of Γ_d and Γ_f defined in the Appendix. Second, the LCR has a negative impact on the demand for foreign power generation equipment.*

The proof is given in the Appendix ■

Corollary 3 (foreign producer) *The LCR does not necessarily lead to a reduction in the foreign power generation equipment producer's profit.*

The proof is given in the Appendix ■

[19] Note that the introduction of the LCR could lead to a domestic monopoly. We do not consider this case where discrimination is obvious.

Proposition 6 throws light on the LCR in a FIT program from two different perspectives. First, it shows that the LCR can be considered a strategic trade policy. The discrimination it implies results in a reduction in the demand for foreign power generation equipment in the domestic market. Note that if the duopoly assumption is relaxed at the extreme, the LCR could lead the foreign power generation equipment producer to exit the market.

When demand for both types of power generation equipment (Proposition 6) decrease, there is a reduction in the renewable energy generated. Therefore, unlike the unconditional FIT program, the LCR can lead to an outcome that is opposite to the energy transition objective, as stated in the following Corollary.

Corollary 4 *The production of renewable energy in the domestic country may decrease under a FIT program with a LCR.*

The proof is given in the Appendix ■

A numerical simulation of the effects of the FIT program with a LCR is given in Table 2. The results show a decrease in the foreign power generation equipment producers variables (price, demand, profit) and an increase in these variables for the domestic power generation equipment producer. In this parameter setting, the introduction of the LCR decreases the total amount of renewable electricity produced in the domestic country.

Characteristics	**Unconditional FIT**	**Conditional FIT**
k_d	667.463	688.875
k_f	455.057	311.648
D_d	0.0559718	0.0569318
D_f	0.0772527	0.0526462
Π_d	19.032	20.2577
Π_f	18.0472	8.46221
CS_d	3.4449	2.2645
CS_f	1.5666	0.485033
kw_d	2.72027	2.76556
kw_f	2.44807	1.68921
W	-9.3043	-8.39254

Table 2: The effects of a FIT program on market characteristics
($a = 2.34$, $\Gamma_d = 50$, $\Gamma_f = 35$, $p = 10$, $p_g = 15$, $\gamma = 1$, and $\lambda = 1$)

Second, Proposition 6 shows that the FIT program with a LCR should not be considered as automatically favoring the domestic power generation equipment producer. The

demand for domestic power generation equipment can decrease compared to the benchmark scenario. Simulations from Table 3 below illustrate this type of result where the foreign firm's profits *do* increase following the setting of a LCR FIT scheme. Depending on the parameter values, the introduction of such programs may increase the foreign power generation equipment producer's profit. In this scenario, equilibrium power generation equipment prices are higher compared to the unconditional FIT and obviously to the benchmark. The total amount of renewable electricity produced in the domestic country also decreases (see Graph B.4 in the Appendix).

Characteristics	**Benchmark**	**Unconditional FIT**	**Conditional FIT**
k_d	83.33	115.12	220.50
k_f	38.88	51.46	63.44
D_d	0.555	0.575	0.551
D_f	0.347	0.338	0.290
Π_d	38.580	57.984	113.957
Π_f	11.574	15.592	17.060
CS_d	154.321	241.195	177.932
CS_f	24.112	34.395	16.836
kw_d	20.061	20.497	19.965
kw_f	3.761	3.454	3.524
W	215.906	188.767	166.596

Table 3: The effects of a FIT Program on market characteristics
($a = 0.01$, $\Gamma_d = 50$, $\Gamma_f = 40$, $\gamma = 1$, $\lambda = 1.2$, $p = 10$, and $p_g = 15$)

5 Discussion

This paper investigates the consequences of a FIT program in the context of energy transition, using an international quality differentiated duopoly model in which power generation equipment producers compete on price. The results can be applied to a discussion of the *Canada – Renewable Energy* case. The ruling of this dispute was based on two main points: National treatment and subsidies. In this dispute, the LCR was found incompatible with the GATT principle of National Treatment since it discriminated between domestic and foreign power generation equipment in favor of the former. The results of our model confirm this idea as long as 'quantities' are taken into account in a duopoly setting.[20] Proposition 6 establishes that, as a result of such a regulatory scheme, demand for domestic power generation equipment does increase, whereas demand for the foreign

[20]Discrimination would be obvious if the LCR created a domestic monopoly (see footnote 19).

power generation equipment decreases. However, introducing a difference in the quality of the power generation equipment produced on both sides of the border questions the discrimination. First, the simulations show that a rise in the profits of the foreign power generation equipment producer can be due to the LCR in a FIT program (see Table 3). In this case, treating the two producers differently should not be considered 'damaging' discrimination. Second, a decrease in the demand for foreign generation equipment can also emerge under the FIT Program without any LCR, as established in Proposition 2. In this case, the LCR would exacerbate discrimination.

