Impacts of the German Support for Renewable Energy on Electricity Prices, Emissions, and Firms

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Most models that are used to analyze support policies for renewable electricity neglect important market features like oligopolistic behavior, emission trading, and restricted cross-border transmission capacities. We use a quantitative electricity market model that accounts for these aspects and decompose the impact of the German Feed-in tariff (FIT) into two frequently counteracting effects: a substitution effect and a permit price effect. We find that the total effect of the policy increases the German consumer price slightly by three percent, while the producer price decreases by eight percent. In addition, emissions from electricity generation in Germany are reduced by eleven percent but are hardly altered on the European scale. Finally, it turns out that price-cost margins of almost all firms are increased by the FIT, while nonetheless, the profits of firms are significantly lowered unless the firms combine relatively carbon-intensive production with a weak connection to the German grid.

1. INTRODUCTION

Today, in most industrialized countries, renewable energy is supported by policy schemes to bring this favorable option to the market. When compared with fossil sources, major advantages attributed to renewable energies include low carbon emissions, sustainability, and enhanced security of supply. Unfortunately, with the exception of long-established large hydropower, renewable energies come at a high price. The hope of the industrial policy makers is that the renewable energy technologies will break even once they are more developed and the external effects of CO_2 emissions are priced in. Therefore, Germany and many other European countries grant a so-called feed-in tariff (FIT) to certain renewable energy technologies. The FIT obliges the established electricity sector to accept any amount of electricity provided by renewable energy producers at the politically predeter-

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mined tariff, while its burden is distributed among suppliers. In addition, the European Emission Trading System (ETS) creates a price for carbon emissions.

The ETS and the FIT do not act independently of each other. On the one hand, the ETS decreases the cost disadvantage of renewable energy supply (RES) and, thus, reduces the costs of renewable support. On the other hand, the support of RES substitutes conventional electricity production and subsequent emissions, leading to a reduction of the emission permit price. Furthermore, these interactions take place on a market that is suspect to market power which influences the channels of the submission of the different price effects. Therefore, our paper elaborates in a quantitative setting the feed backs of the ETS and the influence of market power on the functioning of the FIT in Germany.

Two strands of the literature are of special relevance to our study. The first stream of publications analyzes the compatibility of multiple policy instruments on energy markets. This literature can be separated into analytical and numerical investigations, of which the majority uses analytical models. Amundsen (2001) uses a partial equilibrium model to investigate the interaction of the ETS with green certificates, which create a certain renewable energy quota by means of a market system. He derives comparative static results and shows that trade in electricity matters for the effects of a tightening of the ETS's emission cap on green certificate prices. Morthorst (2001) develops a framework in which he analyzes the interaction of an ETS with the effects of internationally tradable green certificates. He finds that in the absence of an ETS, international trade in green certificates will be biased towards domestic capacity expansion, if a national value is attributed to the induced emission reduction. In a similar three country model, Morthorst (2003) analyzes the promotion of renewable energy usage by alternative instruments and derives results which suggest that renewable energy support schemes are questionable climate policy instruments when an ETS is present. He suspects that a coordinated policy would be more efficient, i.e. the ETS should be tightened if more renewable electricity is induced by other policies. Jensen and Skytte use static models to analyze the impact of green certificates on electricity prices (2002) and the combination of green certificates with an ETS when an emission goal and a renewable energy goal are simultaneously targeted (2003). They find that the effect of a simple green certificate market on electricity prices is ambiguous and that the optimal combination of instruments to reach two goals simultaneously depends on the cost structures. In contrast to analytical treatments, little work has utilized numerical models. One example is provided by Rathmann (2007), who analyzes the support for renewable energy created by the German feed-in tariff by using a model in which he applies assumptions on the cost structure based on real world data. He shows that renewable energy support can reduce electricity prices for certain parameter values.

The second stream of related literature applies numerical models to the analysis of electricity markets under the suspicion of market power. Models that focus on the problem of the presence of market power naturally apply ex post analysis and compare competitive benchmark results with observed market outcomes. An early example is the study of the British electricity spot market of Wolfram (1999) which found significant mark-ups priced on top of marginal costs in the years 1992, 1993, and 1994. However, the full mark-up that a static Cournot model predicted was not reached. Similar results have been found by Borenstein et al. (2002), and Joskow and Kahn (2002) who applied competitive benchmark methods for the Californian electricity market in the year 2000. Again, the observed prices could not be explained only by costs. The paper by von Hirschhausen et al. (2007) provides a comprehensive literature survey on further studies that find market power on electricity markets with a focus on recent developments on the German market. In addition, the authors show with several methods that the German electricity prices still indicate imperfections ex post. The methodology applied in these studies is, however, subject to criticism, e.g. by Swider et al. (2007). One major line of attack points to the lack of detail, especially in regard to start-up costs in the construction of the marginal costs curves. The analysis conducted by Weigt et al. (2008), however, explicitly accounts for the costs induced by start-up processes with a model of high time resolution and still finds significant deviations from the observed market outcomes, amounting on average to mark-ups of eleven percent in baseload, and to thirty percent in peak load periods. These findings suggest that market power is still an important feature, at least of the German electricity market. Therefore, we develop a model that calculates an oligopolistic benchmark together with results that would occur under perfect competition. This procedure allows us to assess the "space of possible static, non cooperative outcomes" as Bushnell et al. (2008) put it.

Many studies of electricity markets take oligopolistic behavior into account. A ground-breaking work is the paper of Green and Newberry (1992) who use a model of duopolistic firms without transmission restrictions which is calibrated to reproduce historic seasonal market outcomes as close as possible. They find that market power has been an important market determinant of the British electricity market in the years 1988 and 1989, and that a division of dominant firms would most likely result in preferable market outcomes.

When one focuses on the electricity grid properties in the presence of market power, a high time resolution and a complex regional resolution may become necessary. An early example of such analysis is provided by Jing-Yuan and Smeers (1999) who develop spatial oligopolistic electricity models with Cournot competition on the producer side and regulated transmission prices. They find that the restrictions of the international transmission lines between France, Italy and Germany, an increased competition is unlikely to emerge from the electricity market liberalization in these countries. In a similar vein, Hobbs (2001) compares market designs with and without arbitrageurs between supply and demand hubs in a Cournot-Nash framework that takes into account both Kirchhoff's laws in a complex nodal structure. He computes unique solutions under the simplifying assumption of price-taking behavior of producers in regard to transmission prices. In a small example for the UK he finds ex ante a welfare enhancing effect of the presence of arbitrageurs in the case of assumed Cournot behavior in regard to output.

