Doctoral School of Management and Business Administration

THESIS SYNOPSIS

András Mezősi

In the jungle of regulatory instruments

Analysis of the interaction of regulatory instruments dealing with the market failures of the electricity sector

Ph.D. Dissertation

Supervisor:

Gabriella Szajkó, PhD
associate professor

Budapest, 2014

Department of Environmental Economics and Technology

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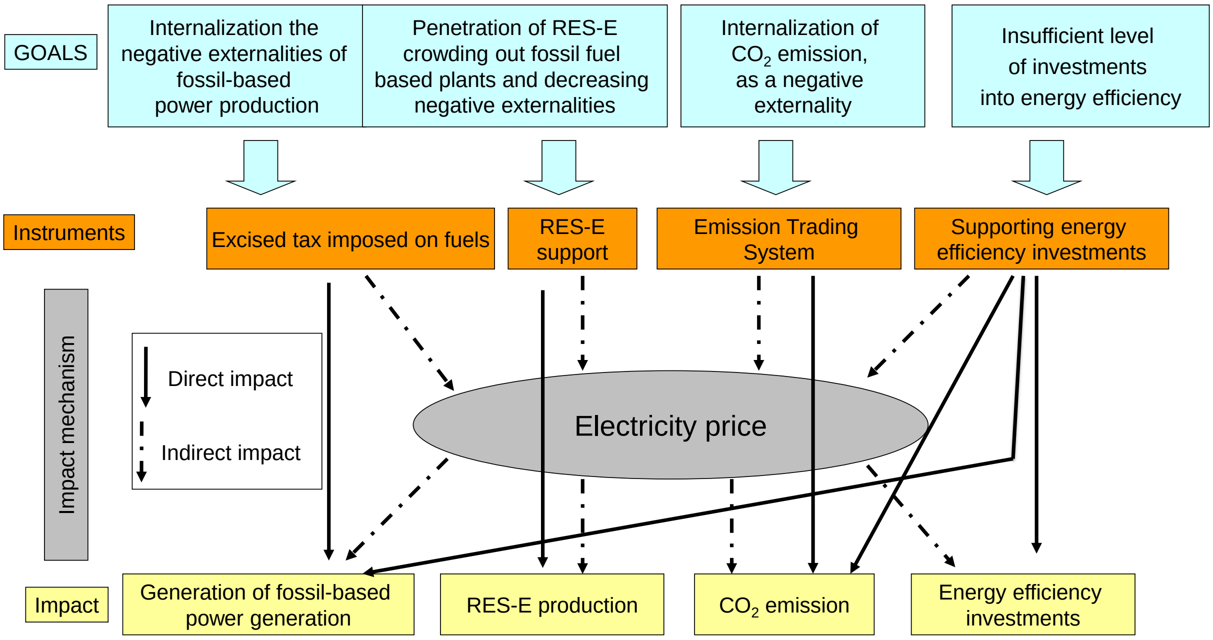
I. BACKGROUND

In the electricity market there are a number of market failures that lead to inefficient allocation of resources from the perspective of society. These include the emissions of power plants, which generate substantial negative externalities. Another market failure is the insufficient volume of investments into energy efficiency. The European Union, having recognised these failures, have set targets that help to augment social welfare. In 2009 the EU adopted the new Climate and Energy Package targeting by 2020 a 20% reduction of greenhouse gas (GHG) emissions, 20% lower primary energy use and a 20% share for renewable energy use. By reaching these goals, the previously mentioned market failures can be substantially eased. In order to get closer to fulfilling the targets, the European Union and the member states have introduced different types of regulatory instruments: a uniform emission trading system, renewable support schemes, excise taxes on the use of fossil fuels, and support for investment into energy efficiency. These instruments, nevertheless, exhibit their effect partly through similar mechanisms, therefore different instruments may cancel or even reinforce each other, as also confirmed by the "Green Paper - A 2030 framework for climate and energy policies" (COM 2013/169) published by the European Commission in March 2013. The document emphasized that the individual policy instruments need to be harmonised so that they would strengthen, instead of offsetting each other's impacts.

