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Department of Economics

Inequitable Rent Generation for Renewable Electricity Producers in Elcertifikatsystemet

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Master's thesis · 30 hec · Advanced level
European Erasmus Mundus Master Program: Agricultural Food and Environmental Policy Analysis (AFEPA)
Degree thesis No 965 · ISSN 1401-4084
Uppsala 2015

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Credits: 30 hec
Level: A2E
Course title: Degree Project in Economics
Course code: EX0537
Programme/Education: European Erasmus Mundus Master Program: Agricultural Food and Environmental Policy Analysis (AFEPA)
Faculty: Faculty of Natural Resources and Agricultural Sciences

Place of publication: Uppsala
Year of publication: 2015
Cover picture: Miao Sun, SLU
Name of Series: Degree project/SLU, Department of Economics
No: 965
ISSN 1401-4084
Online publication: http://stud.epsilon.slu.se

Key words: Elcertifikatsystemet, equity, tradable green certificates

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Acknowledgements

I would like to express my deep gratitude to my thesis supervisor Prof. Rob Hart. The completion of this thesis would not have been possible without Rob’s support along the way. From the very beginning of my thesis ideas, to the extension of my writing period, up until now when I finally finish it, he has been giving encouragements and advice to me, which I appreciate very much. During the writing process of the thesis, he devoted his time to review my drafts, have discussions with me, and follow up on my progress. He helped me to be more and more clear about my research question, and gave me guidelines on how to do a proper academic research, covering a wide range from writing languages to methodology for the research. He has been such a great support and fabulous thesis supervisor that I feel so fortunate to be his student.

I also want to thank Prof. Thomas Heckelei, Prof. Yves Rene Surry, Prof. Bruno Henry de Frahan, and Prof. Frédéric Gaspart, for giving their comments and advice on my thesis at the summer school of AFEPA (Agricultural, Food and Environmental Policy Analysis) Program in 2014. I am grateful for the understanding and cares of Henrich Brunke, Kristina Jansson, together with the AFEPA consortium, during the extension of my study, as well as during the whole program. My thanks are also expressed to Prof. Sebastian Hess and Prof. Ing-Marie Gren for the guidance at the Thesis Course at Department of Economics in Swedish University of Agricultural Science. It has been a wonderful time studying here. I want to show my gratitude to the amazing AFEPA fellows as well, who have been a great asset for me both academically and emotionally.

Abstract

Energy transition is a task faced by every country in order to combat climate change, therefore, the choice of renewable energy supporting policy is a crucial decision for politicians. In Europe, since Renewable Energy Directive was agreed in 2009, various policy schemes have been adopted in many countries, and Swedish Electricity Certificate System is one of them. Starting from 2003 until now, it has assisted Sweden to become the country with highest percentage of renewable electricity in total electricity generation among all the European member countries, and has included Norway from 2012 to create a joint market for electricity certificates between these two counties.

However, the increase of renewable electricity production is only one part of the picture, while the other part is involved with concerns on the inequity among renewable electricity producers within the system. During more than tens years of operation, the systems has generated a large amount of benefits for a small share of renewable electricity producers, who have already been phased out of the system by the end of 2014, after obtaining excess percentage of payment by consumers. The technology-neutral nature of the policy scheme needs to be questioned, because it not only has created the equity issue in the past, but also indicates the same issue potentially in the future. The purpose of this study is to find out to what extent this inequity existed in the past, the impacts on different renewable electricity producers, and whether the inequity will continue to happen in the future. These conclusions will help us to see if the Swedish Electricity Certificate System is really a sustainable policy, or the one needs to be improved.

Table of Contents

List of Figures

List of Tables

Dedication

I would love to dedicate this thesis to my family faraway in China. Due to various reasons, the procedure of completing the thesis is not easy, which takes around more than one year. During this period, I did not travel back to China due to visa issues, but my family has been giving me understandings and unconditional support all the time. That power has supported me to finish my thesis and make the best use of my time here in Sweden. This thesis is also dedicated to the good friends that I have made in Germany and Sweden, without whom my European adventure would not have been complete. Their names are (based on alphabetical order of family names): Ivonne Altamirano, Roger Chang, Grace Chen Jingya, Nadav Chudler, Xin Dai, Markus Danell, Asta Druskinyte, Adrian Ehrnebo, Liang Gong, Carolin Kamrath, Phuongdung Le, Alessandra Puppo, Mahsa Shahbandeh, and Lydia Tan.

1. Introduction

Energy consumption largely affects the progress of the international agenda on climate change. Energy transition from fossil fuels to renewable energy has been acknowledged by more and more people as one of the imperative measures to reduce carbon emissions. Electricity use is undoubtedly the most important part in energy consumption, thus the adoption of clean energy in electricity generation has been listed on many countries' national electricity policy agenda, especially in Europe. In 2009, Renewable Energy Directive (2009/28/EC) set mandatory targets for all member states to fulfill at least 20% of their total energy needs with renewables by 2020 — to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020. Most of the European countries have made continuous efforts in achieving the goal in their national electricity supply.

Although with similar goals to achieve, different countries have implemented different public policies to support the process. This paper has chosen Sweden's tradable green certificates scheme — Electricity Certificate System (ECS) — as the target policy to discuss. Sweden has the second highest percentage of 'share of renewable energy in gross final energy' according to Eurostat.[1] The research on different renewable energy technologies is also at the upfront position in the world. Therefore, the analysis of the Swedish ECS will reflect the lessons learned from a relatively successful result, and shed light on policy-making in developing countries, thus speed up the worldwide development of renewable energy.

To evaluate a policy, there are many criteria. The discussion on Swedish ECS in this paper will focus on whether the policy has given equivalent incentives to different renewable energy producers. Technology-neutral is a major feature of the policy, our research is going to find out whether the impacts of the policy is 'technology-neutral' as well. Therefore, the research question is: will some producers be over-compensated and some under-compensated due to the heterogeneity? Equity is our evaluation criterion in the discussion, not only because it is an important aspect of policy evaluation, but also due to the diversity of producers in the ECS. Equity needs to be guaranteed among different producers, new plants or old plants, new technology or old technology, as long as they are renewable energy producers and contribute to the whole transition of energy supply. Therefore, the purpose of this paper is to examine if

[1] Eurostat's website: http://ec.europa.eu/eurostat/data/database

the Swedish renewable electricity policy has met the equity criterion, and if not, to what extent the inequity exists.

There is not a lot of research specifically on Sweden's Electricity Certificate System, although the discussions on the policy scheme it represents — Tradable Green Certificates (TGCs) — are many. TGCs schemes are frequently compared to another popular scheme, Feed-in Tariff (FIT). They have different policy measures but aim the same goal, which is to stimulate the development of renewable electricity generation. As for TGCs schemes, the discussions have various topics, such as market power (Amundsen and Nese 2002), price and volume effect (Bye 2003, Amundsen et al. 2006), political uncertainty (Canton and Lindén, 2010), as well as the uncertainty when integrated with Emission Trading system in Europe (Böhringer and Rosendahl 2010; Amundsen and Mortensen 2001; Morthorst 2003). When it expands among countries, which is applied in the Swedish and Norwegian case, caution is suggested to be taken (Nielsen and Jeppesen 2003; Rö 2005; Unger and Ahlgren 2005; Toke 2008; Amundsen and Nese 2009; Amundsen and Bergman 2012). More importantly, windfall profit generated in TGCs is at the centre of controversy. It has been 'largely viewed as less equitable than FITs for those looking to invest in the renewable electricity generating industry' (IRENA, 2014). It may create barriers for the entry of new renewable electricity producers and result in the increased market power for larger players (Batlle et al. 2012). High and persistent excessive profits are in place for mature technologies (Verbruggen and Lauber 2012).

In this paper, we are going to refer to Bergek and Jacobsson's research in 2010, which is in response to the three policy expectations of Swedish Electricity Certificate System. By analysing the data from 2003 to 2008, they came to the conclusion that the Swedish TGCs has almost met the expectation for increase in renewable electricity production, but it performs badly in terms of consumer costs, equity, and contribution to technical change and cost reduction. In this paper, we will develop our research based on Bergek and Jacobsson's method, but extend it as well, in order to achieve more detailed and specific conclusions. Based on the data from the accounting system for Swedish ECS from 2003 to 2013, producer surplus is calculated in the form of two types of rents gained by renewable electricity producers. The first type is up-to-now rent, generated from overcompensation for plants that have been phased out of the system by the end of 2014; the second type is future rent projection, under the circumstance that more expensive technology for renewable electricity generation (such as Off-shore wind power) is introduced into the system. In our analysis, the rents are expected to be shown in numerical terms or possible future trend (due to limited data access), so that the conclusions of whether the equity issue does exist and whether it will continue could be made. We are also interested to see the allocation of the inequity among different renewable energy sources.

This study is based on previous studies so the methodology used is not new. Some assumptions were made in order to proceed the discussion, which may not be the same in reality. Due to the data accessibility, some values chosen are not accurate enough. The research is not completely finished yet, given the uncertainty of the policy. However, the discussion is open so further research is easy to carry out based on the conclusions so far.