In a model Comparison study, Neuhoff et. al (2005) show the variety of outcomes that Cournot models of electricity generation and transmission can yield if transmission is itself subject to market power. Although under perfect competition the model results almost match each other, largely different results are obtained which are contingent on minor differences in specification, e.g. the timing of the game. Since our paper focuses on the potential influence of market power on the producer side of the market, we follow the approach of Hobbs (2001) and assume price taking behavior in regard to transmission prices.

A similar specification of transmission pricing has been applied in Amundsen and Bergman (2002). They investigate the impact of cross-ownership on the Nordic power market in a Cournot framework with competitive fringe firms, and cross-border transmission constraints. They find that increased cross-ownership might re-establish market power. A more recent example for market power analysis in electricity markets is provided by Bushnell et al. (2008), who investigate ex post the impact of vertical structures in a hourly resolved model for different markets in the US and find that the presence of vertical arrangements are an important feature for the evaluation of market conduct. They stress the importance of thorough market analysis not only in regard to horizontal market structure, but also in regard to vertical structures prior to ex post policy recommendations. Clearly, this caveat applies also to our analysis.

Few numerical models have so far addressed questions related to emission policies in oligopolistic frameworks. Among these, the model used in Lise et al. (2006) is of special relevance for our study. This model is developed on the basis of the original model documented in Kemfert (2007) that has been applied to the investigation of the liberalization of the German electricity market. In comparison with the original model, Lise et al. introduce several refinements. They extend the country coverage of the model to the Northwestern European electricity market, including Belgium, Denmark, Finland, France, Germany, the Netherlands, Norway and Sweden. In addition, an emission cap for the electricity sector's CO_2 has been implemented. Moreover, the technological richness in the power plant representation has been enhanced, and emissions of different pollutants are considered. Finally, the model incorporates peak and baseload demand. The model is applied to analyze the environmental impact of different behavioral assumptions as well as of demergers under emission trading. One major find of Lise et al. (2006) is that a restructuring of large companies in Belgium and France could benefit the environment and the consumers if market power is present.

The model EMELIE EUR-25, developed in the present paper, shares many features with the model of Lise et al. (2006). However, major differences between the models exist. Firstly, the model EMELIE EUR-25 covers the whole European electricity market.[1] Secondly, the scope of emission policy has been broadened. On the one hand, emission trading covers all sectors which are in-

1. Countries that are not connected to the continental European electricity grid (Cyprus, Ireland, Malta) are not included, while Luxembourg is represented in the German market. In addition to EU countries, Norway and Switzerland are represented, hence EUR-25.

cluded in the ETS. On the other hand, the support for renewable energy by the FIT has been implemented. Thirdly, the representation of the cost functions and the emission functions of electricity production differs from the previous EMELIE applications. For EMELIE EUR-25, we constructed upward sloping marginal cost and emission functions. Fourth, Lise et al. (2006) calculate a sequential Stackelberg leader follower game in addition to perfect competitive equilibria and static Cournot-Nash equilibria in the presence of a competitive fringe. By contrast, we focus on the assumption of static Cournot quantity competition in order to provide a upper bound for market power and its impact on the analyzed RES support.

Figure 1. Model Coherence

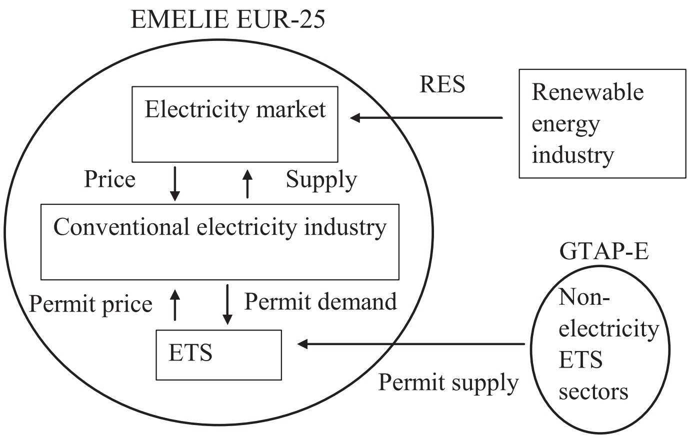


Figure 1 depicts the coherence of the model. The core of the EMELIE EUR-25 model, and the focus of the analysis, is indicated by the red circle. It consists of the conventional electricity sector which is framed by the markets for electricity and emission permits. To the contrary, the non-electricity sectors included in the ETS, and the renewable energy supply sector are not included in our analysis. To assess the supply of emission permits from the non-electricity sectors, we applied the GTAP-E model documented in Truong et al. (2007) for a wide range of emission prices. The resulting estimated supply curve has been used to model the emission market. In regard to renewable energy, we assume either a supply of the current value if the actual FIT is granted or zero supply if no FIT is present. Hence, we abstract from any effects on the renewable energy suppliers.[2]

The focus of our analysis is on the ex post explanation of German FIT's effect on German and European electricity prices, electricity sector emissions, and the mark-up and profit of major conventional electricity producers. In our

2. This abstraction is justifiable insofar that the renewable energy suppliers and the conventional electricity firms are distinct actors in Germany. The incumbent firms do not own significant RES capacity.

baseline setting we assume Cournot-Nash behavior of dominant producers, since, as outlined above, market power seems to be prevailing on the German market. To identify the influence of the feed-back of the emission market, we decompose the total effects of the FIT into substitution and permit price effects. Moreover, we choose sensitivity scenarios that highlight the influence of the central assumption of oligopolistic competition, the availability of transmission capacities, and emission permit supply of other sectors.

The article is organized as follows. In the next section, we introduce an algebraic formulation of the model. In section three, we provide a description of the data concerning the cross-border transmission capacities between countries and the largest players on the electricity market in Europe: plant types as well as marginal cost-and marginal emission functions. In section four, we describe the scenario choice and present results for producer and consumer prices, emissions, relative mark-ups and the profits of fourteen electricity firms in the EU. In addition, section four carries out a sensitivity analysis which shows the robustness of our results. Section five summarizes the findings and concludes with an outlook on future research prospects.

2. THE MODEL

We model the European electricity industry consisting of n conventional electricity producers indexed i, which form the set of producers I.[3] Each firm is related to one country r, which is member of the set of countries R. Each production level y^i of firm i corresponds to a cost and emission level according to the following cost and emission functions: $c^i_y(y^i)$ and $e^i_y(y^i)$. The production y^i of each firm is restricted by its installed capacity $\bar{y}^i$ and may be supplied to the home country r or to the foreign country r^* such that $y^i = \sum_{r \in R} s^{i,r}$, where $s^{i,r}$ denotes the supply of firm i to country r. To put it differently, we assume that the supply of a firm is completely covered by its production.