The most important link between regulatory instruments from the perspective of interactions may be direct or indirect. Figure 1 provides an illustration of the regulatory goal related direct and indirect impacts of the four main regulatory instruments that previously listed.

Figure 1 The goals and impact mechanisms of the inspected regulatory instruments



Each regulatory instrument has its primary goal. The goal of the excise tax imposed on fuels is the reduction of generation by fossil fuel based power plants. Renewable support promotes the penetration of renewable based electricity generation, thereby crowding out fossil fuel based plants, mitigating some of the negative externalities of the electricity sector. The key purpose of the emission trading system is curbing carbon-dioxide emissions. Finally, the purpose of promoting investments into energy efficiency is an increased volume of these investments, thus reducing the insufficient level of investments stemming from asymmetric information and other market failures.

Renewable support directly impacts renewable based electricity generation. A similar direct interaction is observable between the emission trading system and carbon-dioxide emissions, as well as between the excise tax on fuel use and the production of fossil fuel based power plants. Measures targeting energy efficiency deliver two types of direct impacts: on the one hand, the number of investments into energy efficiency will increase, and on the other, as a result of lower electricity consumption, the production of fossil fuel based power plants will decline, similarly to the corresponding carbon-dioxide emission. The realignment of the supply side effects carbon-dioxide emissions, the penetration of renewables and indirectly the level of investments into energy efficiency through the change of electricity prices. In a similar fashion, the other instruments also generate indirect impacts through the price of electricity.

Our thesis aim was to inspect the level of efficiency to which the listed regulatory instruments can work along each other, and whether it is necessary to introduce such a wide range of instruments to handle partly overlapping problems.

II. RESEARCH MODEL AND METHODS

Partly based on literature findings, and partly building on our own results we summarise in Table 1 how the four instruments that we inspected impact those factors that are important from the perspective of our analysis.

In the dissertation we examined all the possible regulatory portfolio combinations that can be created from the four instruments of our analysis. It is essential to keep in mind that the goal of these regulatory instruments is the mitigation of market failures within the electricity sector. The market failures in the focus of our analysis are the following: i) environmental externalities generated by conventional power plants; ii) insufficient level of investments into energy efficiency; iii) the negative externalities of carbon-dioxide emissions. The targets set by the EU are also related to addressing these market failures: higher share of renewables, primary energy savings, and GHG reduction. In Table 1 we used green colour to indicate those cells for which the regulatory instrument portfolio is clearly capable of reaching the given target (at least on a theoretical level), yellow stands for uncertainty in this respect, and adverse impacts compared to the targets are indicated by red.

Table 1 The impacts of given regulatory instrument combinations

Regulatory mix		RES-E production	CO2 emission	Energy efficiency investments
Only emission trading system		Increase	Decrease	Increase
Without emission trading system	RES-E support scheme	Increase	Very likely decrease	May increase and decrease as well
	Excise tax	Increase	Decrease	Increase
	Supporting energy efficiency investenments	Decrease	Decrease	Increase
	Excise tax + RES-E support scheme	Increase	Decrease	May increase and decrease as well
	Excise tax + Supporting energy efficiency investenments	May increase and decrease as well	Decrease	Increase
	RES-E support scheme + Supporting energy efficiency investenments	Increase	Decrease	Increase
	RES-E support scheme + supporting energy efficiency investenments + excise tax	Increase	Decrease	Increase
With emission trading system	RES-E support scheme	Increase	Decrease	May increase and decrease as well
	Excise tax	Increase	Decrease	Increase
	Supporting energy efficiency investenments	May increase and decrease as well	Decrease	Increase
	Excise tax + RES-E support scheme	Increase	Decrease	May increase and decrease as well
	Excise tax + Supporting energy efficiency investenments	May increase and decrease as well	Decrease	Increase
	RES-E support scheme + Supporting energy efficiency investenments	Increase	Decrease	Increase
	RES-E support scheme + supporting energy efficiency investenments + excise tax	Increase	Decrease	Increase

Evidently, there is only one regulatory mix that cannot get closer to reaching the given target, when solely energy efficiency investments are supported by the regulator, as in the long run this hinders the spreading of renewable power plants. All the other combinations, however, can help to achieve the targets, but there are seven instrument mixes when the impact of them is ambiguous.