The question of whether the guaranteed price for electricity under Ontario's FIT Program constituted subsidies was the subject of heated debate in the *Canada – Renewable Energy* dispute. Under Article 1 of the SCM Agreement, a "subsidy shall be deemed to exist if there is a financial contribution by a government" conferring a 'benefit' to its recipient. The Panel tackled this problem by examining whether the FIT Program framework gave an advantage to Ontario's renewable electricity producers. On this issue, the Panel considered that the guaranteed price for electricity should not give "more than adequate remuneration" to the renewable electricity producers, and that this 'adequacy' had to be assessed compared to regular market conditions. In line with previous rulings, the requirement was considered by the Panel as a context where supply and demand affect price even if the market is not perfectly competitive. Therefore, the question of what price can be used as benchmark became central (rather than the LCR). The Panel refused to consider the wholesale price for electricity – which Japan and the EU had asked for – as the benchmark because it clearly appeared that this price was distorted by the policy of the Government of Ontario (acting simultaneously as a buyer and a producer of electricity). Therefore, the Panel concluded that the claimants had failed to establish the existence of subsidization.[21] Against this background, a dissenting opinion of one Panel member was recorded in the Panel's Report. According to this member, the fact that every party recognized that the guaranteed price fixed in the FIT Program is a condition for the existence of renewable energy producers, clearly shows that the FIT Program conferred a benefit on these producers.

If the FIT program had been considered as constituting subsidies, the question of whether these subsidies were prohibited would inevitably have been addressed. In light of the Panel's conclusion about national treatment, and Article 3 of the SCM Agreement prohibiting subsidies contingent "upon the use of domestic over imported goods", it is highly likely that the FIT program would have been found incompatible with the SCM Agreement, without consideration of its environmental dimension.

In the model, the FIT Program (whatever form it takes) is *assumed* to constitute subsi-

[21] The Appellate Body reached the same conclusion but choosing the market for renewable energy rather than the wholesale market as the benchmark.

dies in light of the preceding debate: the guaranteed price is set higher than the wholesale price. Nevertheless, we believe that this theoretical framework provides interesting insights into the debate.

The first point that can be discussed is how subsidies are identified. In the vertical relation between power generation equipment producers and electricity producers, presented in the model, Proposition 3 shows that subsidizing the latter clearly benefits the former (with a 'pass-through effect'). The problem of protectionism that has to be addressed, therefore rests on the power generation equipment not the electricity market. Japanese and European electricity generators are not in competition with Ontario's. Competition is among power generation equipment producers. As a consequence, the effects of the subsidies implied by the FIT program on prices, quantities, and profits, should be assessed on the power generation equipment market where the LCR is potentially damaging.

The second point worth discussing is the way that LCR is excluded from the debate over subsidies. Japan and the EU would not have claimed that Ontario's FIT Program constituted subsidies if the LCR had not been part of the FIT program. While this requirement is therefore at the heart of the dispute, the Panel did not consider it when discussing subsidies, to avoid the risk of ruling on FIT programs more generally (and dangerously as we argue below). Our model shows that the FIT program without LCR can distort trade (on the power generation equipment market), but not systematically however.

Finally, the third point is the way the environment was excluded from the Panels ruling. If one agrees with the dissenting Panel member's view referred to above, the question of justification for the subsidies is unavoidable: Can environmental protection and energy transition be put forward as reasons for subsidizing renewable energy producers in light of the SCM Agreement? Our model shows that the FIT Program with no LCR, undisputably raises the production of renewable energy (Corollary 1). As Rodrik (2013) argues, "industrial policies have an indispensable role in putting the global economy on a green growth path."[22] What is the real weight of such an argument in this kind of dispute especially in the face of discrimination? Should renouncing the LCR be seen as the ultimate solution? Discussing the case, Cosbey and Mavroidis (2014) point out that even with no LCR, FIT programs could be found incompatible with the SCM Agreement since no attention is paid to the environmental protection motive in this Agreement.