Furthermore, we take the limitation of international electricity transmission into account. The total electricity export from the home country r to the foreign market r^*, $Ex^{r,r^*}(\tau^{r,r^*})$, is restricted by the installed transmission capacity $\overline{Ex}^{r,r^*}$ between the respective countries and depends on the price for cross-border transmission service τ^{r,r^*}. We assume that the market for transmission service clears at the nonnegative price for transmission service such that: $\overline{Ex}^{r,r^*} \geq Ex^{r,r^*}(\tau^{r,r^*})$, and $\tau^{r,r} = 0$ for transmission service inside a country.

Similarly, the permit price σ is determined on the emission market, which is restricted by the total emission cap $\bar{E}$ and depends on the total demand for emission permits of the electricity sector $E(\sigma)$ and of the non-electricity sectors that are included in the ETS: $E^{nely}(\sigma)$. Market clearing on the emission permit market, $\bar{E} = E(\sigma) + E^{nely}(\sigma)$, results in a nonnegative permit price.

In addition to conventional energy, renewable energy is supplied at the given regional FIT ζ^r to the electricity market of country r, and, hence, the total

3. See Table 1 for an overview of the notation of the model.

supply in a country, Q^r, is the sum of renewable energy Z^r and conventional energy supply S^r: $Q^r = S^r + Z^r$. The burden of the FIT is equal to the product of the amount of renewable energy and the difference between FIT and producer price and is evenly distributed among the total supply of electricity to that country. Consequently, the regional FIT drives a wedge equal to $(\zeta^r - P^r_S)\, Z^r / Q^r$ between the regional producer price of the conventional sector P^r_S and the regional consumer price $P^r(Q^r)$ written as the inverse demand. In equilibrium, the inverse demand equals the sum of the producer price for conventional production plus the average extra costs of the tariff: $P^r(Q^r) = P^r_S + (\zeta^r - P^r_S)\, Z^r / Q^r$. Isolation of the producer price yields: $P^r_S = P^r(Q^r)\,(Q^r / S^r) - \zeta^r\,(Z^r / S^r)$, which can be interpreted as the inverse demand faced by the conventional producers.

The problem of firm i can be stated as the following Lagrangian of the Kuhn-Tucker type:

$$L^i = \sum_{r \in R} \left(P^r\left(Q^r\right) \frac{Q^r}{S^r} - \zeta^r \frac{Z^r}{S^r} \right) s^{i,r} - C^i\left(y^i\right) - \sigma E^i\left(y^i\right) + \kappa^i\left(\bar{y}^i - y^i\right) - \sum_{r^* \neq r} \tau^{r,r^*} s^{i,r^*}, \tag{1}$$

where κ denotes the shadow price of the capacity restriction. The first term on the right hand side of equation (1) sums up the revenues from supply in all countries, the second term accounts for the production costs, the third for the costs of emission permits, the fourth for the restriction of production capacity, while the last sum accounts for the cross-border transmission costs for the restricted supply into foreign countries. The optimality conditions of the problem can be summarized in the following way:

$$\frac{\partial L^i}{\partial s^{i,r}} \le 0, \qquad s^{i,r} \ge 0, \qquad \frac{\partial L^i}{\partial s^{i,r}} s^{i,r} = 0,$$

$$\frac{\partial L^i}{\partial \kappa^i} \ge 0, \qquad \kappa^i \ge 0, \qquad \frac{\partial L^i}{\partial \kappa^i} \kappa^i = 0, \qquad \forall r \in R, \forall i \in I.$$

The main driver of the model is the derivative of the Lagrangian with respect to the supply of the firm in a certain country: $\partial L/\partial s^{i,r}$, which is dependent on the assumed market behavior. In our model we can represent two behavioral assumptions of firms: price-taking behavior and strategic quantity-setting behavior à la Cournot. We start with the analytically simpler case of price-taking behavior. The derivative of the problem of the price-taking firm with respect to supply can be written as:

$$\frac{\partial L^i}{\partial s^{i,r}} = P^r\left(Q^r\right) \frac{Q^r}{S^r} - \zeta^r \frac{Z^r}{S^r} - C^i_y\left(y^i\right) - \sigma E^i_y\left(y^i\right) - \kappa^i - \tau^{r,r^*}. \tag{2}$$

The first order condition (2) resembles the well known marginal cost pricing rule under perfect competition. Here the price is the producer price derived above and the marginal costs include the marginal emission costs $\sigma E^i_y(y^i)$, the shadow price of production capacity and the price of cross-border transmission service.

Table 1. Notation

I	Set of firms
R	Set of countries
$P^r(Q^r)$	Inverse demand for electricity in country r
P^r_0	Consumer price of electricity in country r in the base period
P^r_S	Producer price of electricity in country r
σ	Emission permit price
Q^r	Electricity consumption in country r
Q^r_0	Electricity consumption in country r in the base period
$E(\sigma)$	Total emissions of the electricity sector
$E^{nely}(\sigma)$	Total emissions of the non-electricity sector
$Ex^{r,r*}$	Export from country r to $r*$
y^i	Electricity production of firm i
Q^r	Total electricity supply in country r
$s^{i,r}$	Electricity supply of firm i in country r
S^r	Total electricity supply of conventional firms in country r
Z^r	Renewable electricity production in country r
ζ^r	Feed-in tariff in country r
$C^i(y^i)$	Costs of electricity production of firm i with marginal costs $C^i_y(y^i)$
$E^i(y^i)$	Emissions of electricity production of firm i with marginal emissions $E^i_y(y^i)$
$\overline{y}^i$	Capacity restriction of power plants of firm i
$\overline{Ex}^{r,r*}$	Transmission restriction from country r to $r*$
κ^i	Shadow price of capacity restriction of installed power plants of firm i
$\tau^{r,r*}$	Price of cross-border transmission capacity from country r to $r*$
ε^r	Residual demand elasticity
$\vartheta^{i,r}$	Market share of firm i in country r
$PCM^{i,r}$	Price-cost margin of firm i in country r
l^i	Binary variable representing different behavioral assumptions with regard to firm i
a^i,b^i	Axis intercept and slope parameter of the marginal cost function of firm i
f^i,g^i	Axis intercept and slope parameter of the marginal emission function of firm i