In this paper, the arrangement for chapters are as follows: chapter 2 starts with the concept of Tradable Green Certificates and the key agents in the Swedish scheme, and is continued with some important policy tools and indicators that formulate the system. Chapter 3 briefly introduces the criteria in renewable energy policy evaluation and identifies the one used in this paper, the equity criterion. Chapter 4 and 5 are the main body of this paper with theoretical foundation of the analysis and the empirical results. The results of the analysis will lead to the conclusions in Chapter 6.

2. Tradable Green Certificates

2.1 What is a TGCs scheme?

Tradable Green Certificates (TGCs) is a policy scheme deployed by a few European countries so far for the development of renewable energy, based on their national goals in order to achieve the 2020 target of EU. Countries that have adopted TGCs include the Netherlands, Belgium, UK, Sweden, etc. An alternative policy scheme for that is Feed-in Tariff (FIT), which is also widely used as a renewable energy policy in Europe. Germany and Spain are among the others the ones that have adopted FIT for a longer time.

The TGCs system is basically designed to increase the electricity production from renewable sources. To achieve this, usually the electricity consumers are required to include a certain percentage of renewable electricity in their overall electricity consumption. This percentage requirement is set by the government, different and on a increasing trend year after year. This part of energy consumption needs to be realised by purchasing electricity certificates from renewable electricity producers. The certificate-entitled producers get the certificates from government agency based on their production units, e.g. one unit of electricity production gets one certificate. Therefore, the price of certificates is generated by demand and supply on the market: demand from electricity consumers and supply from renewable electricity producers. In this way, renewable electricity producers can get an extra price from the certificate other than the electricity price, which formulates a subsidy for their higher marginal cost. TGCs may have different design characteristics and specific targets in each country, however, it is considered to be a market-oriented subsidy aiming at stimulating electricity generation from renewable sources in a cost-efficient manner. The market-driven nature also guarantees that it is technology-neutral.

However, TGCs has been questioned ever since this scheme was introduced. The perspectives are various. In regard to a national TGCs scheme, it might not perform as efficiently as expected in reality due to the existence of market power (Amundsen and Nese 2002), price and volume effect when raising quota (Bye 2003, Amundsen et al. 2006), or political uncertainty (Canton and Lindén, 2010). When integrated with electricity market, the effectiveness and the possible contributions to national GHG-reduction strategies might not hold (Morthorst 2003). The overlapping of TGCs and EU ETS and its influence on both goals—the renewable energy goal and the CO2 emission goal—are also hot topics (Amundsen and Mortensen 2001, Böhringer and Rosendahl 2010). In this paper, we will focus on national TGCs scheme itself.

2.2 Tradable Green Certificates in Sweden

2.2.1 Swedish Electricity Certificate System (Elcertifikatsystemet)

Sweden is one of the earliest European countries in introducing TGCs. In May 2003, the Swedish Electricity Certificate System (*Elcertifikatsystmet* in Swedish) was established by Swedish Energy Agency (SEA), a government agency for national energy policy issues. An initial goal was to increase 10 TWh ‘green’ power by 2010 relative to that of 2002, in response to the EU’s RES-E Directive. This goal was subsequently increased during several policy changes until in 2009, which was raised to 25 TWh increase by 2020. Since Jan 2012, a common certificate market with Norway was established, whose goal is to increase renewable electricity production by a total of 26.4 TWh—13.2 TWh each country—between 2012 and 2020. The common electricity certificate market is due to continue until the end of 2035. Recently, the ambition of a 30 TWh increase of renewable electricity under the certificate system by 2020 is proposed by SEA and that will again lead to a policy adjustment in Sweden.

According to Eurostat, the share of renewable energy in gross final energy consumption in Sweden is 51% in 2012, exceeding the target of 49% set by European Union. The percentage of electricity generated from renewable sources is 60% in 2012, which is also at a leading position among all European countries. After more than ten years of operation, the number of plants, installed capacity, and electricity production from renewable electricity producers in Elcertifikatsystemet have all made obvious progress. Figure 2.1, 2.2 and 2.3 are the illustrations of these three main indicators.

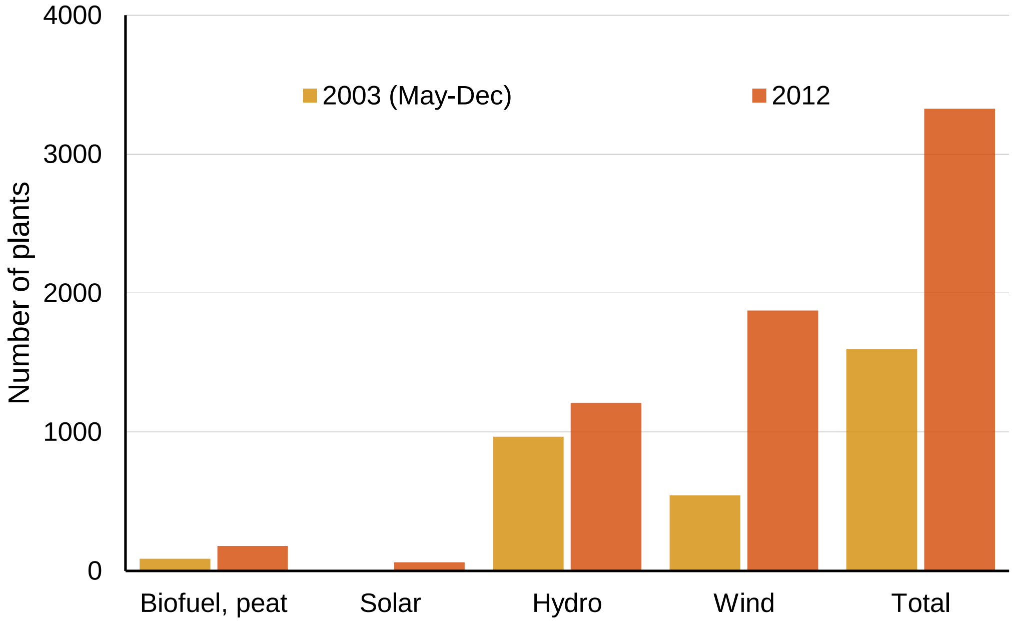

Figure 2.1 Number of certificate-entitled plants in ECS in 2003 and 2012

Source: Svenska Kraftnät's accounting system (Cesar); Swedish Energy Agency

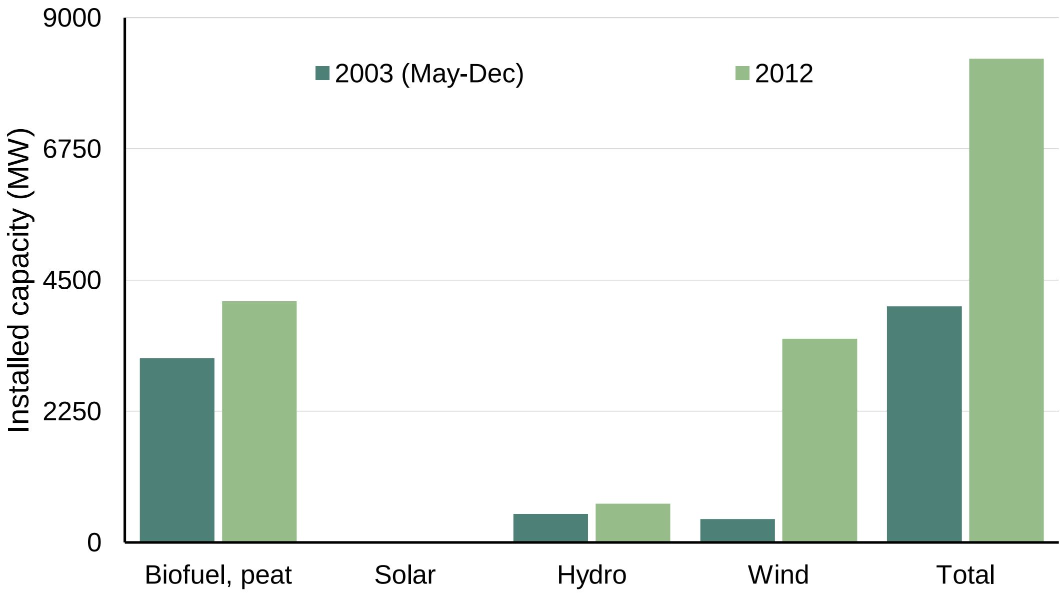

Figure 2.2 Installed capacity of renewable electricity entitled by ECS in 2003 and 2012