This debate over the possibility of subsidies for environmental purpose takes place in a particular context. During the first years of the WTO's existence, such "green subsidies" were possible under Art. 8 of the SCM Agreement. However, this article had a limited life span of five years and was not extended. At the end of the day, the Panel and the Appellate Body may have been wise in their approach to this issue. What would have happened

[22] See also Rubini (2012).

were the FIT Program to have been classified as an illegal subsidy without discussion of the appropriateness of such a policy? The Panel would have been deciding a sensitive issue on behalf of WTO Members. This would have questioned all the renewable energy funding programs across Europe, Canada, and other countries. Were such a debate to take place, the economic reasoning developed in our model clearly establishes the positive characteristic of a FIT program (increased production of renewable energy) as well as its main limitations, i.e. possible welfare reduction and eventual decreased production of renewable energy if the LCR were adopted.

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A Proofs of Lemmas, Propositions, and Corollaries

Most proofs use *Mathematica 9.0* software. Computing codes and details are available upon request.

A.1 Proof of Lemma 1

Consider the situation where power generation equipment d is the most efficient: $\Gamma_d > \Gamma_f$. Using (3) and (4) permits to write $\theta_d > \widetilde{\theta}$ as $\frac{k_d\Gamma_f - k_f\Gamma_d}{\Gamma_d(\Gamma_d - \Gamma_f)} > 0$. As $\Gamma_d > \Gamma_f$, we must have $\frac{k_d}{k_f} > \frac{\Gamma_d}{\Gamma_f}$. When θ_d is greater than θ_f, we have $1 - \frac{k_d}{p\Gamma_d} > 1 - \frac{k_f}{p\Gamma_f}$, or $\frac{\Gamma_d}{\Gamma_f} > \frac{k_d}{k_f}$. We therefore have $\theta_f > \theta_d$ when $\theta_d > \widetilde{\theta}$.

Under the same reasoning we can show that $\theta_d < \widetilde{\theta}$ implies that $\frac{k_d}{k_f} < \frac{\Gamma_d}{\Gamma_f}$ when $\Gamma_d > \Gamma_f$, so that we can deduce that we must have $\theta_d > \theta_f$.

A.2 Proof of Proposition 1

Both derivatives of k_d^* and k_f^* with respect to price p are always positive under the duopoly constraint. As a consequence, the effect of a price increase will always lead to a rise in power generation equipment prices at equilibrium. Remember that power generation equipment prices are strategic complements. If the domestic firm increases its price, the foreign rival's best strategy is to do the same.

In addition, the derivative of k_d^* with respect to price p is higher than the derivative of k_f^* . In other words, *ceteris paribus*, an unconditional FIT has a larger impact on the domestic power generation equipment price than on the foreign power generation equipment price.

A.3 Proof of Proposition 2

Plugging the equilibrium prices k_d^* and k_f^* into the demand functions gives the two following equilibrium demands for power generation equipment goods:

$$D_d^* = \frac{2p\Gamma_d\left(\Gamma_d\left(p + a\Gamma_f\right) - p\Gamma_f\right)}{4p\Gamma_d^2\left(p + a\Gamma_d\right) + \Gamma_d\Gamma_f\left(2a\Gamma_d\left(p + 2a\Gamma_d\right) - 5p^2\right) + p\Gamma_f^2\left(p - 2a\Gamma_d\right)} \tag{A.1}$$

$$D_f^* = \frac{p\Gamma_d\left(\Gamma_d\left(p + 2a\Gamma_d\right) - p\Gamma_f\right)}{4p\Gamma_d^2\left(p + a\Gamma_d\right) + \Gamma_d\Gamma_f\left(2a\Gamma_d\left(p + 2a\Gamma_d\right) - 5p^2\right) + p\Gamma_f^2\left(p - 2a\Gamma_d\right)} \tag{A.2}$$