Under Cournot behavior, the firms take the effect on the revenue caused by the choice of output into account. If we write the residual demand elasticity[4] as

$$\in^r = \left| \frac{dQ^r}{dP^r} \frac{P^r_0}{Q^r_0} \right|$$

and the regional market share of firm *i*, $\vartheta^{i,r}$, the derivative of problem (1) with respect to the supply in a Nash equilibrium can be expressed as:

$$\frac{\partial L^i}{\partial s^{i,r}} = P^r\left(Q^r\right)\frac{Q^r}{S^r} - \zeta^r \frac{Z^r}{S^r} - C_q^i\left(y^i\right) - \sigma E_q^i\left(y^i\right) - \kappa^i - \tau^{r,r*}$$
$$-\vartheta^{i,r}\left(\frac{P^r(Q^r)}{\in^r} - (P^r(Q^r) - \zeta^r)\frac{Z^r}{Q^r}\right). \tag{3}$$

If we compare the optimality conditions under the Cournot-Nash assumption with those of the price-taking case, it is apparent that only a term which depends on the market share is added in equation (3). The last term in equation (3) is the total mark-up which includes the mark-up $\vartheta^{i,r}$ $P^r(Q^r)/\in^r$ known from conventional oligopoly models, and the term $\vartheta^{i,r}(P^r(Q^r) - \zeta^r)\, Z^r/Q^r$ induced by the FIT ζ^r which adds to the total mark-up if the FIT is greater than the consumer price P^r. This second term results from the firm's conjecture about a constant output of its rivals in the Nash-equilibrium with regard to a marginal change in its own output. Consequently, the firm reckons with an increase of market share after its output increase. Since the burden of the FIT is distributed in accordance with the market shares, the firm takes the change of the burden subsequent to a change in the market share into account. Therefore, the oligopolists reduce their output after the introduction of the FIT more drastically when compared to the reaction of price-taking firms. For the analysis of market power, we divide the total mark-up by the producer price and get the following price-cost margin

$$PCM^{i,r} = \frac{\vartheta^{i,r}}{P_S^r}\left(\frac{P^r(Q^r)}{\in^r} - (P^r(Q^r) - \zeta^r)\frac{Z^r}{Q^r}\right). \tag{4}$$

The *PCM* defined in (4) will be our measure of market power in the analysis of results in section 4. The combined optimality condition for price takers and strategic firms can be expressed as

$$\frac{\partial L^i}{\partial s^{i,r}} = P^r\left(Q^r\right)\frac{Q^r}{S^r} - \zeta^r \frac{Z^r}{S^r} - C_q^i\left(y^i\right) - \sigma E_q^i\left(y^i\right) - \kappa^i - \tau^{r,r*}$$
$$-l^i\vartheta^{i,r}\left(\frac{P^r(Q^r)}{\in^r} - (P^r(Q^r) - \zeta^r)\frac{Z^r}{Q^r}\right), \tag{5}$$

4. The residual demand elasticity refers to the demand elasticity after the supply of the price taking firms is subtracted.

where the binary variable l^i is set to zero in the case of price-taking firms and to 1 in the case of dominant firms.

3. DATA AND CALIBRATION

The supply side of the model is represented by a bottom-up approach where generation capacities are characterized by the used energy carrier -water, uranium, hard coal, lignite, natural gas and heavy oil -and, in case of the thermal power plants, additionally by the technology that is applied. Altogether, the production capacity is represented by twelve technology classes where the thermal production technologies are described in Table 2. Both power plants that burn solid fossil fuels and the nuclear power plants use steam turbines for electricity generation. These plants are classified into efficiency clusters ranging from 32 percent in the case of small nuclear power plants to 43 percent for comparatively new hard coal and lignite firing units. Natural gas and heavy oil are used in power plants equipped with gas turbines as well as steam turbines. The combination of both technologies – the so-called combined cycle gas turbines (CC) – reach the highest efficiencies ranging from 52 to 59 percent with an average of about 55 percent. In accordance with these efficiency parameters, and fuel prices that are taken from IEA (2006), the variable costs of the technologies, which include own estimates of operation and maintenance costs, range between 0.66 and 6.35 Eurocent per kilowatt hour. The specific emissions are between 0 and 1.17 kg CO_2 per kilowatt hour.

Table 2. Technologies of Conventional Power Plants in the Model

Fuel type	Plant type	Fuel price* [€-cent/kWh$_{fuel}$]	Efficiency [%]	Emissions factor [kg/kWh$_{el}$]	Variable cost [€-cent/kWh$_{el}$]
Uranium	small	0.21	0.32	0.00	0.66
	large	0.21	0.34	0.00	0.76
Lignite	old	0.45	0.34	1.17	1.58
	new	0.45	0.43	0.93	1.31
Hard coal	old	0.72	0.34	1.01	2.33
	new	0.72	0.43	0.79	1.88
Natural gas	gas turbine	2.17	0.35	0.57	6.35
	steam turbine	2.17	0.40	0.49	5.57
	combined cycle	2.17	0.55	0.36	3.87
Heavy oil	gas turbine	1.72	0.33	0.84	5.37
	steam turbine	1.72	0.38	0.73	4.69

*Fuel prices are taken from IEA (2006) or, for lignite, based on own calculations.

Furthermore, the simulation of strategic behavior demands a detailed assessment of the plant ownership structure of the dominant players. Therefore, a database has been constructed on the basis of annual reports and Meller et al.

(2006), where a thorough description of the companies including main assets and ownership structure can be found. Table 3 summarizes the resulting capacities that are available for the fourteen largest companies and their major foreign subsidiaries based on a multiplicative calculation of effective shares in cases where several ownership layers are present. Based on these figures, we calculated continuous marginal costs and emissions functions for annual electricity supply of the dominant firms and the competitive fringe in each country. The marginal cost function of firm *i* is

$$C_y^i(y^i) = a^i \exp(b^i \frac{y^i}{\bar{y}^i}), \quad (6)$$

where $\bar{y}^i$ denotes the maximum annual generation of firm *i* in country *r*. The emission functions are closely linked to the production. Each production level of firm *i* yields a unique level of marginal emissions. The marginal emissions function of firm *i* for production in country *r* is:

$$E_y^i(y^i) = f^i \exp(g^i \frac{y^i}{\bar{y}^i}), \quad (7)$$

Table 3. Net Capacities [GW] of the Fourteen Largest Firms in the Europe Union

Firm	Hydro	Nuclear	Coal	Gas & Oil	Total
EdF (FR)	6.51	62.96	6.38	6.89	82.75
Enel (IT)	2.43	0.00	8.48	22.18	33.09
E.ON (DE)	1.51	7.64	11.25	5.35	25.75
RWE (DE)	0.64	3.54	13.07	3.00	20.25
Endesa (ES)	1.95	2.63	6.76	5.97	17.32
E.ON (UK)	0.00	0.00	8.66	6.53	15.19
Vattenfall (DE)	0.00	1.42	8.97	2.75	13.14
Vattenfall (SE)	6.74	5.12	0.13	0.93	12.91
Iberdrola (ES)	3.78	1.73	0.67	5.84	12.02
British Energy (UK)	0.00	9.28	1.72	0.00	11.00
Suez (BE)	0.00	4.68	1.32	3.15	9.14
EnBW (DE)	0.43	4.02	3.08	1.48	9.01
EDP (PT)	3.03	0.00	1.81	2.04	6.88
FNM (Cz)	0.47	2.34	3.89	0.05	6.75

Source: Own calculations based on Meller et al. (2006) and annual reports.