Source: Svenska Kraftnät's accounting system (Cesar); Swedish Energy Agency

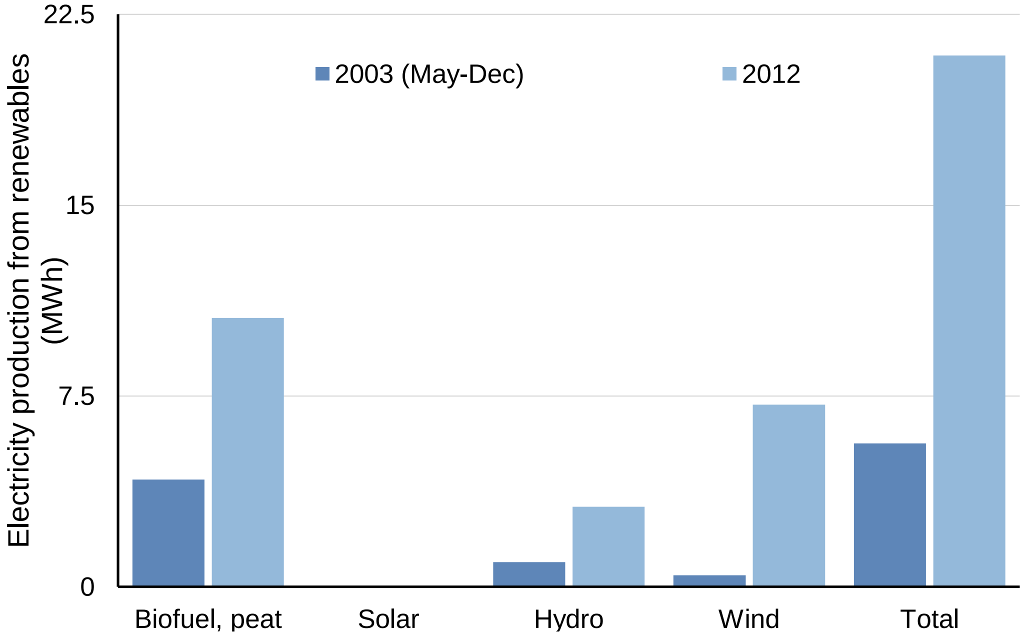

Figure 2.3 Renewable electricity production entitled by ECS in 2003 and 2012

Source: Svenska Kraftnät's accounting system (Cesar); Swedish Energy Agency

Figures 2.1 and 2.2 clearly show that, in Elcertifikatsystemet, number of commissioned plants and installed capacity in 2012 were both roughly twice as large as in 2003. Furthermore, in Figure 2.3 the electricity production from the commissioned renewable producers in 2012 are 3.7 times of that in 2003. So far the Swedish TGCs seems to be performing well in regard to the initial goal to stimulate electricity production from renewable sources.

In order to have a better understanding of how Elcertifikatsystemet works, we will firstly identify the key agents, and then elaborate the mechanism of the system.

2.2.2 Agents in Elcertifikatsystemet

As mentioned above, the percentage requirement of 'green power' in total electricity consumption is a government measure in TGCs and it links the participants together in the system. In Sweden, this percentage is named 'quota' or 'quota obligation', which has the same definition as in general TGCs designs. The agents in Elcertifikatsystemet are defined slightly differently in Sweden but they still have a direct or indirect connection with quota obligation. They include official agencies SEA and Svenska kraftnät (Swedish National Grid), electricity producers, suppliers, and consumers.

SEA and Svenska kraftnät are the surveillance authority and the accounting registrar respectively, and they share the responsibility for Elcertifikatsystemet in Sweden. SEA is responsible for the rules and principles of the system, such as the approval of certificate allocation to plants, decision of late delivery penalty, monitoring and analysis of the development of the certificate market, etc. It is also the body who decides the quota obligation. Svenska kraftnät is a state-owned public enterprise, whose duties include responsibility for controlling Sweden's electricity production in real time, and the import, export, and balance of power. In Elcertifikatsystemet, it

- "Issues electricity certificates based on metered values from certificate-entitled electricity production
- Compares and maintains the certificate register, with details of certificate holdings
- Cancels certificates on 1st April each year, in accordance with information in the returns received and checked by the Swedish Energy Agency
- Regularly publishes information on the number of certificates issued, traded and cancelled, together with their average price."[2]

Producers in Elcertifikatsystemet are defined as the certificate-entitled renewable electricity producers. Their production of electricity will be commissioned by green certificates on a one certificate per MWh basis. According to SEA, the energy sources that are entitled to certificates in Sweden include[3]:

- Wind power
- Solar energy
- Wave energy
- Geothermal energy
- Biofuels, as defined in the Ordinace (2011: 1480) concerning electricity certificates
- Hydropower
    - small-scale hydro power which, at the end of April 2003, had a maximum installed capacity of 1500 kW per production unit
    - new plants
    - resumed operation from plants that have been closed, if they have been so extensively rebut or received such investments that the plants are to be regarded as new plants
    - increased production capacity from existing plants

[2] The Swedish-Norwegian Electricity Certificate Market, Annual Report 2012, the Norwegian Water Resource and Energy Directorate (NVE) and the Swedish Energy Agency, P14.
[3] The Electricity Certificate System 2012, Swedish Energy Agency, P7, and the website of Swedish Energy Agency

- o plants that can no longer operate in an economically viable manner due to decisions by the authorities, or to extensive rebuilding
- Peat, when burnt in combined heat and power (CHP) plants[4]

In order to be equitable, it is stated that facilities built before May 2003 have to phase out of the system by the end of 2012 or 2014, depending on the type of subsidies they used to get from the government.[5] New plants that become operational after the implementation will be entitled with certificates for 15 years, until the end of 2035.

On an electricity market, electricity suppliers or electricity trading companies, are those who purchase electricity from the producers or on the electricity exchange, and resell it to the end users. Therefore, they have commercial contracts with both electricity producers and end users. In Elcertifikatsystemet, electricity suppliers are required to hold a certain percentage of certificates —quota—in relation to their sale of electricity. In fact, suppliers are not the only one who has quota obligations in the system. According to SEA, the quota-obligated parties include[6]:

- Electricity Suppliers
- Electricity consumers who use electricity that they themselves produced, if such production exceeds 60 MWh per accounting year, and has been produced in a plant with an installed capacity exceeding 50 KW
- Electricity consumers to the extent that they have used electricity that they have imported or purchased on the Nordic power exchange
- Electricity-intensive industries registered by SEA

They are all required to comply with the annual quota set by SEA in relation to their sale or use of electricity. The term 'suppliers' used in this paper will represent all the quota-obligated parties, if not specified.

Electricity consumers, or electricity purchasers, or end users, are not directly connected to certificate trading. However, the certificate price indirectly and ultimately comes from consumers because it is embedded in their electricity bills. Therefore, it is the consumers who bear the payment for extra revenue received by renewable electricity producers. It is estimated by SEA that the average cost to consumers in 2011 was 4,4 öre per kWh. VAT and

[4] Peat was introduced into the certificate system in 2004 despite the fact that it is not strictly classified as a renewable fuel. The reason is based on environmental considerations.
[5] See 5.1.1 for policy details.
[6] The Swedish-Norwegian Electricity Certificate Market, Annual Report 2012, the Norwegian Water Resource and Energy Directorate (NVE) and the Swedish Energy Agency, P10.

transaction costs will further increase the price.[7] However, several researches have revealed a much higher consumer cost and transition cost than the government estimation (Bergek and Jacobsson, 2010; Nilsson and Sundqvist, 2007).

In Sweden, other than the key agents mentioned above, Cesar is a registry and accounting system that records the trading of certificates. It is not a marketplace for the trading, as it only shows the completed transactions between the two parties, e.g. who is the new owner of the certificate, price and quantity of the certificates traded. From 1st January 2015, SEA has taken over the role of the accounting authority for certificates and guarantees of origin from Svenska kraftnät.

Since the formation of a common certificate market between Sweden and Norway, corresponding agents in Norway are in place for the system as well. The Norwegian Water Resources and Energy Directorate (NVE) has the same role as SEA, and Statnett and NECS are respectively responsible for accounting registrar and accounting system, corresponding to Svenska Kraftnät and Cesar in Sweden.

A council and a committee for the ECS are also set up in accordance with the agreement between Noway and Sweden. The council's task is to facilitate planning and the implementation of progress reviews, among other items. The committee shall keep itself informed and discuss the design and implementation of the regulatory framework.[8]

2.2.3 Mechanism of Elcertifikatsystemet

Quota obligation is always proposed by SEA in government documents, starting from the publishing year until the end year of the system. The quota is different from year to year. When the goal of policy changes, the adjustment of quota is necessary. Figure 2.4 is a summary of the quota adjustments due to target changes since 2003.

[7] The Electricity Certificate System 2012, Swedish Energy Agency, P27

[8] The Swedish-Norwegian Electricity Certificate Market, Annual Report 2012, the Norwegian Water Resource and Energy Directorate (NVE) and the Swedish Energy Agency, P15.

