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# *COMPATIBILITY OF GREEN, WHITE AND BLACK CERTIFICATES IN ELECTRICITY MARKETS*

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## Overview

We consider the simultaneous functioning of systems of Tradable Green Certificates (TGCs), Tradable White Certificates (TWCs) and CO2 permits/taxes designed to attain targets on shares of renewables; energy saving, and reductions of CO2-emission, respectively, as they interact in electricity markets. Jointly, these systems influence the generation of electricity based on renewable sources ("green" electricity) and on fossil sources ("black" electricity). Also, they influence electricity saving and end users' consumption of electricity equivalents (i.e. sum of electricity consumption and electricity savings). Applying an analytical model as well as a numerical model it turns out that several of the effects of these systems are indeterminate and outright counteractive as they act in concert.

## Method

Generally we apply economic modelling. The more general analytical model is based on previous work by Amundsen and Mortensen (2001), Bye (2003) and Amundsen and Nese (2009), while numerical model is based on previous work by Bye (2003). The earlier work only included a TGC market and a CO2 permit market/ CO2 tax. The models developed here are extensions that also include a TWC market that interacts with the other markets. The numerical model is based on Norwegian data. Other more recent work within this strand of literature includes Montero (2009), Boehringer and Rosendahl (2010), Fischer, C. (2010), Green, R. and A. Yachew (2012).

## Results

In general, the model shows that a TGC system and a TWC system may achieve their objectives, namely to increase the share of green electricity and to increase the share of electricity saving out of total electricity consumption, respectively. However, these are targets formulated with respect to percentages and, therefore, one cannot immediately draw any conclusions with respect to the effects on quantities of green electricity generated and on energy saving of introducing such systems. In fact, the specific analysis performed here show that not very much can be said at all of such effects.

In particular, it is shown that an increase of the percentage requirement for green electricity does not necessarily lead to increased generation of green electricity, nor does an increased percentage requirement for electricity saving necessarily lead to additional electricity saving. For instance, if the increase of the percentage requirement of green electricity leads to a reduced demand for electricity, the generation of green electricity may fall and still satisfy the increased percentage requirement provided that the percentage reduction of green electricity is less than the percentage reduction of electricity consumption. Likewise for an increase of the percentage requirement of electricity saving. The only general clear cut result on quantity effects from introducing TGC and a TWC system is that the generation of black electricity definitely will fall when increasing the percentage requirement for green electricity.

Apart from this the analysis shows that an increase of the carbon price will lead to a reduction of the generation of black electricity when interacting with TGC and TWC systems. However, it will also lead to a reduction of green electricity generation and of electricity saving, which may be seen as unwanted side effects of the carbon price increase. These results are due to the design of the TGC and the TWC systems. In particular, it is shown that the end user price of electricity equivalents in equilibrium should be equal to a marginal cost composed as a linear combination of the marginal costs of generating all kinds of electricity in the correct proportions. As the carbon price increases it merely shifts the weighted marginal cost curve upwards and thus leads to less electricity consumption and a unilaterally reduction of all kinds of electricity.

An important result of this analysis is that the total demand for electricity equivalents actually may increase as a result of increased percentage requirements and lead to a lower wholesale price of electricity. This is important for tax incidence and for the question of who is really paying for the extra costs of increasing shares of green electricity and electricity saving. It turns out that this is not only a theoretical possibility but may well be the case of a real world setting. The model analysis based on Norwegian data shows that this is, indeed, the case for percentage requirements up to 20 percent in both the TGC and the TWC markets. The consequence of this is that end users get cheaper electricity and that the extra costs of increasing the shares of green electricity and the electricity saving are paid by the existing producers of electricity.

**Conclusions**

The TGC, the TWC and the CO2 permit market systems are not very compatible. For instance, an increase of the percentage requirement of green electricity may increase the demand for electricity while an increase of the percentage requirement of electricity saving may do the opposite and, hence, may out-weight the former effect. In general, the problem with the TGC and the TWC instruments is that it is very unclear which kinds of market failures they are intended to deal with. This is in sharp contrast to the CO2 permit system or a CO2 tax that are targeted at CO2 emissions and that have clear cut effects both in theory and in practise.

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