The values for the parameters of the marginal cost and emission functions of the fifteen largest firms of the EU represented in the model are listed in Table 4. Furthermore, the transmission capacities between countries are calculated from ETSO (2006) net transfer capacities where summer and winter indicative values are equally weighted with half a year in order to receive maximum annual transfer capacities.

Table 4. Parameters of the Marginal Cost and Emission Functions of the Fifteen Largest Firms in Europe

Firm	$\bar{y}$ [TWh]	a [€-cent/kWh]	b	f [kg CO_2 /kWh]	g
EdF (FR)	613.8	0.6	0.4	0.0	2.1
Enel (IT)	242.3	1.8	0.0	0.6	0.1
E.ON (DE)	188.7	1.3	0.2	0.5	0.2
RWE (DE)	149.6	1.5	0.1	0.7	0.1
Endesa (ES)	126.3	1.5	0.1	0.5	0.2
E.ON (UK)	110.9	1.8	0.0	0.8	0.1
Vattenfall (DE)	97.6	1.5	0.1	0.8	0.1
Vattenfall (SE)	90.7	0.7	0.9	0.2	0.5
Iberdrola (ES)	86.4	1.1	0.3	0.2	0.6
British Energy (UK)	82.2	0.8	0.3	0.1	2.0
Suez (BE)	68.4	1.8	0.4	0.2	0.5
EnBW (DE)	66.4	1.1	0.2	0.3	0.4
EDP (PT)	50.0	0.9	0.0	0.4	0.4
FNM (Cz)	49.9	1.1	0.1	0.6	0.3

The reference demand and reference prices are taken from Eurostat[5] or, if available, from electricity market places.[6] For the calibration of the model, the residual demand elasticity ε^r of the inverse isoelastic demand function $P^r(Q^r) = P^r_0 (Q^r/Q^r_0)^{\frac{1}{\in^r}}$ is chosen to replicate the benchmark values for prices and quantities in Germany under price-taking behavior of minor actors and strategic behavior of dominant firms à la Cournot. The value for the residual demand elasticity found for a good replication of the benchmark under a assumed permit price of 20 Euro per ton of CO_2 has been 0.47.

Finally, on the market for emission permits, the total supply is fixed by the amount of permits that are allocated by the national authorities. As the model is calibrated on values of the year 2006, the allocation of the first trading period broken down to annual allocation applies. We assume a total allocation for one year to be 2234 million tons of carbon dioxide.[7] The demand side of the emission market can be broken down into two parts, i.e. the demand of the electricity sec-

5. Draft from September the 4th, 2006 where a discount of fifty percent on tax free prices has been applied to account for transmission and distribution services

6. Amsterdam Power Exchange (apx), Amsterdam; Powernext, Paris; European Energy Exchange (EEX), Leipzig; Mercado de Electricidad (OMEL), Madrid; NordPool, Oslo.

7. The figure is in line with Deutsche Emissionshandelsstelle (2005) and the information on the internet page of the European Commission while taking the opt-in reserve into account.

tor, which is calculated directly by the EMELIE model, and the demand of the non-electricity emission trading sectors. The determination of the non-electricity permit demand simulations based on the GTAP-E model yielded the following permit demand of the non-electricity emission trading sector in mega tons of CO_2 in dependence of the permit price σ

$$E^{nely}(\sigma) = 1032 - 40.35\ln(\sigma), \tag{8}$$

where the first term on the right hand side is the baseline emission, and the second term represents the permit supply curve of the non-electricity sector.

4. RESULTS

For the presentation of the results, we first describe in subsection 4.1 the scenario choice and introduce the central outcomes attained under our baseline assumptions, i.e. oligopolistic competition with a competitive fringe, in terms of price effects of the FIT on the German market. In subsection 4.2, we introduce the respective price effects on the European markets and consider additionally the effects in regard to emissions of the European electricity sector. Subsection 4.3 highlights the oligopolistic behavior of the firms by showing how the mark-ups are impacted by the FIT under the baseline assumption. The section 4.3 also reports on the FIT effect on the profits of major firms in order to identify possible winners and losers of the RES support in the conventional industry. Finally, subsection 4.4 tests the sensitivity of the model by changing the baseline assumption in regard to market behavior of German firms, emission permit supply of non-electricity ETS sectors, and the availability of cross-border transmission capacity.

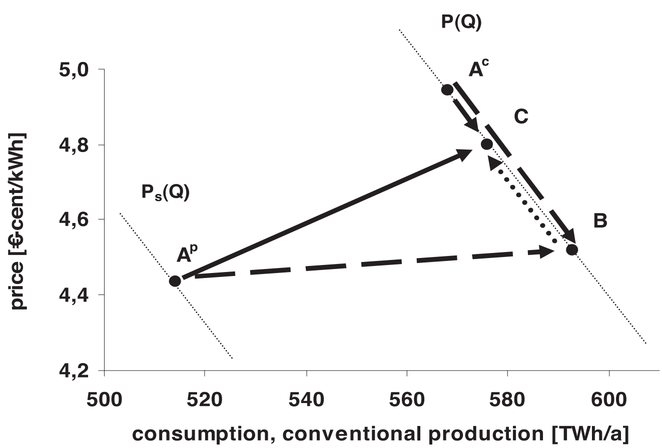
4.1 Scenarios and Basic Effects

We study three scenarios, which allow us to decompose the overall effect of the FIT into a permit price effect and a substitution effect. The baseline scenario A represents the situation in Germany in 2006 with 54 terawatt hours RES supported by an average FIT of 10.3 euro cent and with an ETS with endogenous emission prices. For scenario B, we fix the permit price at the baseline level and remove the RES. Finally, in scenario C, we remove the RES and allow for endogenous determination of the permit price. Figure 2 shows the price and quantity effects on the German electricity market under oligopolistic behavior.

In the baseline scenario A, the inverse demand faced by the conventional producers $P_s(Q)$ in Germany differs by the amount of RES from the inverse demand of the consumers $P(Q)$, indicated by the difference of the two downward sloping dashed lines. Hence, conventional producers and consumers realize different price quantity pairs at A^p and at A^c respectively, where the difference in prices is related to the extra costs of RES charged on top of the conventional producer price. Removing the supported RES from the market shifts the residual demand faced by the producers back to the inverse demand of the consumers and closes the gap between producer and consumer prices.