The derivative of D_d^* with respect to p is always positive. Thus, guaranteeing a price $p_g > p$ increases domestic demand for power generation equipment. The derivative of D_f^* with respect to p is positive only if two conditions are met simultaneously:

$$k_d^* - k_f^* < 2a\,\varphi\left(\Gamma_d, \Gamma_f\right) \quad \text{and} \quad p < 2a\,\psi\left(\Gamma_d, \Gamma_f\right) ,$$

with $\varphi(\Gamma_d, \Gamma_f)$ and $\psi(\Gamma_d, \Gamma_f)$ having the following strictly positive values:

$$\begin{aligned}
\varphi(\Gamma_d, \Gamma_f) &= \frac{1}{\sqrt{\frac{2\Gamma_d - \Gamma_f}{\Gamma_d^3 \Gamma_f (\Gamma_d - \Gamma_f)}} - \frac{1}{\Gamma_d^2}} \\
\psi(\Gamma_d, \Gamma_f) &= \sqrt{\frac{\Gamma_d^5 \Gamma_f (2\Gamma_d - \Gamma_f)}{(\Gamma_d - \Gamma_f)\left(2\Gamma_d^2 - 2\Gamma_d\Gamma_f + \Gamma_f^2\right)^2}} + \frac{\Gamma_d^2 \Gamma_f}{2\Gamma_d^2 - 2\Gamma_d\Gamma_f + \Gamma_f^2}.
\end{aligned}$$

A.4 Proof of Corollary 1

The rise in renewable energy production under a guaranteed price results from the increases in θ_f and $\widetilde{\theta}$.

A.5 Proof of Proposition 3

Guaranteeing a price p_g higher than the market price for electricity p raises the profits of both power generation equipment producers since the profit functions $k_i(p)Q_i(p) - C_i(Q_i(p))$ $(i = d, f)$ are strictly increasing in p at equilibrium.

The electricity producers fall into two categories: those using domestic power generation equipment located in the segment $\left[0; \widetilde{\theta}\right]1$ and those using foreign power generation equipment in the segment $\left[\widetilde{\theta}; \theta_f\right]$. Implementing a FIT program pushes up $\widetilde{\theta}$ and θ_f. The rise in $\widetilde{\theta}$ means that at least one producer θ finds it more profitable to use domestic than foreign power generation equipment. As a consequence, the profit of each producer under θ increases under a FIT program. The rise in θ_f means that at least one producer θ finds it profitable to enter the market and produce using the foreign power generation equipment. Thus, the profit of each producer using foreign power generation equipment under θ increases under a FIT program. These two effects imply that electricity producers' total profits increase when a guaranteed price higher than the market price is proposed.

A.6 Proof of the Proposition 4 and Corollary 2

The welfare expression defined in (11) is strictly increasing in p. However, the sign of its second derivative is undefined. The amount that has to be spent to implement the FIT program, $\lambda k w_g(p_g - p)$ is strictly increasing at a decreasing rate. As a consequence, the welfare expression in (13) may be increasing in p (strictly or eventually after reaching a minimum) or continuously decreasing in p. No p_g maximizing the domestic welfare can thus be determined.

A.7 Proof of Proposition 5

First, we can show that $k^*_{d,cg} > k^*_d$. Second, the inequality $k^*_{f,cg} < k^*_f$ does not hold for all parameter values. For clarity we do not provide the different conditions under which the above inequality holds. We provide *Mathematica* outputs for further details.

A.8 Proof of Proposition 6

At equilibrium, the demand for domestic power generation equipment is the following:

$$D^*_{d,cs}\left(\Gamma_d,\Gamma_f\right)=\frac{2p_g\Gamma_d\left(p_g\Gamma_d\left(p+a\Gamma_f\right)-p^2\Gamma_f\right)}{4p_g^2\Gamma_d^2\left(p+a\Gamma_f\right)+p^2\Gamma_f\left(p\Gamma_f-2a\Gamma_d^2\right)+p_g\Gamma_d\left(4a\Gamma_d^2\left(p+a\Gamma_f\right)-p\Gamma_f\left(5p+2a\Gamma_f\right)\right)} \tag{A.3}$$