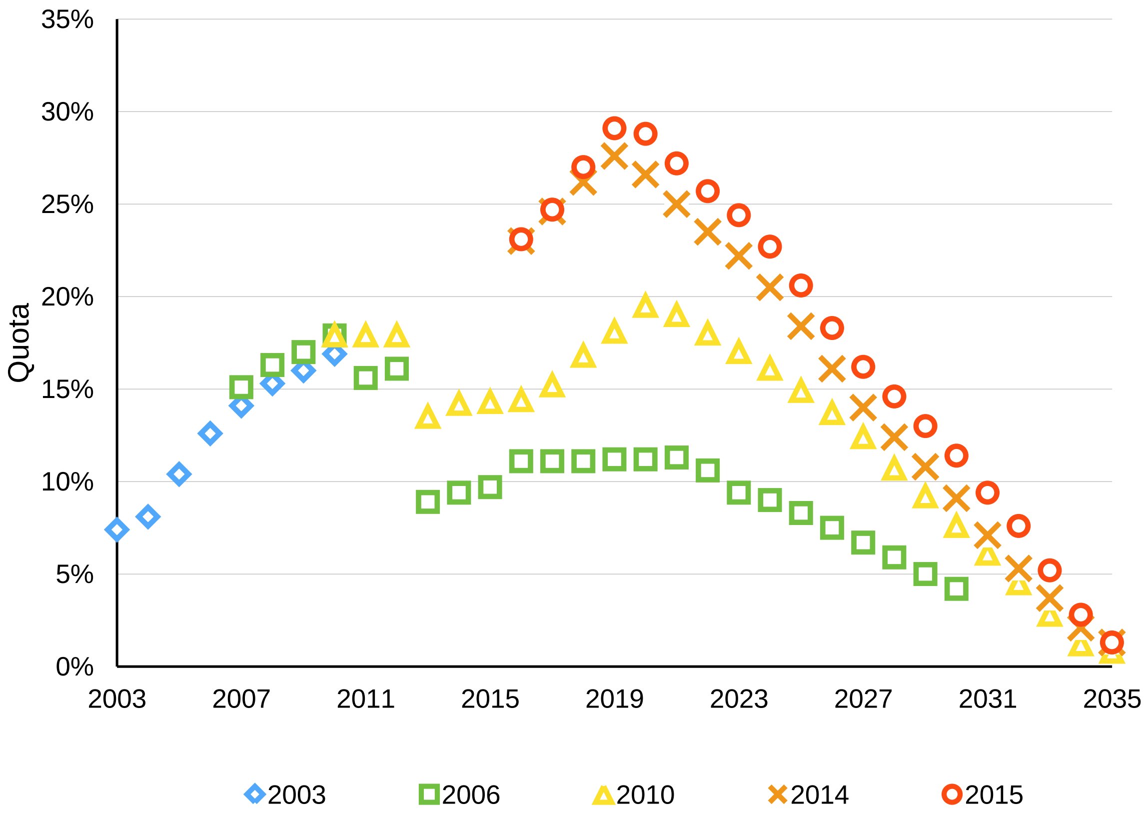

Figure 2.4 Planned quotas for each year (2003-2015)[9]

Source: Kontrollstation för elcertifikatsystemet 2015 (ER 2014:04) P79, Finansiering av 30 TWh ny förnybar el till 2020 (ER 2015:07) P15

Figure 2.4 has shown the planned quotas for each year from 2003 to 2015. Due to several times of policy changes, the planned quota in one year may be higher or lower than the previous value. Take 2010 as an example, when the policy was firstly implemented in 2003, the planned quota obligation was 16,9%. However, in 2006 when some amendments were made in the policy, the planned quota for 2010 was adjusted to 17,9%. The planned quotas for future years have also been adjusted for several times. For example, the quota for 2019 was planned to be 11,2% in 2006, 18,1% in 2009, 27,6% in 2014, and 29,1% in 2015. The actual goal will refer to the most recent policy planning. Up until now, the quota schedule has been adjusted four times, and the planned period has been prolonged over time. These adjustments were all triggered by a more ambitious goal in renewable electricity production, reflected in a higher quota level planned for the same year. A longer policy period shows a sustaining

[9] The colours represent policy changes in 2003, 2006, 2010, 2014 and 2015. They correspond to target changes. See Appendix I.

political interest in Elcertifikatsystemet, which is good for policy stability, although not sufficient. The figure also shows that, obligated quota always has the trend to increase first and then decline after the peak. This is to guarantee enough demand on the market before some plants phasing out.

Once quota is set, the demand for certificates from the suppliers are created. On the supply side, renewable electricity producers have to submit their applications to SEA for the certificate entitlement. After the examination of the application, Svenska kraftnät issues electricity certificates on the 15th of each month or the next non-holiday day, based on the reported metrics from previous month. Producers receive one electricity certificate per MWh for 15 years maximum. The entitled certificates could then be sold on the market. In this way, producers get an extra income from selling the certificate for each MWh electricity that they generate, equivalent to the certificate price.

How to ensure that the suppliers have fulfilled their quota obligation? It is done through the cancellation of certificates in the accounting system Cesar. By March 1st each year, suppliers are required to submit a declaration to SEA to specify the electricity use and deductions from quota obligation from the past year. They must also ensure that the equivalent amount of certificates in relation to their obligation is held on their account by 31st March. On 1st April, the obligated certificates will be cancelled thus they could not be used or sold again. If insufficient certificates are on the account, SEA shall decide to impose a quota obligation charge, which amounts to 150 percent of the volume-weighted average price under the accounting year for each missing certificate.

Historically, the fulfilment of obligation has been almost 100 percent in Sweden. Table 2.1 shows the cancellation and fulfilment rate of the quota obligation in Sweden from 2003 to 2013.

Table 2.1 Cancellation of Certificates 2003-2013

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Electricity with quota obligation (TWh)	63,3	97,4	97,6	97,1	96	94	90,6	98	92,5	91	93,4
Quota	7,4%	8,1%	10,4%	12,6%	15,1%	16,3%	17%	17,9%	17,9%	17,9%	13,5%
Number of cancelled certificates (million)	**3,49**	**7,83**	**10,12**	**12,39**	**14,46**	**15,32**	**15,40**	**17,54**	**16,53**	**16,29**	**12,30**
Quota obligation fulfilment (%)	**77,00**	**99,20**	**99,90**	**99,90**	**99,80**	**99,96**	**99,99**	**99,99**	**99,80**	**99,95**	**97,68**
Quota obligation fee* (SEK/each)	175	240	306	278	318	431	470	402	310	298	301
Total quota obligation fee (MSEK)	182,8	14,4	3,1	2,3	8,3	2,3	0,7	0,8	9,5	2,6	88,1

* Quota obligation fee=1.5×average certificate price (March of the year to April of the next year)
Source: Cesar and own calculation for the year of 2013

From the table above, it can be seen that the quota obligation has been fulfilled quite well during the 10 years, except the starting year 2003 and the first year after common market with Norway in 2013. In these two years, the quota obligation fee is much higher than the others, which is an extra income for the government. It is not known yet how it is used by the government.

In 2012, Sweden and Norway started the operation of a common electricity certificate market. The goal is to increase renewable electricity production in a more cost-effective way instead of having two national markets. A larger group of participants and an increased liquidity could be expected. In fact, it is suggested that the creation of a trading market of certificates, in a Swedish-Norwegian context, could bring benefits such as to mitigate market power (Amundsen and Bergman 2012), but it also requires caution since the quota is not a very precise policy measure for stimulating green electricity generation (Amundsen and Nese 2009). Furthermore, if a Nordic common certificate market exists, electricity supply based on biomass combustion will dominate the TGCs scheme, at least in the short run, and wind power may increase the share along the time (Unger and Ahlgren 2005). Some research also extend this to an European-wide TGCs to see if harmonisation of the system is feasible in practice. They suggest that benefits from effectiveness and cost-efficiency are possible but should be taken care of with caution. Certain factors such as eligible technologies, market stabilisation mechanisms, co-existing renewable energy regulations (Nielsen and Jeppesen 2003, R ό 2005) should also be considered. However, disadvantages of high certificate price due to under-supply, regulatory uncertainty (Toke 2008), as well as little chance for immature technologies (R ό 2005) might also happen in a pan-EU trading mechanism.

The fundamental principles for the certificate market in Norway are the same as in Sweden, including agencies, important dates, cancellation, and etc.. However, there are certain differences between the legislation. For example, peat is only entitled to electricity certificate in Sweden, while the proportion of biofuel in mixed waste qualifies for the certificates in Norway. Also, there is a possibility for a plant to get electricity certificates for the entire production following a major reconstruction in Sweden, while in Noway only the production increase will be entitled.[10] In 2012, a total of 18.7 million electricity certificates were cancelled in the common market, 16.3 million in Sweden and 2.4 million in Norway. In 2013, the cancellation decreased to 16.2 million, 12.3 million in Sweden and 3.9 million in Norway.

[10] Other differences include: plants that become operational in Sweden after 2020 can receive electricity certificates, and some minor difference in exception rules for electricity-intensive industry.

3. Evaluation of Renewable Energy Policies

3.1 Four Criteria

In the recent report by IRENA (International Renewable Energy Agency), effectiveness, efficiency, equity, and institutional feasibility are the four core criteria in regard to renewable energy deployment policy evaluations.[11]

According to IRENA, the first two criteria have more reference in literature and are more easily measured through indicators. For effectiveness, there are ‘installed capacity’, ’electricity output and growth rates’, or ‘deployment against a country’s overall potential over a period of time’, and etc.; for efficiency there are ‘remuneration level’, ‘profits and adequacy indicators’, and ‘total costs indicator’ and many more. These two criteria interact closely with each other and are usually considered together to show whether a policy is successful or economically efficient. Our discussion in Chapter 2 on Elcertfikatsystemet’s number of plants, installed capacity and electricity production from renewables are relative to the criterion of effectiveness. Based on the results, the Swedish TGCs has met the criterion. Institutional feasibility is concerned with political factors that affect the policy. It is most appropriate for ex-ante evaluation to see if the policy environment is favourable or not.