The exclusion of RES under constant permit prices results in the move from points A^p and A^c to B, the substitution effect in the following, which is indicated in figure 2 by the dashed arrows. Excluding the RES under endogenous emission prices yields the moves from points A^p and A^c to point C, represented by the bold arrows which show the total effects of the exclusion of the RES on consumers and conventional producers. Since the only difference between scenario B and C is the permit price, the move from point B to C, the dotted arrow, perfectly resembles the effect induced via the ETS and is, therefore, termed permit price effect.

Figure 2. Effects of a Removal of the FIT on German Consumer and Producer Prices



As illustrated by Figure 2, the substitution effects experienced by the consumers and producers differ substantially. The producer price increases and the consumer price decreases, while both the conventional produced quantity and the demand of consumers expand. Clearly, the expansion effect is larger on the producer side due to the substitution of RES by conventional production. To the contrary, the permit price effect is the same for consumers as well as producers.

4.2 Impact of the Fit on European Electricity Markets

For the assessment of the impact of the FIT under the ETS, we have to reverse the order of our reasoning, i.e. we infer the substitution and the permit price effect of the impact of the current FIT by moving from scenario C, via B, to scenario A. We obtain largely differing results. Some countries are only affected by the permit price effect, others additionally by the substitution effect. For the exposition of the variety of results, we choose those countries that experience both a permit price and a substitution effect, either on prices or on emissions, together with France and Poland. France and Poland are examples of countries that are only impacted by the permit price effect and have a significant different plant structure which makes them suitable candidates for demonstration of possible outcomes. While France electricity production is mainly based on low carbon nuclear power plants, Poland is dominated by high emission production in old cold fired plants.

The first three columns of Table 5 report the substitution effects, permit price effects and total effects of the FIT relative to scenario C, while the permit price itself decreases by 15 percent from 23 to 20 euro per ton of CO_2. We find that the total effect of the FIT decreases German producer prices by eight percent, while it increases consumer prices by three percent. On the producer side, the total effect consists of a negative substitution effect of two percent and a negative permit price effect of six percent. As mentioned earlier, on the German consumer side, the two effects have opposite directions. While the permit price effect induces a reduction of consumer prices of six percent, the substitution effect raises prices by nine percent.

The effects on the remaining countries are simpler, since only the German consumers are charged with the extra costs of German RES, and only the German conventional producers experience a shift of their demand. By contrast, the other European countries are only impacted by the dampening effects of the German FIT in regard to electricity and permit prices. Moreover, while all countries are affected by the permit price reduction, only a few countries are additionally impacted by the substitution effect. Thus, we find a much more pronounced permit price effect than substitution effect on the European producer price index[8] shown in the last row of Table 5, i.e. minus one and minus four percent respectively.

More in detail, we find that France and Poland, as well as the countries not included in Table 5, experience no significant substitution effect. By contrast, Switzerland and the Netherlands are, apart from Germany, the only countries whose prices are influenced by the substitution effect. This pattern can be explained by limited cross-border transmission capacities between the markets. Clearly, any price decrease on the German market would be followed by an equally sized price decrease in all other countries, if abundant transmission capacity were available, and, thus, the scarcity price of transmission were equal to zero.

The permit price effect of the FIT has a broader impact on prices compared to the substitution effect, since the trade on the emission market is not limited and a uniform permit price is obtained. It ranges between a one percent price reduction in France and an eight percent price reduction in Poland and the Czech Republic. Clearly, countries with a high share of low carbon electricity production,[9] like France, experience a much less pronounced impact of the permit

8. Average volume weighted producer price.

9. See the power plant structure and marginal emission functions of the dominant firms laid out in Table 3 and Table 4 of the previous section.

prices, while countries with coal-dominated power plant structures, like Poland, are much more impacted.

Table 5. The Impact of the German FIT on European Electricity Prices and Emissions

	Effect on prices relative to C			Effect on emissions relative to C		
Country	**Substitution**	**Permit Price**	**Total**	**Substitution**	**Permit Price**	**Total**
Ch	-2%	-5%	-6%	0%	0%	0%
Cz	0%	-8%	-8%	-1%	5%	4%
DE	-2% (9%)	-6%	-8% (3%)	-16%	5%	-11%
DK	0%	-7%	-7%	-2%	10%	7%
FR	0%	-1%	-1%	0%	0%	0%
NL	-2%	-5%	-7%	-2%	1%	-1%
Pl	0%	-8%	-8%	0%	6%	5%
EUR 25	-1%	-4%	-5%	-4.5%	3.9%	-0.5%

In regard to the emissions related to European electricity production, the FIT induces ambiguous signals. On the one hand, the drop in producer prices leads to a reduction in production of conventional electricity and, thus, a reduction of emissions. On the other hand, the drop in permit prices tends to increase electricity emissions. Illustrating the quantitative impacts of the FIT, the last columns of Table 5 shows the outstanding substitution effect on emissions in Germany with 16 percent reduction. The explanation is that the FIT's quantity effect, triggered by the reduction of residual demand, takes place only in Germany, while other countries are impacted only indirectly. Thus, similar to the effect on prices, only countries neighboring the German market are significantly influenced by the substitution effect. Notably, in the Netherlands, the induced price reduction matches the induced emission reduction of two percent. However, even qualitatively the price and the emission effect induced by the substitution effect of the FIT do not always match each other.

When we compare the substitution effects on prices with those on emissions, we find that Switzerland does not experience a reduction of its emissions despite the induced drop in prices, while the Czech Republic and Denmark decrease emissions although prices are not significantly influenced. The explanation for these findings is that in Switzerland no production is crowded out due to high competitiveness of generation, while in the Czech Republic and Denmark less competitive domestic production is substituted by foreign sources.

Regarding the total emission effect, we find that the emission reductions induced by the substitution effect in Denmark and Czech are overcompensated by the emission increases due to the permit price effect, as can be seen from the last columns of Table 5 above. To the contrary, in Germany and the Netherlands, the permit price induced emission increases are smaller than the reductions induced by the substitution effect. In the case of Germany, this can be explained by the pronounced substitution effect which is only partially offset by a significant permit price effect, while the reaction on the Dutch is due to a minor permit price effect. In the remaining countries, only the permit price effect takes place and increases the emissions by up to seven percent. Not surprisingly, those countries with a high share of low carbon plants, like France and Switzerland, experience no significant effects.

The effect on the whole European electricity sector emissions is rather modest due to the counteracting directions of the substitution and the permit price effect. We find that both effects induce a relative change of approximately four percent in opposite directions such that the total effect is only about a half percent emission reduction by the FIT, as shown in the last row of Table 5.