The impact on the demand for domestic power generation equipment of a LCR in a FIT can be calculated as $D^*_{d,cs}-D^*_d$ with D^*_d calculated at p_g using equation A.1. The positiveness of this difference is verified under two conditions:

$$p<a\kappa\left(\Gamma_d,\Gamma_f\right) \tag{A.4}$$

$$p_g<\xi\left(a,\Gamma_d,\Gamma_f\right) \tag{A.5}$$

where κ and ξ are positive functions defined as following:

$$\kappa\left(\Gamma_d,\Gamma_f\right)=\frac{4\Gamma_d\Gamma_f\left(2\Gamma_d-\Gamma_f\right)}{\sqrt{4\Gamma_d^4+8\Gamma_d^3\Gamma_f-32\Gamma_d^2\Gamma_f^2+28\Gamma_d\Gamma_f^3-7\Gamma_f^4}-1} \tag{A.6}$$

$$\begin{aligned}\xi\left(a,\Gamma_d,\Gamma_f\right)=&\frac{2ap\Gamma_d^2+\Gamma_f\left(p^2a\Gamma_d\left(p+2a\Gamma_d\right)\right)}{2\Gamma_d\left(a\Gamma_f+p\right)}\\&+\frac{\sqrt{\frac{4ap\Gamma_d^4(a\Gamma_d+p)(2a\Gamma_d+p)-\left(\Gamma_d-\Gamma_f\right)4ap\Gamma_d^3(2a\Gamma_d(a\Gamma_d+p)+p^2)}{\Gamma_d-\Gamma_f}}}{2\Gamma_d\left(a\Gamma_f+p\right)}\\&+\frac{\sqrt{\left(a\Gamma_d+p\right)\left(2a\Gamma_d+p\right)\left(p^2+a\Gamma_d\Gamma_f^2\left(2a\Gamma_d-p\right)\right)}}{2\Gamma_d\left(a\Gamma_f+p\right)}\end{aligned}$$

A.9 Proof of Proposition 6

At equilibrium, the demand for foreign power generation equipment is as follows:

$$D^*_{f,cs}\left(\Gamma_d,\Gamma_f\right)=\frac{pp_g\Gamma_d\left(\Gamma_d\left(p_g+2a\Gamma_d\right)-p\Gamma_f\right)}{4p_g^2\Gamma_d^2\left(p+a\Gamma_f\right)+p^2\Gamma_f\left(p\Gamma_f-2a\Gamma_d^2\right)+p_g\Gamma_d\left(4a\Gamma_d^2\left(p+a\Gamma_f\right)-p\Gamma_f\left(5p+2a\Gamma_f\right)\right)} \tag{A.7}$$

The impact on the demand for foreign power generation equipment of a LCR in a FIT is computed as $(D^*_{f,cs}-D^*_f)$ with D^*_f calculated at p_g using equation (A.2). This difference is always negative.

Conditioning the FIT to LCR has an ambiguous effect on the foreign firm's profit. As the intuition suggests, it is not always negative. The FIT can have a positive impact $(\Pi^*_{f,cg}>\Pi^*_f)$ under the types of constraints below.

$$a<\bar{a}_1,\quad \text{with}\quad p_g>p,\quad \text{or,}$$

$$\bar{a}_2<a<\bar{a}_3,\quad \text{with}\quad p<p_g<\bar{p}_g\,.$$

A.10 Proof of Corollary 4

Proposition 6 shows that the FIT program with a LCR systematically decreases the demand for foreign power generation equipment. Also, Proposition 6 shows that the program increases demand for domestic power generation equipment only under certain circumstances. Therefore, the production of renewable energy may decrease under this program.

B Graphs

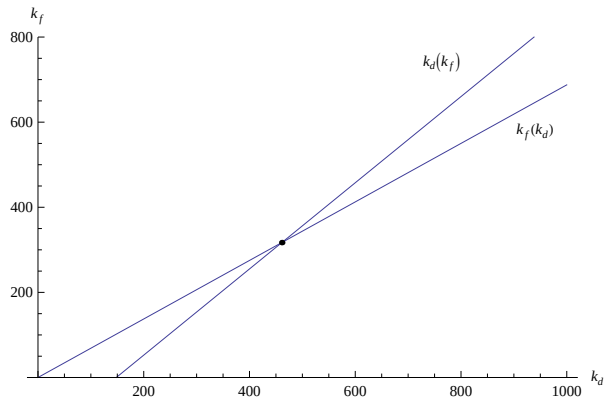

Figure B.1: Nash equilibrium in power generation equipment prices
($a = 2.34$, $\Gamma_d = 50$, $\Gamma_f = 35$, and $p = 10$)