Compared with other criteria, equity has a wider social concern. It jumps out of the box to see the impacts on different parties under the policy. The success and economic efficiency are important performances for a public policy, nevertheless, if equity is somehow lost in implementation, it could not be considered adequate. Therefore, despite of the difficulty in identifying the indicators, equity criterion should not be neglected in policy evaluation. In this paper, it is the main criterion in delivering the result.

3.2 Equity Criterion for Elcertifikatsystemet Evaluation

Recall that in Chapter 2, we have known the characteristics of Elcertifikatsystemet, including key agents and how the system works. The purpose of this paper is to evaluate Elcertifikatsystemet using equity criterion. Equity is concerned with the distribution of policy impacts, but among literatures, specific indicators were only identified for consumer impacts. A wider range of aspects such as the distribution of costs, impacts on producers and other players, has equivalent importance as consumer impacts, thus the development of relative

[11] Evaluating Renewable Energy Policy: A Review of Criteria and Indicators for Assessment, IRENA UKERC Policy Paper, January 2014

indicators should also be given attention to. In the analysis of Elcertifikatsystemet in this paper, the focus of equity evaluation will be the impacts on renewable electricity producers, financially the main beneficiaries of this policy. Since there are not as many research as those for effectiveness and efficiency, it is hard to identify a well-accepted measurement for equity.

Claimed by policy makers, technology-neutral is an important feature of TGCs., which indicates that it is always the cheapest technology that is chosen first. However, renewable electricity producers are heterogeneous in term of energy sources, technology, operation time, scale, rate of return, etc. Will the impacts of the policy be ‘technology-neutral’ as well? Will some producers be over-compensated and some under-compensated due to the heterogeneity? These are the questions that we are going to answer in this paper. In fact, TGCs have been ‘largely viewed as less equitable than FITs for those looking to invest in the renewable electricity generating industry’ (IRENA, 2014). It may create barriers for the entry of new renewable electricity producers and result in the increased market power for larger players (Batlle et al. 2012). High and persistent excessive profits are in place for mature technologies (Verbruggen and Lauber 2012). Bergek and Jacobsson (2010) evaluated Elcertifikatsystemet in response to the three policy expectations in Sweden.[12] By analysing the data from 2003 to 2008, they came to the conclusion that the Swedish TGCs has almost met the expectation for increase in renewable electricity production, but it performs badly in terms of consumer costs, equity, and contribution to technical change and cost reduction. Their analysis on equity in terms of the two types of rents in Elcertifikatsystemet sheds light on the discussion in this paper. We will explore further in a similar manner and measure the impacts on different producers, in order to see if equity issue does exist in Elcertifikatsystemet.

[12] The three policy expectations are summarised as: to substantially increase the share of electricity generated from renewable energy sources, the expansion in the supply of ‘green’ power was to be done in a cost-efficient manner, and it would increase the competitiveness of electricity from renewable energy sources through technical change.

4. Theoretical Foundation

4.1 Definitions of Type I and Type II Rent

As previously mentioned in Chapter 2, the certificate price has been introduced as an extra income for renewable electricity producers. In other words, a reasonable certificate price should be the difference between producers' marginal cost and the electricity price on the market. However, if the certificate price exceeds the price gap of a certain producer, over-compensation will occur; and if this happens to a large number of producers, equity issue rises. The 'rent', is thus generated through the over-payment for those producers, who have an advantage in their marginal cost.

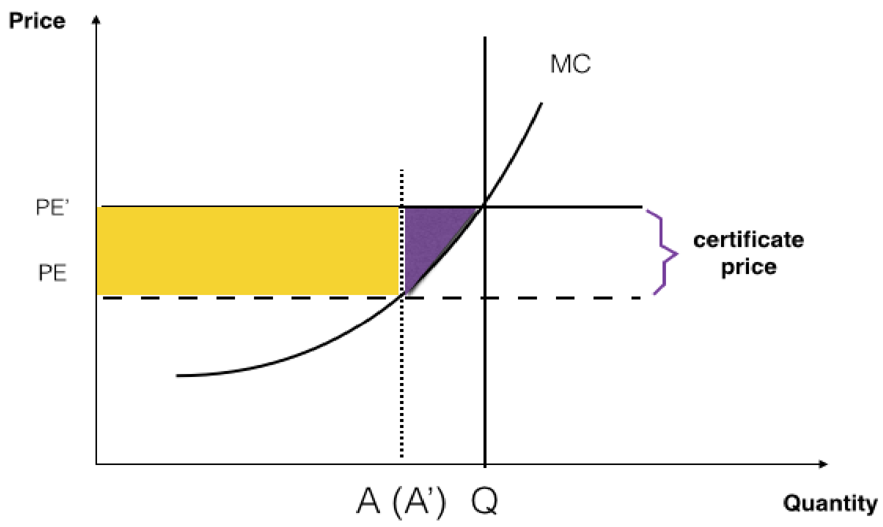

Figure 4.1 Type I and Type II Rent for certificate-entitled renewable electricity producer

The cost structure of renewable electricity producers could be very different, either within one specific source or among different energy sources. Rent is generated in two situations: 1. marginal cost is below or just equivalent to the market price of electricity; 2. marginal cost is in between of the electricity price and the certificate-price-added electricity price. We assume perfect competition on the demand side, and on the supply side, that there are lots of 'small' producers, indexed by *k*, each with a marginal cost MC_k, which may differ between producers. Furthermore, each producer has a fixed limit on capacity. That implies if a producer 'enters' the market, he will produce at his full capacity with his marginal cost MC_k. Under these assumptions, the market will look like Figure 4.1. *PE* and *PE'* are market prices for electricity before and after the certificate system, *MC* is the marginal cost curve for renewable electricity producers, each point represents one small producer.

Situation 1 applies to the producers with *MC* up until point *A*, where *MC* intersects *PE*, indicating that these producers are already profitable without the certificate system. They will get Type I rent in the yellow area, as a result of the pure price increase for the existing production. Situation 2 applies to the producers with *MC* in-between quantity *A* and *Q* on the curve. Their *MC* is higher than *PE*, but lower than *PE'*, thus the purple area is the extra payment above their profitable level. That is defined as Type II rent. In our analysis for Type II rent, all the existing plants in the system are considered to have the marginal costs unlimitedly approaching *PE'*, thus Type II rent is very small. However, it may be big if the certificate price is driven up by more expensive technologies in the future, which is the scenario we will discuss. The figure also shows that Type I and Type II rent in combination are actually the producer surplus from price increase.

In our analysis for Elcertifikatsystemet, Type I rent depends on the identification of quantity A, or possibly a point A' very close to A. Following Bergek and Jacobsson's idea (2010), A is the certificate-entitled production in 2003, and A' is the easily accessible production by plants with fairly low cost in production increase. The former (A) is the production that is eligible to enter Elcertifikatsystemet and receive the certificates in 2003. A total amount of 11,527 TWh renewable electricity (including peat) was generated in 2003, with 6,5 TWh certificate-entitled production (excluding peat). That includes 4,3 TWh of biofuel, 1,7 TWh of hydro power, and 0,5 TWh of wind power, as shown in Figure 4.2. The latter (A') is the production level specifically through fuel conversion or increase in full-load hours in existing CHP plants, which requires much lower cost than investment in other energy sources or new CHP plants.[13] The calculation of the easily accessible production will be discussed further in ***5.1.1***. Other than that, we will also analyse the Type I rent by different energy sources.

[13] It could also be interpreted as Type II rent, however, in this paper, this is defined as Type I rent.

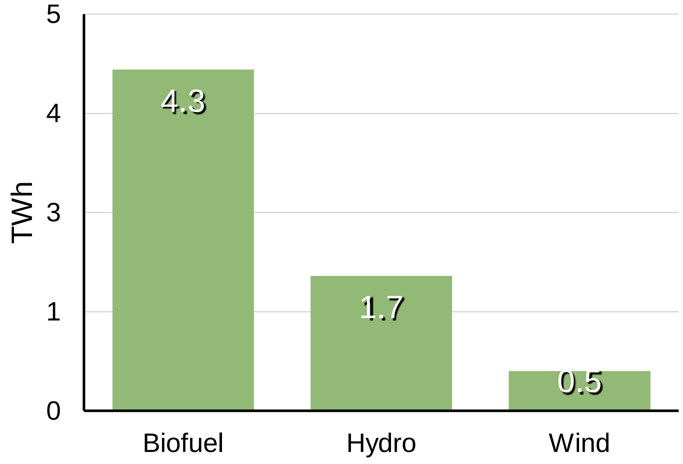

Figure 4.2 Certificate-entitled Production in 2003

Source: Förnybar el med Gröna certifikat, Swedish Energy Agency, 2008

Type II rent in this paper considers larger variation in marginal cost among producers, thus focusing on different technologies. More expensive technology could drive up the certificate price, ending up with producers of cheaper technologies receiving rents. Bergek and Jacobsson consider off-shore wind power driving up the certificate price to 500 SEK in 2015. The estimated Type II rent generated until 2030 for new plants in 2003 - 2014 would be 19 billion SEK (i.e., about 2 billion Euro) (Bergek and Jacobsson 2010). However, whether or not the introduction of off-shore wind power into the system is possible depends on the potential of renewables on the market. If the existing energy sources could provide enough electricity generation to meet the goal, off-shore wind will not be introduced soon. In this paper, regarding the uncertainty of Type II rent, we are going to estimate the supply curve of electricity certificate based on accessible data, and then make a rough prediction on Type II rent.