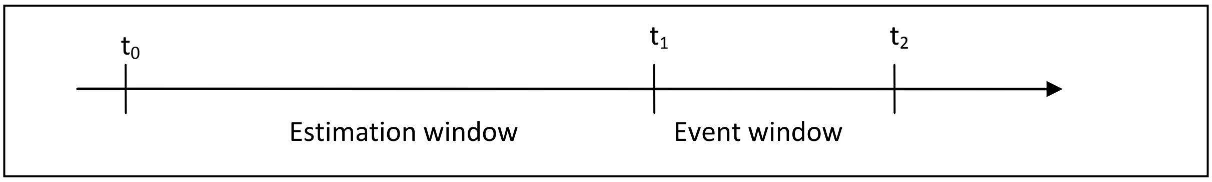
II.1. Empirical analysis

Within the dissertation we employ a tool called event study to examine how the price of the different credits reacted to the publication of the draft Energy Efficiency Directive and then the adoption of the final version of the Energy Efficiency Directive.

Based on their efficiency Fama (1970) divides markets into three groups: markets of weak, semi-strong and strong efficiency. A market is in a weak state of efficiency when past information has been fully integrated into prices. A market should be viewed as having semi-strong efficiency when all publicly available information is incorporated into market prices, while in case of a market with strong efficiency all public and non-public information is already reflected by prices. Based on the results of Mezősi (2008) the efficiency of the European carbon-dioxide market can be considered as at least semi-strong. Thus, whenever new and substantial information appears it is quickly processed by market participants and incorporated in credit prices. This offers an opportunity to answer the above mentioned research questions.

During the event study we analyse if the returns (or other statistical attributes) of a given period are significantly different from the returns and standard deviation of the reference period.

Figure 2 The two periods of the event study



Source: MacKinley (1997), p.: 20

As a first step of the event study we need to create a so called estimation window, in which we measure the daily returns and standard deviation of the price. At t_1 time an event takes place, and we are interested to know how that event impacts the price. Applying statistical methods we examine if the returns within the event window are significantly different from those of the estimation window. If we experience a significant difference then we can claim that a new piece of information that was previously not reflected by prices has just been incorporated into the price. If, on the other hand, we do not find a statistically valid difference, then we can safely assert that the event did not include new information (Brown-Warner, 1985).

II.2. Description of the power model

The European Electricity Market Model[1] (EEMM) simulates the wholesale electricity markets of 36 European countries, assuming perfect competitive market conditions (REKK, 2011). The EEMM distinguishes three types of market participants: the producer, the consumer and the trader. Perfect competition is assumed for each of these, that is, market participants are price takers.