4.3 Impact of the Fit on Price-Cost Margins and Firm Profits

For the assessment of the impact of the FIT on dominant firms, we first consider the mark-up in proportion to the producer prices, i.e. the price-cost margin (PCM), of dominant firms. We find that in cases when the firms control large, on the national markets highly competitive generation assets[10] the mark-ups contribute to producer prices by more than fifty percent. Examples are EdF (FR), EDP (PT) and British Energy (UK) with respective PCMs of 84, 77, and 58 percent in scenario A.[11] Most of the other dominant firms realize a PCM between 20 and 40 percent. The lowest PCMs are experienced by E.ON (UK) and FNM (Cz) with PCMs of eleven and seventeen percent respectively in the baseline scenario, indicating only minor influence of market power of these firms.

The substitution effect, the permit price effect and the subsequent total effect of the FIT on price-cost margins are reported in the last columns of Table 6. It turns out that, in total, the mark-ups gain importance in price determination for all companies, with the only exception of British Energy. Moreover, apart from German EnBW (DE), the total effects are in most cases to the major part induced by the permit price effect. On the one hand, these observations suggest a market power enhancing effect of the FIT, and on the other hand, they stress the importance of the feed-backs of the ETS, especially under conditions of imperfect competition. Furthermore, market power tends to shift the burden of the FIT from the producers to the consumers and, thus, counteracting a theoretically possible price reduction effect on the consumer side under perfect competition.

Similar to impacts on prices and emissions, the permit price effect has a broad impact, and price-cost margins of most firms are influenced. If we concentrate on the firms that induce significant mark-ups, we find predominantly positive permit price effects on the price-cost margins, ranging between one and ten percent. Only EnBW (DE) and British Energy (UK) reduce price-cost margins, which can be explained by the comparatively low emission intensity of their production and the reduction of their competitiveness under lower permit prices.

10. See for instance the marginal cost functions laid out in Table 4.
11. See Table 8 of the appendix for absolute values of scenario A in the baseline setting.

Only small substitution effects on the price-cost margins of most companies can be reported, and, thus, we find the market positions of the major actors untouched by the FIT. An exception is the case of EnBW (DE), which realizes both a significant price-cost margin and a major increase of its pricecost margin induced by the substitution effect. The intuition behind this result is that the competitive production of EnBW (DE) is only under proportionally crowded out by the introduction of RES such that the respective market share increase significantly and, as a consequence, the mark-up and price-cost margin.

Table 6. The Impact of the German FIT on Price-cost Margins and Firms' Profits

	Effect on PCM relative to C			Effect on profit relative to C		
Firm	**Substitution**	**Permit Price**	**Total**	**Substitution**	**Permit Price**	**Total**
EdF (FR)	0%	1%	1%	0%	-1%	-1%
Enel (IT)	0%	6%	6%	-1%	10%	9%
E.ON (DE)	2%	1%	3%	-17%	-1%	-18%
RWE (DE)	0%	4%	5%	-26%	8%	-19%
Endesa (ES)	0%	10%	10%	0%	16%	16%
E.ON (UK)	0%	25%	25%	0%	53%	53%
Vattenfall (DE)	1%	5%	6%	-30%	11%	-20%
Vattenfall (SE)	0%	1%	1%	0%	-2%	-2%
Iberdrola (ES)	0%	1%	1%	0%	0%	0%
British Energy (UK)	0%	-2%	-2%	0%	-5%	-5%
Suez (BE)	0%	0%	0%	-1%	-1%	-2%
EnBW (DE)	18%	-2%	16%	-2%	-5%	-7%
EDP (PT)	0%	2%	2%	0%	2%	2%
FNM (Cz)	-1%	1%	1%	-3%	-3%	-6%

Concerning the dominant actors on the European electricity market, a second important aspect of the FIT is its impact on profits. In scenario A, profits range from 475 million euro annually for FNM (Cz) to almost 12 billion euro annually for EdF (FR). As can be observed from the last column of 6, the increases in the PCMs of almost all companies are not necessarily followed by an increase of operative profits. Most notably, all German companies are negatively impacted and realize a profit reduction ranging from 7 percent in case of EnBW (DE) up to 20 percent in case of Vattenfall (DE). However, some companies benefit considerably from the FIT in Germany. For instance, E.ON (UK) can increase its profits significantly due to the reduction of permit prices which is not fully compensated by a substitution effect. In fact, all British companies are not impacted by the substitution effect which can be explained by limited cross-border transport capacities. We find that the effect of the FIT on profits of the major players is negative unless the companies are not too closely linked to the German market and have a relatively high emission intensity compared to their local competitors.

In general, it turns out that the substitution effect triggers, if seizable, negative effects. This result says that the substitution effect decreases prices more than it potentially increases the mark-ups of the firms. For instance, the price-cost margin of EnBW (DE) on the German market significantly increases, while its profit decreases. Thus, even for EnBW (DE), the induced increase in PCM cannot compensate for the producer price decrease caused by the substitution effect of the FIT. Moreover, only those companies on or close to the German market are affected by the substitution effect, while companies in countries that are sufficiently separated from the German market, e.g. Britain, Spain and Portugal, are not impacted.

Different from the substitution effect, the permit price effect of the FIT impacts the profits of all listed companies, which can be seen from column permit price in the right hand side of the Table 6. We observe that most firms experience significant relative permit price effects, but the direction of the effect is ambiguous. On the one hand, E.ON (UK) and Vattenfall (DE) are, with an increase of profits by 53 and 11 percent respectively, impacted the most. On the other hand German EnBW and British Energy (UK) experience considerable reductions of five percent each.

If we compare these effects with those on the PCMs laid out in Table 6, we find that German EnBW and British Energy (UK) are the only firms that reduce their PCMs in response to the permit price effect such that a negative profit effects is in line with the intuition. To the contrary, some firms like E.ON (DE) and Vattenfall (SE) raise their PCM in response to the permit price effect and at the same time realize profit reductions.

These permit price effects on profits can be explained by the plant structure and the emission coefficients of the companies. Firms with high emission coefficients as documented in Table 4, like E.ON (UK), have positive permit price effects on profits. By contrast, companies which have a low emission coefficient compared with their major domestic competitors realize the most pronounced profit reductions by the FIT-induced permit price decrease. This observation supports the intuition that emission intensive companies benefit from permit price drops, and low carbon companies are penalized.