4.2 Calculation of Type I Rent

For the certificate-entitled production, recalling in Figure 4.1 quantity *A*, the certificate price is hundred percent transformed into the unit price for the rent, so the calculation should be:

$$R_{1,i}=Q_0\times P_i$$

$R_{1,i}$ is the Type I rent in year i, Q_0 is the certificate-entitled production, which is 6,5 TWh in 2003, and P_i is the average certificate price in year i. We define the result of this calculation as *Estimation I*.

As previously discussed, easily accessible production (A') is the production level that could be achieved at much lower cost, and it is the sum of certificate-entitle production and the production increase. Therefore, Type I rent for easily accessible production has two parts: one from certificate-entitled production with unit price as certificate price (*Estimation I*), the other from production increase with unit price as the difference between certificate price and marginal cost. Estimation I and the rent from production increase together, are defined as *Estimation II* (and *III*, see **5.1.2**). If Q_i is the certified renewable electricity production in year i, Q_1 is the accessible production (fixed value, see **5.1.1**), then the production that actually gains additional rent in year i could be obtained by taking the minimum value between Q_i and Q_1. [14] Assuming MC_{CHP} is the marginal cost from production increase, therefore, the calculation for Type I rent in *Estimation II* (and *III*) will be:

$$R_{1,i}=Q_0\times P_i+(Q_{0,i}-Q_0)(P_i-MC_{CHP})$$
$$Q_{0,i}=min\{Q_i,Q_1\}$$

In addition, we are also interested the distribution of Type I rent by energy sources. The three estimations above roughly show the amount of over-compensation that existing producers have gained from Elcertifikatsystemet from 2003 to 2013. The payment includes all the renewable energy sources and presents a holistic picture of Type I rent. However, what can not be reflected is the distribution of Type I rent among all the energy sources. This is important because it concerns the equity issue not only among old/new plants, but also among old plants with regard to different energy sources. A breakdown of the Type I rent by energy source is necessary, and also valuable in examining the equity criterion furthermore. Energy sources included in the analysis will be hydropower, wind power, biofuels, peat, and solar energy. The calculations will be similar as that in *Estimation I* and *II*.[15]

4.3 Calculation of Type II Rent

4.3.1 Background

Recalling Figure 4.1, Type II rent is considered very small at the moment. However, as the demand of certified electricity goes up, new technologies such as offshore wind power may be introduced into the certificate system, in which case, the certificate price will be

[14] This means that we make modest estimation using the smaller value of rent-gaining production.

[15] Hydropower, wind power, peat, and solar energy will have one estimation based on certified production in 2003, but biofuels will have two estimations. See 5.1.2.

driven up because of the higher marginal cost. That will lead to a higher retail price of electricity as well, thus brings Type II rent for certified producers with lower marginal cost. The shape of retail supply curve is of our interest, because it could largely affect the quantity of Type II rent: in Figure 4.3, convex supply curve (S_2*) will cause larger Type II rent than concave supply curve (S_1*). The area with shades is the difference of Type II rent between S_2* and S_1*.

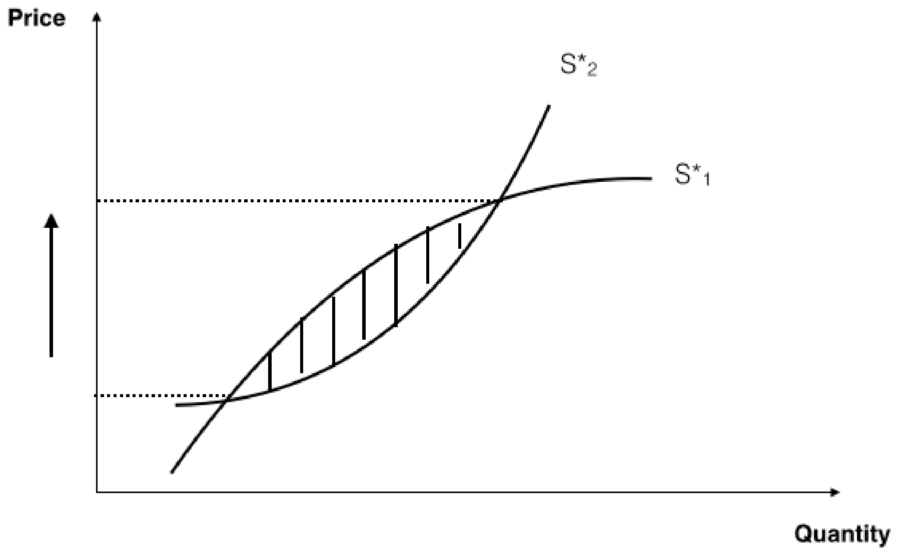

Figure 4.3 Type II Rent and Shape of Retail Supply Curve

In this paper, the area with shades will not be estimated numerically. However, we want to predict the shape of retail electricity supply curve based on relevant data and analysis, so that the potential scale of Type II rent could be predicted. In order to do that, we can start with a micro-model .

4.3.2 Shape of Retail Electricity Supply Curve

Assuming the total electricity supply on the retail market includes certified electricity from certificate-entitled renewable producers, and non-certified electricity. To derive the supply curve of electricity on the retail market given a TGCs system, I follow the steps as:

(1) Derive the supply curve for non-certified electricity;

(2) Derive the supply curve for certified electricity;

(3) Derive supply curve for retail electricity given that quota δ must be certified.

In Sweden, non-certified electricity will mainly be large scale hydro power and nuclear power, together with phased-out CHPs and other thermal electricity. In 2013, total electricity production in Sweden amounted to 149,2 TWh, of which 40,8% was produced by hydro power, 42,6% by nuclear power, 6,6% by wind power and the remaining 10 % by biofuel and fossil based production.[16] Norway, Finland, and Denmark are the main electricity importers and exporters of Sweden.

Since hydro power and nuclear power are the main producers, we can write the *cost function (supply curve) for non-certified electricity* as:

$$p_e = p_{e0} + m(1-\delta)Q$$

p_e is the marginal cost of non-certified production, if only non-certified electricity is available. δ is the quota in Elcertifikatsystemet set by the government, Q is the total demand for electricity. Therefore, $(1-\delta)Q$ is the demand for non-certified production. p_{e0} is the global market price of electricity, whereas p_{e0} and m $(m>0)$ together show the linear relationship between p_e and Q.

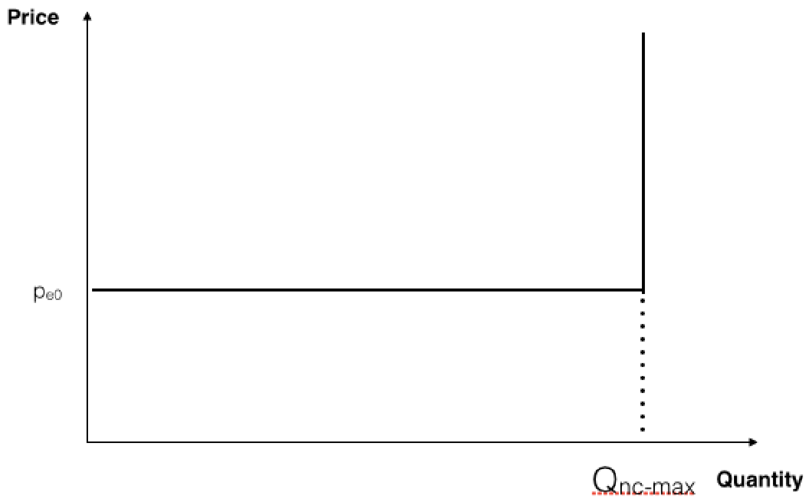

Figure 4.4 Supply Curve of non-certified electricity in an open but restricted marke

A special case of the supply curve may look like Figure 4.4. In a small country like Sweden, the electricity price will not have much effect on the global price, so in an worldwide open market, $m=0$ thus $p_e = p_{e0}$. Furthermore, under a strict regulation on the non-certified electricity production, e.g. new nuclear power plants or import of non-certified electricity

[16] Own calculation based on Energiläget i siffror 2015, Swedish Energy Agency

from other countries is prohibited, there will be no more non-certified electricity produced within Sweden when $(1-\delta)Q$ exceeds the full capacity of hydro and nuclear power. Under these circumstances, if the demand continues to go up, production will come from certified producers anyways, and the certificate price will be null. Figure 4.4 is an illustration of the situation.

In relation to that, how does the *cost function (supply curve) of certified electricity* look like? Since we do not know the shape, we assume the function as follows:

$$p_e' = p_{e0}' + m'(\delta Q)^\alpha$$

In this function, δ and Q are still the quota and total demand for electricity, thus δQ is the demanded certificates. p_e' is the acceptable electricity price for renewables, and p_{e0}', $m'(m'>0)$, and α ($\alpha>0$) are corresponding parameters. Depending on $\alpha<1$ or $\alpha>1$, the supply curve for certified electricity could be concave or convex. When $\alpha=1$, the supply curve is linear.