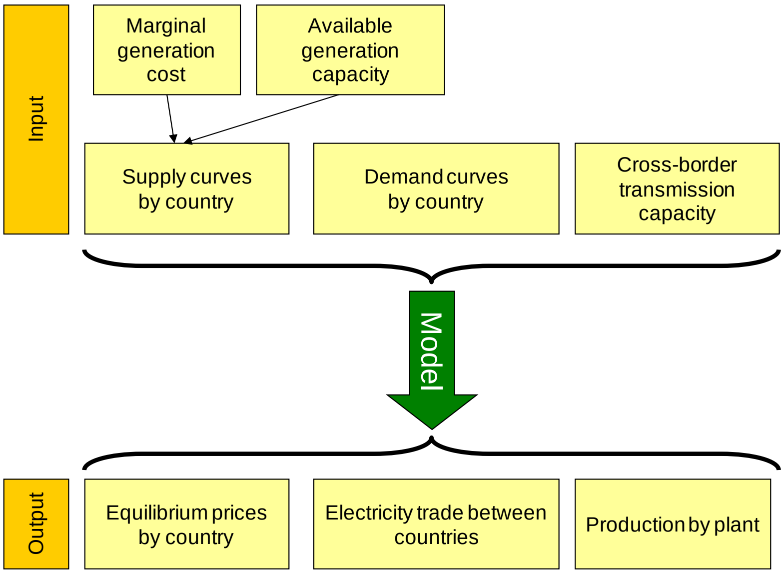
The short run marginal cost can be calculated for each power plant. Production is constrained by capacity, equal to the installed capacity of each power plant unit. Within the electricity sector we distinguish 12 different technologies: biomass fired power plants, coal fired plants, lignite fired plants, geothermal plans, heavy fuel oil fired plants, light fuel oil fired plants, hydropower plants, wind power plants, solar power plants, nuclear plants, natural gas fired plants and tidal power plants. The model makes use of only the short run variable costs: fuel cost, variable operating cost, including the excise tax, and carbon-dioxide costs (in case they exist). Consumers in the model are aggregated as a category, the slope of the demand curve is the same for all countries.

Within the model a country appears as a node, that is, there are not any network constraints within the country, only between countries. The cross border capacities linking the countries are constrained, approximated with available capacities in the model. Traders make the connection between the producer and consumer side of the market by exporting electricity to more expensive countries and importing electricity from less expensive ones.

When modelling hourly markets are simulated, and these simulations are independent from each other, that is, ramp-up costs are excluded. Within the model the equilibrium for a given hour (with respect to quantities and prices) is reached simultaneously, at the same time by the producer and transmission segments. Figure 3 describes the operation of the model.

[1] The first version of the EEMM was developed by A. Kiss in the Regional Centre for Energy Policy Research. Model has been further improved which has been carried out partly by A. Kiss, the inventor of the model and partly by other colleagues of REKK, including myself.

Figure 3 The operation of the model



Source: REKK (2011)

By determining the short run marginal cost and available capacity for each power plant we can construct the supply curve for each country, in other words, the merit order curve. Considering the constraints of cross border capacities and the demand curves characterising each country, we arrive at the input parameters of the model. The model applies this data to maximise European welfare, which is the sum of producer and consumer surpluses. As a result of model computations we get the hourly equilibrium price for each country, the hourly commercial transfers between the countries, and the production of each power plant unit. During the simulation we utilised the previously described EEMM model, which, however, had to be further developed to some extent. We supplemented the power model with four components in total: we installed a long run price elasticity factor; investments into renewable electricity producing capacities used to be an exogenous variable of the model, we turned this into an endogenous attribute; moreover, we depicted the impact of investments into energy efficiency on electricity consumption, that is, how much consumption can be reduced this way. Finally, we provided a detailed analysis of the relation between the price of the carbon-dioxide credit and its emissions.

III. RESULTS

From the most important results of the dissertation, first we define and answer to the hypotheses related to the empirical research. After that those research questions and hypotheses are inspected, which is executed by modeling, and we also summarize the main results of them.

III.1.Hypotheses inspected by empirical analyses

In the dissertation we applied empirical analysis to inspect the relationship between different regulatory instruments. Such an analysis becomes feasible when a transparent price emerges in the market created by the regulatory instrument: that is, when a white or green certificate market operates in the country in question, but carbon-dioxide credits can also be analysed with this method.

H_{11}: The price of carbon-dioxide credits and green certificates substantially decreased as a result of publishing the draft Energy Efficiency Directive and the text of the final Directive.

The price of carbon-dioxide credits (EUA – EU Emission Allowances) notably oscillated for the observed period, covering almost a decade. The most significant price change took place in May 2006, when the price of the credits suddenly halved in just a few days. As part of the dissertation we inspected whether this large price drop also triggered changes of the same magnitude in the operating green certificate markets. The applied method is given by the previously demonstrated event study. Based on the analysis we arrived at the following conclusions.