Table 7. Results for the Sensitivity Analysis

	Effect on price relative to C			Effect on permit price rel. to C
	Substitution	Permit Price	Total	
Baseline	-2% (9%)	-6%	-8% (3%)	-15%
Perfect Competition	-7% (6%)	-4%	-11% (2%)	-14%
Trade	-2% (11%)	-5%	-7% (6%)	-13%
Increased Permit Supply	-2% (9%)	-6%	-7% (4%)	-15%

4.3 Sensitivity

The previous analysis has highlighted the importance of our assumptions in regard to firm behavior, permit supply of other ETS sectors, and international transmission restrictions for the results. To test the sensitivity of our model, we, therefore, calculate the model in three counterfactual settings: "Perfect competition" assumes price-taking behavior of the dominant German companies, "Trade" assumes by fifty percent increased cross-border transmission capacities, and "Increased permit supply" assumes a doubling of the permit supply of the non-electricity ETS sector. Table 7 reports the results of the experiments. If we compare the counterfactual scenarios with our baseline setting it turns out that the signs of the effects remain unchanged over all settings, thus indicating considerable robustness. Moreover, the size of the effect varies in the expected directions. Most notably, when we move from the baseline to the scenario "perfect competition," the substitution effect on producer prices more than quadruples, while the respective effect on consumer prices decreases by 30 percent. This observation suggests that the introduction of more competition would shift the burden of the FIT from consumers to producers, which is in line with the effects on the PCM under the baseline assumptions documented in the previous section.

Doubling the cross-border transmission capacities has less pronounced effects. The permit price effect of the FIT decreases with increasing cross-border transmission capacity from 15 to 13 percent emission price reduction. As a result, the permit price effect on prices decreases while we experience a pronounced substitution effect. Most notably, the substitution effect on the consumer price increases from 9 to 11 percent, while the producer price effect remains at a two percent reduction. The intuition behind these results is that increased international transmission capacities increase the shift of supplies away from the encumbered German market.

Finally, the scenario "increased permit supply" delivers barely significant changes as can also be seen from the comparison with the baseline results reported in Table 7. Clearly, the level of emission prices is lower than in the baseline setting, but the relative effect of the FIT on emission prices stays almost unchanged. This observation suggests a predominant importance of the electricity sector in the emission trading system and only a minor role of the other sectors that are involved in the ETS.

5. CONCLUSIONS

We investigated effects of the German FIT with the numerical EMELIEEUR 25 model of the European electricity market and analyzed impacts on producer and consumer prices, electricity sector emissions, price-cost margins, and on the firm's profits from plant operation. To highlight the transmission channels, we decomposed the effects of the FIT into a substitution effect, triggered by the replacement of conventional by renewable sources, and a permit price effect induced via the ETS. Furthermore, we conducted a sensitivity analysis by altering seemingly crucial assumptions in regard to market behavior of dominant firms, cross-border transmission capacity, and the permit supply of the non-electricity sector.

We find that the substitution effect is limited to countries neighboring Germany, while the permit price effect impacts all countries. In regard to producers' prices, both effects have a dampening impact of between one and eight percent on the different markets, with a European average of five percent price reduction. By contrast, the effects on German consumer prices go into opposite directions. The substitution effect increases prices by nine percent, while the permit price effect reduces prices by six percent.

Similarly, the two effects impact the electricity sector emissions of the countries in different directions. While the substitution effect tends to reduce emissions, the permit price effect induces an increase, leaving a total effect on the emissions of different countries with an ambiguous sign. However, on the European scale emissions of the electricity sector are reduced, albeit by a mere half percent.

Furthermore, the FIT increases the price-cost margins of almost all dominant firms, indicating a market power enhancing effect under our baseline assumption of oligopolistic competition. However, the impact of the FIT on the profits of most conventional firms is ambiguous. Two characteristics of the firms are crucial: The physical connection with the German market and the carbon intensity. While the unambiguously negative substitution effect does not apply to firms that are only weakly connected with the German electricity grid, the permit price effect is determined by the firms' emission intensity. Hence, we find that firms that are only loosely connected with the German grid and have high emissions are likely to benefit from the German FIT. At the same time, firms with low emissions on or close to the German market suffer losses.

The sensitivity analysis documents the robustness of the model since the respective counterfactual experiments show results that do not differ qualitatively from the results of the baseline setting. Quantitatively, we find that the counterfactual adoption of price-taking behavior of German firms has the strongest influence on our results and tends to shift the burden of the FIT from consumers to producers. To the contrary, an enforcement of the cross-border transmission capacity by fifty percent strengthens the price increase on the consumer side and dampens the decrease on the producer side. Finally, doubling the permit supply of the non-electricity sectors of the ETS has only minor influence on our results, highlighting the importance of the electricity sector in the ETS.

In light of the discussion in the literature, we do not find evidence of the theoretically possible decrease in consumer prices due to renewable energy support documented in the case study in Rathmann (2007). Rather we show that under the assumption of Cournot competition of major companies, a pronounced increase of consumer prices by the FIT can be expected since it induces an increase in price-cost margins of suppliers of conventional electricity. Furthermore, the paper studies the mostly negative quantitative effects of the FIT on conventional firms' profits, and develops the crucial firm characteristics that determine this impact. Moreover, regarding effects on the emissions, our findings are in line with the analytical results found in Morthorst (2003) insofar that renewable energy induced emission reductions in one country will be partly compensated by increases in other countries. Our contribution assesses these effects quantitatively, distinguishes between a substitution and a permit price effect and demonstrates that both effects nearly balance each other.

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APPENDIX

Table 8. Baseline Results for Countries (left) and Firms (right) in Absolute Values

Country	Price [cent/kWh]	Emission [Mt CO2]	Firm	PCM	Profit [Mio. €]
AT	2.6	25	EdF (FR)	0.84	11738
BE	4.3	26	Enel (IT)	0.27	1057
BG	2.2	14	E.ON (DE)	0.41	2982
Ch	3.7	17	RWE (DE)	0.31	1305
Cz	3.0	45	Endesa (ES)	0.23	350
DE	4,4 (4,9)	293	E.ON (UK)	0.11	82
DK	3.4	27	Vattenfall (DE)	0.27	888
EE	3.0	9	Vattenfall (SE)	0.36	963
ES	3.4	106	Iberdrola (ES)	0.40	1365
FI	2.7	36	British Energy (UK)	0.58	2078
FR	5.9	52	Suez (BE)	0.50	1860
GR	2.6	31	EnBW (DE)	0.27	1567
HU	3.4	13	EDP (PT)	0.77	956
IT	4.0	154	FNM (Cz)	0.17	475
Lt	3.5	0			
Lv	3.2	3			
NL	3.8	66			
NO	2.3	2			
Pl	3.6	74			
PT	7.4	11			
RO	2.4	24			
SE	2.8	35			
Si	3.8	3			
SK	2.9	9			
UK	3.7	155			