Retail supply curve is the aggregated supply curve of non-certified and certified electricity. Certificate price will be the difference between p_e' and p_e.

$$\begin{aligned} p_c &= p_e' - p_e \\ &= p_{e0}' + m'(\delta Q)^\alpha - p_{e0} - m(1-\delta)Q \\ &= m'(\delta Q)^\alpha - m(1-\delta)Q + (p_{e0}' - p_{e0}) \end{aligned}$$

The retail price p^* could be derived through

$$\begin{aligned} p^* &= \frac{p^* \times Q}{Q} = \frac{p_e' \times \delta Q + p_e \times (1-\delta)Q}{Q} = p_e'\delta + p_e(1-\delta) = p_e + \delta p_c \\ &= p_{e0} + m(1-\delta)Q + \delta[m'(\delta Q)^\alpha - m(1-\delta)Q + (p_{e0}' - p_{e0})] \\ &= \delta m'(\delta Q)^\alpha + m(1-\delta)^2 Q + \delta p_{e0}' + (1-\delta)p_{e0} \end{aligned}$$

So now both the certificate price p_c and retail price of electricity p^* are functions of quota δ, electricity demand Q, world electricity price p_{e0} and a few parameters: p_{e0}', m, m' and α. Based on these two functions, we can come up with two conclusions.

i) As the total demand of electricity goes up, retail price of electricity will definitely go up.

$$\frac{\partial p^*}{\partial Q} = \alpha m'\delta^{\alpha+1}Q^{\alpha-1} + m(1-\delta)^2 > 0$$
$$\frac{\partial^2 p^*}{\partial Q^2} = \alpha(\alpha-1)m'\delta^{\alpha+1}Q^{\alpha-2}$$

Fist order condition (F.O.C) is positive so p^* will go up as Q increases. With a up-going trend, the shape of retail supply (p* and Q) depends on α.

When $0<\alpha<1$, $\partial^2 p^*/\partial Q^2<0$, the retail supply curve is concave. Type II rent will be small (S_1^* in Figure 4.3); when $\alpha>1$, $\partial^2 p^*/\partial Q^2>0$, the retail supply curve is convex, thus the Type II rent will be big (S_2^* in Figure 4.3); when $\alpha=1$, all the supply curve is linear.

ii) As the total demand of electricity goes up, the certificate price may either increase or decrease, depending on the parameters.

$$\frac{\partial p_c}{\partial Q} = \alpha m'\delta^{\alpha}Q^{\alpha-1} - m(1-\delta)$$
$$\frac{\partial^2 p_c}{\partial Q^2} = \alpha(\alpha-1)m'\delta^{\alpha}Q^{\alpha-2}$$

From the above F.O.C, the sign is not certain, so the direction of p_c's change is not certain either. However, we can assume special values for the parameter to see how p_c changes.

If $m=0$ (as in Figure 4.4), the supply curve for non-certified electricity is horizontal, and $\partial p_c/\partial Q > 0$, indicating certificate price will increase as demand increases. Furthermore, according to second-order condition, the shape of the certificate supply curve will be similar to the retail supply curve in **i)**, which depends on the value of α.

If $m\neq 0$, the influence of δ on $\partial p_c/\partial Q$ could be identified more easily. According to the value of δ ($0<\delta<1$), when $\delta\to 0$, the quota for renewable electricity is very low, $\partial p_c/\partial Q = -m<0$, certificate price will decrease as demand increases. Although certified electricity is more expensive, this conclusion is possible because, as demand goes up, $(1-\delta)Q$ increases much faster than δQ when δ is very small, thus p_e increases faster than p_e', and can be even higher in values. Therefore, according to the F.O.C, p_c will decrease and even become negative. However, the certificate price will be decreasing and reach zero as the end, because negative certificate price indicates that consumers are paid to buy certificates, which may not happen in reality. When $\delta \rightarrow 1$, the use of renewable electricity becomes an ultimate obligation, $\partial p_c / \partial Q = \alpha m' Q^{\alpha-1} > 0$, certificate price will increase as demand increases. In this situation, the retail supply curve is exactly the certificate supply curve.

After the analysis above, we already have a picture on how the shape of retail electricity supply may affect the amount of Type II rent in the future. In Chapter 5, we are going to look at the data and carry out our empirical prediction.

5. Empirical Analysis

Based on the understanding of policy scheme and the theoretical foundation, Chapter 5 will present the result of historical Type I rent generated from Elecertifikatsystemet until 2013, and also make projections for Type II rent based on the shape of retail electricity supply curve.

5.1 Up-to-now Rent Generation

5.1.1 Policy Background

Recall that facilities built before the policy was implement are planned to phase out by the end of 2012 or 2014, while new plants starting operation after May 2003 will be commissioned for 15 years. Those old plants were included in the system from the beginning to ensure the liquidity of the certificate market. However, in order to limit the consumer costs from electricity generated in these commercially viable plants, they are entitled certificates only until the end of 2012. For those received some public grant assistance for investment or conversion of the plant, they are entitled certificates until the end of 2014. However, any such grant must have been paid after 15th February 1998, as part of a programme of investments in the energy sector.[17]

Table 5.1 shows the relevant data from different reports, which amounts to a total electricity production of 10,3 TWh or 11,8 TWh respectively, that is planned to phase out by the end of 2014.

Table 5.1 Planned phasing-out of electricity production capacity in 2012 and 2014

	The Swedish-Norwegian Electricity Certificate Market - Annual Report 2012, SEA		The Electricity Certificate System 2012, SEA	
Energy Source	**2012**	**2014**	**2012**	**2014**
Biofuel	6647	943	8122	977
Solar	0	0	0	-
Hydro	1896	14	1981	11
Wind	262	545	203	481
Total (GWh)	8805	1502	10306	1469
Total in 2012 and 2014		**10307**		**11775**

Source: The Swedish-Norwegian Electricity Certificate Market, Annual Report 2012, NVE and SEA; The Electricity Certificate System 2012, SEA

[17] The Electricity Certificate System 2011, Swedish Energy Agency

Our analysis of Type I rent is mainly the rent for these old plants, therefore, by the end of 2014, Type I rent will end together with the phasing-out of plants built before May 2003. The up-to-now rent generation in this section will be Type I rent.

5.1.2 Data

As previously mentioned, Cesar is the accounting system for Elcertifikatsystemet. Real time data of the certificate market on average price, transfer list, issuing, transfers and cancellation could be found on the website.[18] It provides the data from the implementation of the policy in May 2003 until now, and covers the transactions in both Sweden and Norway.

The data used for calculating Type I rent will be 'average price' and 'cancellation' of each accounting year. The monthly average price of certificate is shown in Figure 5.1, with a range between 150 SEK and 350 SEK.

Figure 5.1 Monthly average price of transactions in SEK
Source: Cesar

The use of 'cancellation' might underestimate the result because suppliers only need to cancel the obligated amount of certificates, if they hold more certificates than that. Since the extra certificates have already been paid for the producers, this part of the rent is not identified. This applies to *Estimation I, II (and III)*. However, when calculating Type I rent from different energy sources, data on cancellation by energy source is not available in Cesar, so the available indicator 'issuing' will be used instead. That may cause overestimation because not every issued certificate has been definitely sold out. We should be aware of the over- and underestimation, but they will not affect the result too much.

[18] https://cesar.energimyndigheten.se/WebPartPages/SummaryPage.aspx

We have already known that in *Estimation I*, the certificate-entitled production in 2003 Q_0 is 6,5 TWh, Q_i is the yearly cancellation of certificates, Q_1 (accessible production) and MC_{CHP} (marginal cost from production increase) are still unknown. In a government document in 2011, short-term potential of biofuel is estimated to be 3,7-4,7 TWh in total, including a 2 TWh increase in biomass CHP in district heating plants and a 1,7-2,7 TWh increase in industrial back-pressure processes (SOU, 2001:77). This amounts to an easily accessible production of 10,2-11,2 TWh (including 6,5 TWh of Q_0). From Table 4.1, the planned phasing-out production is 10,3 TWh or 11,8 TWh, which is another way of identifying the easily accessible production. Therefore, we choose 10,2 TWh as the minimum level and 11,8 TWh as the maximum level of Q_1 in this paper, and define the results of Type I rent as *Estimation II* with regard to 10,2 TWh, and *Estimation III* with regard to 11,8 TWh. MC_{CHP} in existing CHP plants is ranged from 0 SEK/MWh (increase full-load hours) to 80 SEK/MWh (fuel conversion) (SOU, 2001:77). We will choose the average value 40 SEK/MWh[19].

When calculating Type I rent from different energy sources, similarly, there will be two estimations for biofuels. The first one is the certified electricity production in 2003 (4,3 TWh), and the second one is based on easily accessible production chosen as 8,5 TWh—4.3 TWh plus the mean value of short-term potential.

So far, we have the data for all the parameters in *Estimation I*, *II*, and *III*.

P_i= *average monthly price*

Q_0 = 6,5 TWh

Q_i = cancellation in year i

Q_1 = 10,2 TWh or 11,8 TWh

MC_{CHP} = 40 SEK/MWh

5.1.3 Rent Generation (Type I Rent)

The result of the three estimations are presented in Table 5.2 and Figure 5.2.

[19] 40 SEK/MWh is the same value as used in Bergek and Jacobsson (2010)'s analysis.