- The Commission proposal on energy efficiency, announced on 22 June 2011, has a substantial impact on the price of carbon-dioxide credits.
- Based on the above statement our hypothesis, according to which the draft Energy Efficiency Directive substantially affected the price of the carbon-dioxide credit, can be declared as valid, but we reject the hypothesis according to which carbon-dioxide prices notably changed when the Energy Efficiency Directive was finally adopted.
- As a result, there is a significant impact between the two regulated areas (energy efficiency regulation and trading of carbon-dioxide credits), the direction of which is the same as we had expected.

$H_{12:}$ A sudden and lasting decline of the price of carbon-dioxide credits substantially reduces the market price of green certificates.

Theoretically the price of the EUA and the price of the tradable green certificate (TGC) should be negatively correlated. We inspected the tradable green certificate markets of Europe, and only the Swedish market was found to be suitable for the desired analysis. Based on monthly data we could neither prove, nor reject the hypothesis on the negative correlation between the price of the green certificate and the EUA.

III.2. Hypotheses and research questions inspected by modeling

RQ_1: The quantitative analysis of the following question: under those regulatory instrument combinations for which the direction of impact on specific variables (RES-E production, carbon-dioxide emission, investments into energy efficiency) cannot be unambiguously identified in a theoretically sound way, how do these variables actually change if we increase renewable support, the support provided to energy efficiency investments, the rate of the excise tax, or reduce the number of carbon-dioxide credits.

Altogether we identified seven regulatory instrument combinations in case of which theoretical demonstration is not sufficient to reveal the direction in which the three most critical variables (RES-E generation, energy efficiency investments and carbon-dioxide emissions) move. We provided a quantitative answer to this question using the competitive market model, which simulate the European electricity market.

During the analysis we started from a hypothetical case without any regulation in place: there is no Europe-wide carbon-dioxide trading, none of the modelled countries support renewable generation or energy efficiency investments, and they do not impose an excise tax on fuel use. We will refer to this as the reference case.

Compared to the reference case we gradually tightened the regulatory instruments: for example, we increased the rate of the excise tax or reduced the amount of carbon-dioxide that is allowed to be emitted, and so forth. We looked at combinations of instruments in the case of which the direction of the impact on the three most important factors (renewable generation, carbon-dioxide emissions, investments into energy efficiency) is not clear.

When working with this research question, the group of examined countries was not limited to the member states of the European Union, we considered the results for all the 36 modelled countries. Furthermore, the regulatory instruments were uniformly applied to all modelled countries: we assumed a uniform excise tax, the same support to renewable generation, and identical support to energy efficiency investments for all analysed countries.

Table 2 provides a summary of our main modelling results.

Table 2 Modelling results pertaining to RQ1

Analysed instruments mix	RES-E production	Carbon-dioxide emission	Energy efficiency investments
RES-E support without emission trading	Increase	Decrease	Until medium support level stagnate, than increase
Excise tax and RES-E support without emission trading	Increase	Decrease	Increase
Excise tax and support of energy efficiency investments without emission trading	Increase	Decrease	Increase
RES-E support with emission trading	Increase	Decrease	Increase
Support of energy efficiency investments with emission trading	Increase	Decrease	Increase
Excise tax and support of energy efficiency investments with emission trading	Increase	Decrease	Increase
Excise tax and support of energy efficiency investments with emission trading	Increase	Decrease	Increase

In order for results to be reliable, we carried out a partial sensitivity analysis for three factors. While the generated modelling results are slightly changed, our conclusions in relation to research question RQ_1 do not need to be revised, thus our results can be viewed as robust.

H_2: Any combination of the four regulatory instruments (excise tax, renewable support, emission trading, support to energy efficiency investments) that we inspect is sufficient to reach the 20-20-20 target set by the EU for 2020, except when the only available instrument is the support to energy efficiency investments.

Model simulations have shown that the 20-20-20 targets of the EU can be reached for all regulatory instrument combinations. Thus, we rejected the H_2 hypothesis, since the targets can also be attained with energy efficiency investment support on its own.