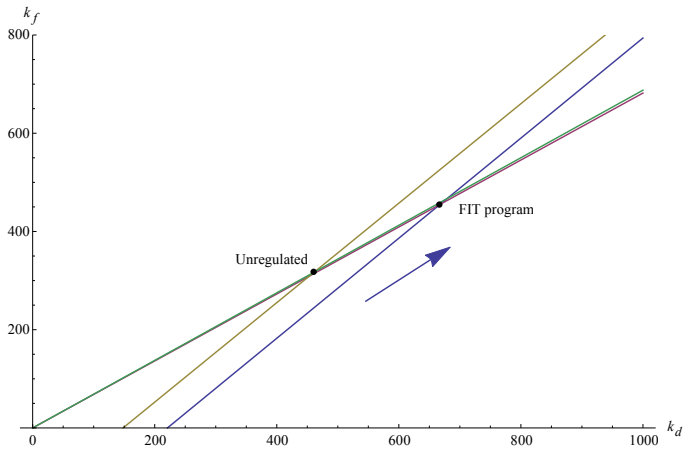

Figure B.2: Nash equilibrium in power generation equipment prices: The effect of an unconditional feed-in tariff ($a = 2.34$, $\Gamma_d = 50$, $\Gamma_f = 35$, $p = 10$, and $p_g = 15$)

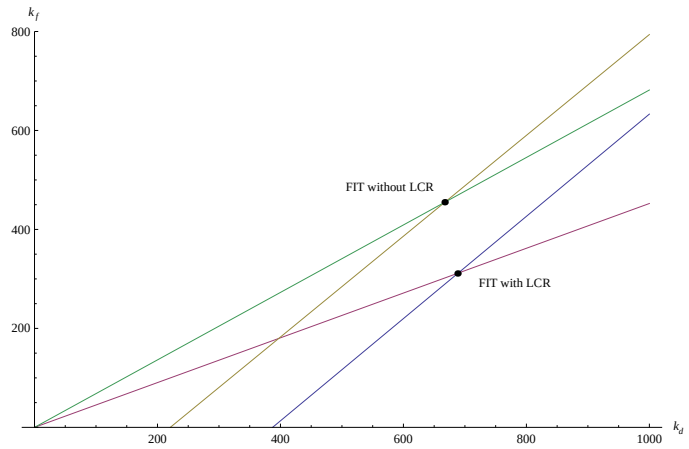

Figure B.3: Nash equilibrium in power generation equipment prices: Unconditional versus conditional feed-in tariffs ($a = 2.34$, $\Gamma_d = 50$, $\Gamma_f = 35$, $p = 10$, and $p_g = 15$)

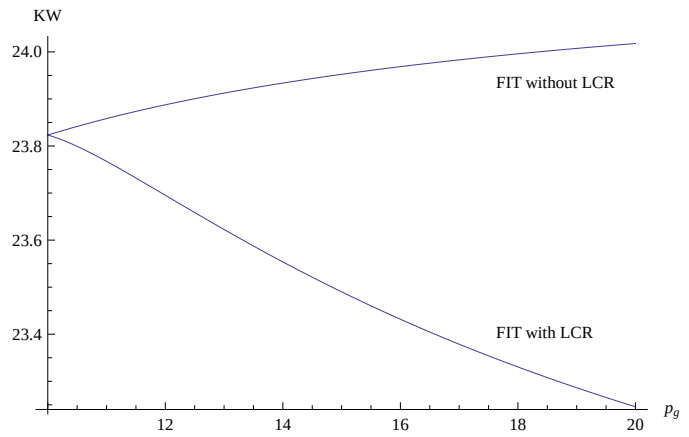

Figure B.4: The effects of a FIT Program on the amount of renewable energy ($a = 0.01$, $\Gamma_d = 50$, $\Gamma_f = 40$, $\gamma = 1$, $\lambda = 1.2$, and $p = 10$)