The application of quantitative modelling offered a number of important lessons.

- One of the most important conclusions is that the higher the number of utilised regulatory instruments, the less extreme will the values of the most important variables be. Even though the three targets set by the EU can be accomplished through any combination, the application of 3-4 regulatory instruments is advisable, as the prices, the electricity-mix or the carbon-dioxide emissions will change less dramatically compared to the case without any regulation. If, for example, only renewable support is applied then the wholesale price of electricity can be especially low, which can then transform the operation of the European electricity market, while the retail price paid by consumers may get close to 100 €/MWh.
- The renewable target is frequently reached because it has been set as a percentage value and not as an absolute figure. If renewable support is not utilised then the volume of renewable energy does not change in a meaningful way compared to the

case without regulations. Importantly, however, during the analysis when we looked at the impact of a given regulatory instrument, we only considered a range within which the targets are already accomplished. Thus we did not inspect the impact of a very tight emission cap, or a high level of excise tax on renewable resources.

- The excise tax and emission trading are almost perfect substitutes of each other, therefore for administrative reasons it is advisable to use only one of them. There is not any significant difference between the two instruments, since they both target fuel use, that is, they reward the improvement of the efficiency factor (lower tax payment per unit of energy output). There is only one slight difference: carbon-dioxide trading burdens coal fired plants more than the excise tax.

RQ_2: Which regulatory instrument combinations that satisfy the 20-20-20 targets of the European Union are favourable from the perspective of Hungary.

When analysing the hitherto outlined research question, we cannot create indicators that would clearly determine which regulatory instrument combination is the most advantageous. Thus, during the analysis of RQ_2 we start from the principles outlined in the Energy Strategy (2012) adopted by the Parliament.

In Table 3 we used green colour to indicate the cases that are in harmony with the Energy Strategy, and red to indicate those that aren't. As shown, there are not any instrument combinations that would suit the Energy Strategy for all six result variables. The instrument combination that satisfies the highest number of conditions is the one including emission trading, excise tax as well as support to energy efficiency investments. We should note that in this case additional renewable capacities are not built in Hungary either compared to the reference case without regulation. There are altogether four cases in which four out of the six result variables suit the principles of the Energy Strategy. These include the case in which all four regulatory instruments are used with the exception of emission trading, and also the case in which renewable support is supplemented only with energy efficiency investment support or emission trading. For the last two cases the renewable ratio set by the Energy Strategy are also met.

Table 3 Summary of the impacts on specific factors under each of the regulatory instrument combinations

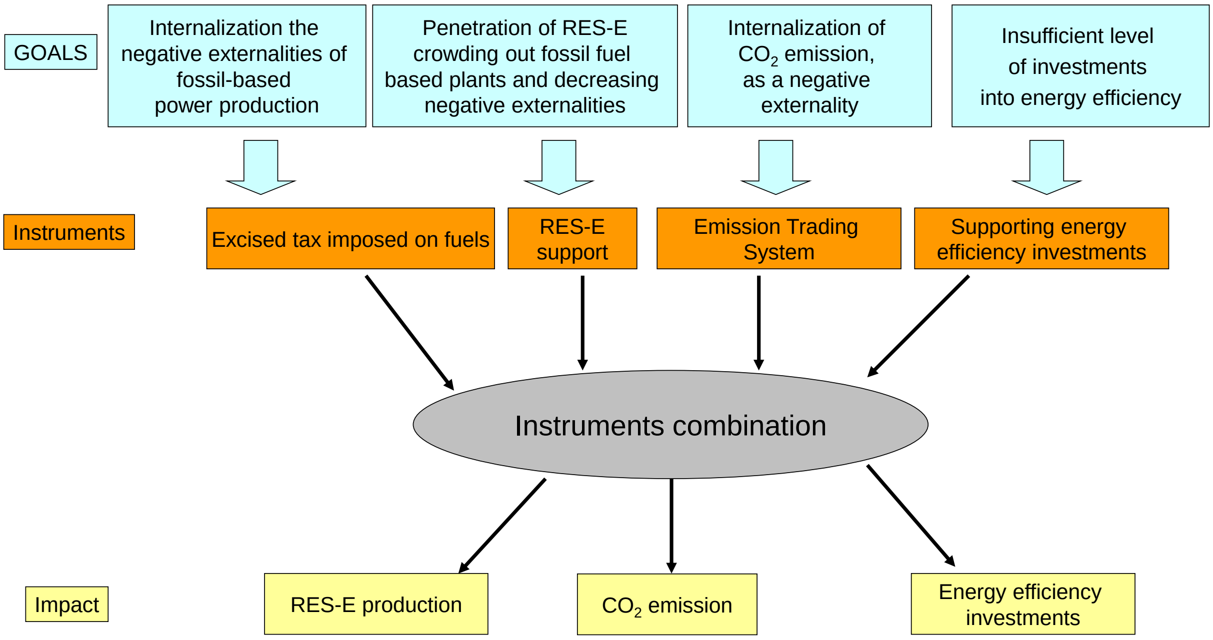
	One instrument				Two instruments						Three instruments				Four instruments
Emission trading	X				X	X	X				X	X	X		X
RES-E support		X			X			X	X		X	X		X	X
Excise tax			X			X		X		X	X		X	X	X
Energy efficiency investments				X			X		X	X		X	X	X	X
RES-E share															
Electricity price															
Coal-based power production															
Electricity consumption															
Net import															
Nuclear based power generation															

Similarly to hypothesis H_2, we carried out the sensitivity analysis of the three most important factors for this case as well. From all the scenarios (base case and three sensitivity analyses) the results are best in line with the principles of the Energy Strategy when three or four regulatory instruments are applied. There is one exception from this observation, when we apply all regulatory instruments together except for the support to energy efficiency investments. Therefore we can claim that the sensitivity analysis does not modify our conclusions, thus our results can be viewed as robust.

IV. CONCLUSIONS AND PROPOSALS

There are a number of market failures within the electricity sector, of which we introduced three in detail in our dissertation: environmental externalities, market failures related to energy efficiency investments, and negative externality of carbon-dioxide emission. A number of regulatory instruments are available to manage these market failures. These include the excise tax imposed on more polluting technologies, support to cleaner technologies, the introduction of emission trading or some support to investments into energy efficiency. These instruments, nevertheless, deliver their impacts through similar mechanisms, thus they directly or indirectly influence each other through the price of electricity. The main theme of the dissertation was the analysis of this interaction (Figure 4).

Figure 4 The targets, the applied instruments and the factors through which the targets can be measured



We examined the interaction of regulatory instruments in four steps:

- theoretical, microeconomic approach
- literature review
- analysis of empirical, European data
- modelling of the European electricity sector.

During the examination of the **theoretical, microeconomic** approach we analysed the impact of all the instrument combinations created from the four regulatory instruments on the three most important factors, which reflect the degree of the market failures. These three most important factors are the volume of renewable electricity production, carbon-dioxide emissions, and the level of energy efficiency investments.

One of the conclusions of the analysis is that in seven of the 15 combinations the applied instruments deliver a clearly positive impact on the previously listed factors, thus the level of both market failures declines. In seven other cases a definite stand cannot be taken with regard to the direction of impact on the three main factors. Finally, in one case, when only energy efficiency investments are applied, the impact on the penetration of renewable energy sources is negative.

For the **literature review** the inspected literature has been split into two. In one group the interaction of regulatory instruments has been inspected from a theoretical perspective, while in the other group the tool of modelling is used to answer the analysed question. Part of the model-based literature makes use of general equilibrium models, while the other part employs sectoral models assuming perfect competition. We can identify only a few pieces of literature that use oligopolistic models to analyse the interaction of regulatory instruments. The literature review has shown that most literature typically analyse the interaction of the green certificate and the emission trading system. During my research I have not seen any articles that would have used modelling to examine the interaction of at least three or four regulatory instruments

During the **empirical analysis** we looked at two questions. In the first instance we utilised statistical methods to prove that there is a relation between the Energy Efficiency Directive proposal and the price of carbon-dioxide credits. When the Draft Directive of the European Commission was published, the price of carbon-dioxide credits notably fell. This rhymes to what we expected from a theoretical perspective. Furthermore, we also inspected the relations between the European carbon-dioxide credits and the price of tradable green certificates. A relatively liquid, European tradable green certificate market without an effective price cap is necessary to analyse this question. As we pointed out in the dissertation, only the Swedish market seemed appropriate. Based on the analysis of monthly data, however, we were neither able to prove, nor reject the hypothesis that there is a negative relation between the tradable green certificate and the price of the EUA.

Finally, we also examine the interaction of regulatory instruments with **modelling**. The European Electricity Market Model simulates the wholesale electricity markets of 36 European countries assuming perfectly competitive market conditions. Having implemented a number of upgrades on the Electricity Market Model we gained an opportunity to explore the interactions in more depth. In the dissertation we identify seven regulatory instrument combinations for which – from a theoretical point of view - we could not unambiguously identify the impacts on the three factors in the focus of our analysis. We also use modelling to answer this question.

During our research we focused on the instrument combinations through which the 20-20-20 targets of the EU can be achieved, and the advantages/disadvantages of simultaneously using more regulatory instruments. One of the most important results is that the higher the number of simultaneously applied regulatory instruments, the less extreme will the values of the most important variables be. Although the three EU targets can be achieved under any combination, it is still advisable to use 3 or 4 regulatory instruments. As a result the prices, the electricity mix or the carbon-dioxide emission change less dramatically compared to a case without any regulation. If, for example, we only use renewable support, then the wholesale price of electricity may be quite low, which may rearrange the operation of the European electricity market. In addition, the retail prices paid by consumers may increase above 100 €/MWh.

We pointed out that the renewable target of the EU is often achieved because it has been set as a percentage and not as an absolute value. If a renewable support instrument is not applied then the quantity of generated renewable energy does not change significantly compared to the case without regulation. Nevertheless, it should be noted that during the analysis we inspected the impact of the level of given regulatory instruments only in a range within which the targets are already met.

We also pointed out that the excise tax and emission trading are almost perfect substitutes of each other, thus due to administrative reasons it is advisable to use only one of them. There is not really a notable difference between the two instruments, since they both apply to fuel use, that is, they reward the improvement of efficiency (resulting in less tax per unit of energy output). As a minor difference, carbon-dioxide trading burdens coal fired power plants more than the excise tax.

Lastly, we employed modelling to determine which one of the regulatory instrument combinations that satisfy the all-European 20-20-20 targets is the best for Hungary. During the analysis of the research question we kept the principles contained in the National Energy Strategy in mind. We showed that there is not any instrument combination at which all the six examined factors (renewable ratio; price of electricity; coal based generation; electricity consumption; net import and nuclear production) would change in line with the Energy Strategy. Most criteria are satisfied by the instrument mix under which emission trading, an excise tax and energy efficiency investment support are applied together. We should note that in this case additional renewable capacities are not created compared to the reference case without regulation in Hungary either. There are altogether four cases in which four out of the six result variables comply with the principles of the Energy Strategy.

The following recommendations can be made as a result of the dissertation:

- It is advisable to use three regulatory instruments to reach the European targets, as a result of which the market failures of the electricity market can be reduced. The recommended regulatory instruments include renewable support and energy efficiency investment support, supplemented with either emission trading or an excise tax. Within the dissertation we also provided quantitative evidence that these last two regulatory instruments are practically substitutes of each other.

- In case of renewables it is more reasonable to set absolute targets, since otherwise energy efficiency or energy saving measures may also lead to the fulfilment of the targets without creating new renewable capacities.
- During the analyses we only inspected the electricity sector. Although sectoral models have a lot of advantages, but further investigations are needed with economic model covered the whole energy sector.

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VI. THE AUTHOR'S OWN PUBLICATIONS ON THE TOPIC

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