Table 5.2 Type I Rent 2003-3013

Year	(A) Certificates Cancellation (Thousand)	(B) Production for Type I Rent (GWh)			(C) Overcompensation per certificate (SEK)		(D) Type I rent (MSEK)		
		≤ 6,5 TWh	6,5 - 10,2 TWh	6,5 – 11,8 TWh	≤ 6.5 TWh	> 6.5 TWh	Estimation I	Estimation II	Estimation III
2003 (May-Dec)	3 490	3 490	0	0	200,81	160,81	701	701	701
2004	7 832	6 500	1 332	1 332	231,38	191,38	1 504	1759	1759
2005	10 120	6 500	3 620	3 620	216,50	176,50	1 407	2046	2046
2006	12 391	6 500	3 700	5 275	191,13	151,13	1 242	1802	2040
2007	14 464	6 500	3 700	5 275	195,40	155,40	1 270	1845	2090
2008	15 322	6 500	3 700	5 275	247,21	207,21	1 607	2374	2700
2009	15 405	6 500	3 700	5 275	293,20	253,20	1 906	2843	3241
2010	17 536	6 500	3 700	5 275	294,57	254,57	1 915	2857	3258
2011	16 527	6 500	3 700	5 275	246,96	206,96	1 605	2371	2697
2012	16 289	6 500	3 700	5 275	200,15	160,15	1 301	1894	2146
2013	12 316	0	1 395	2 970	203,30	163,30	0	228	485

Source: Cesar and own calculation

Column (A) and first column in (C) are yearly certificate cancellation and price, and column (D) shows the results of three estimations. It is based on the formulas in **4.2**. A few points are worth noting here: *a.* In 2003, the cancellation amount is less than 6,5 TWh, thus the actual number of cancellation is used in *Estimation I*. *b.* From January 1st 2013, a total amount of 8,805,000 certificates were phased out, which leads to a deduction in the production for generating Type I rent. That explains why in 2013, column (B) is respectively 0, 1,359 and 2,970,[20] and in column (D) Type I rent in three estimations all decreased largely.

[20] The result of 6,5 - 8,805, 10,2 - 8,805, and 11,8 - 8,805.

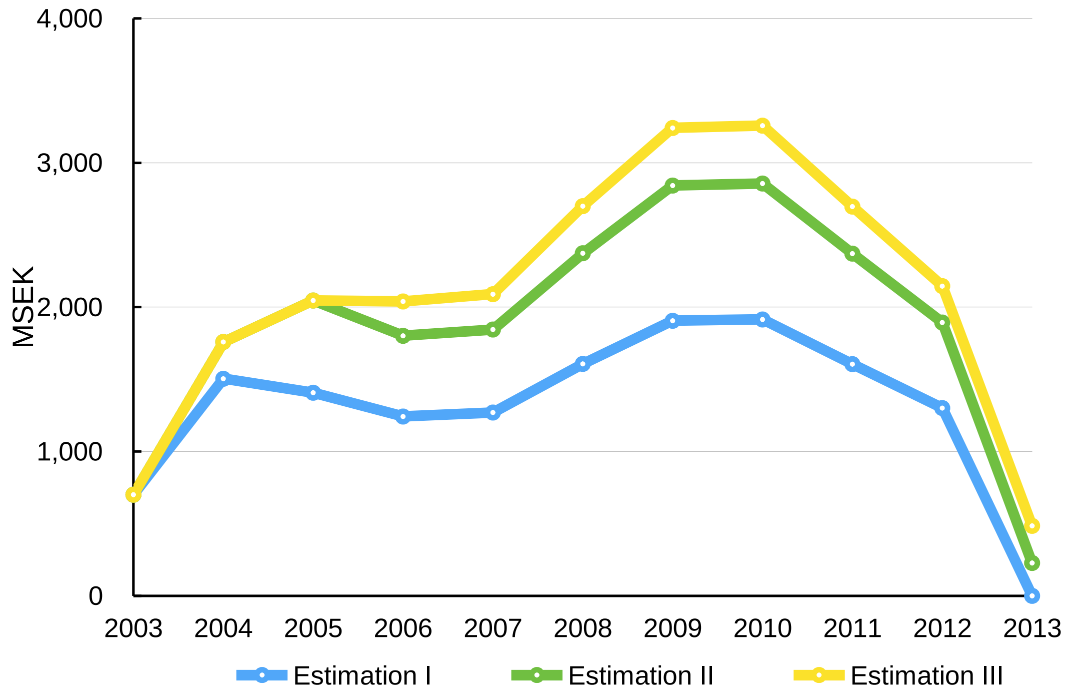

Figure 5.2 Type I Rent 2003-2013

Source: Cesar and own calculation

Three estimations of Type I rent have inverted U-shape curves. In 2006 and 2007, the curve had a downward trend, but recovered quickly in 2008. This happened again in 2011 until the production finally phased out of the system in 2012. The two drops in Type I rent are mainly due to the price decrease in the certificate market. The prices in 2006 and 2011 hit the lowest level since the policy was implemented, as shown in Figure 5.1. Meanwhile, cancellation of certificates kept increasing from 2003, and only dropped slightly in 2011 and 2012. The curve in *Estimation I* hits the *x* axis in 2013, representing the termination of Type I rent from certificate-entitled production before May 2003. In our analysis, this production is fixed level (6,5 TWh) so that Type I rent will be high as long as certificate price is high in *Estimation I*. This violates the intention to support new plants, because when the certificate price is high, more supply is needed to meet the market demand, but with such high rent for old producers, new plants will be very difficult to scale up.

The value of Type I rent is between 1-2 billion SEK per year in *Estimation I*, and 2-3 billion SEK per year in *Estimation II* and *III*. These are huge amount of payments from the consumers but gained only by commercially viable producers established before May 2003.

To illustrate the result furthermore, we can calculate the percentage of Type I rent in the total payment for certificates per year.

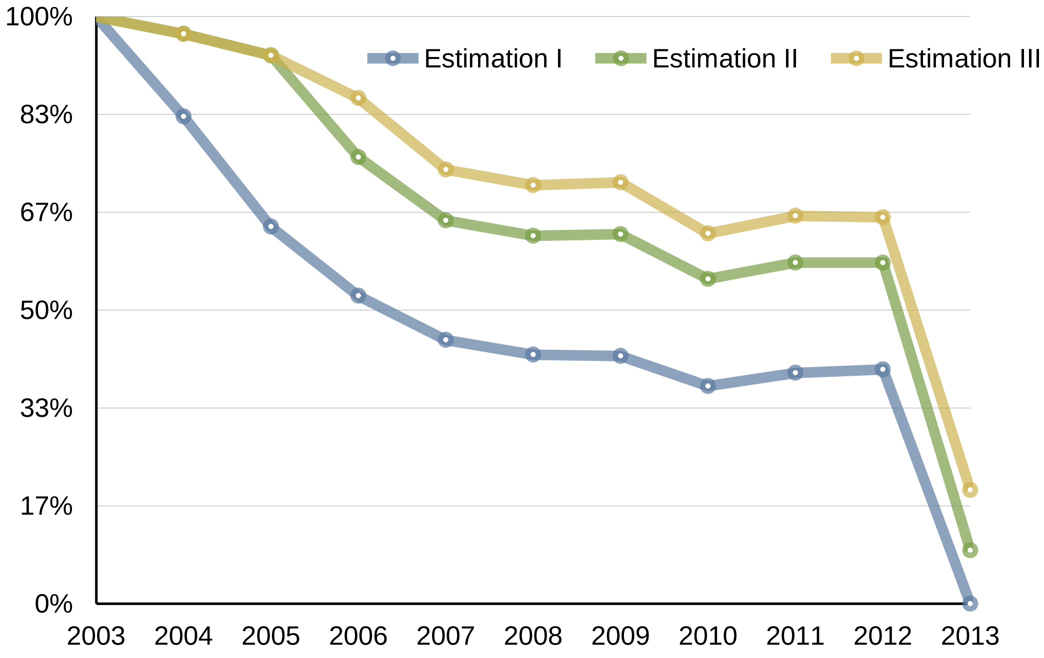

Figure 5.3 Percentage of Type I Rent in total payment for certificates

Source: Cesar and own calculation

Figure 5.3 shows the percentage of Type I rent in the total payments for electricity certificate from 2003 to 2013. The total payment is calculated based on certificate cancellation and the average price of the year. In *Estimation I*, the rent still contributes as high as 40% at the last year before phasing out, and even higher in previous years. In *Estimation II* and *III*, the situations are worse. Type I rent contributes 58% and 66% respectively in the total payment in 2012, indicating that such high share in total payment has lasted so long for nine years, and that there is so little incentive for new plants to grow.

If we look into different energy sources, the yearly Type I rent by energy source from 2003 to 2013 is shown in Table 5.3 and Figure 5.4.

Table 5.3 Distribution of Type I Rent (MSEK)

Energy Source	Water	Wind	Bio	Peat	Solar
2003	194	91	847	0	0
2004	393	116	995	126	0
2005	368	108	931	118	0
2006	325	96	822	104	0
2007	332	98	840	106	0
2008	420	124	1 063	135	0,01
2009	498	147	1 261	160	0,012
2010	501	147	1 267	161	0,012
2011	420	123	1 062	135	0,010
2012	340	100	861	109	0,008
2013	0	48	0	0	0

Source: Own calculation

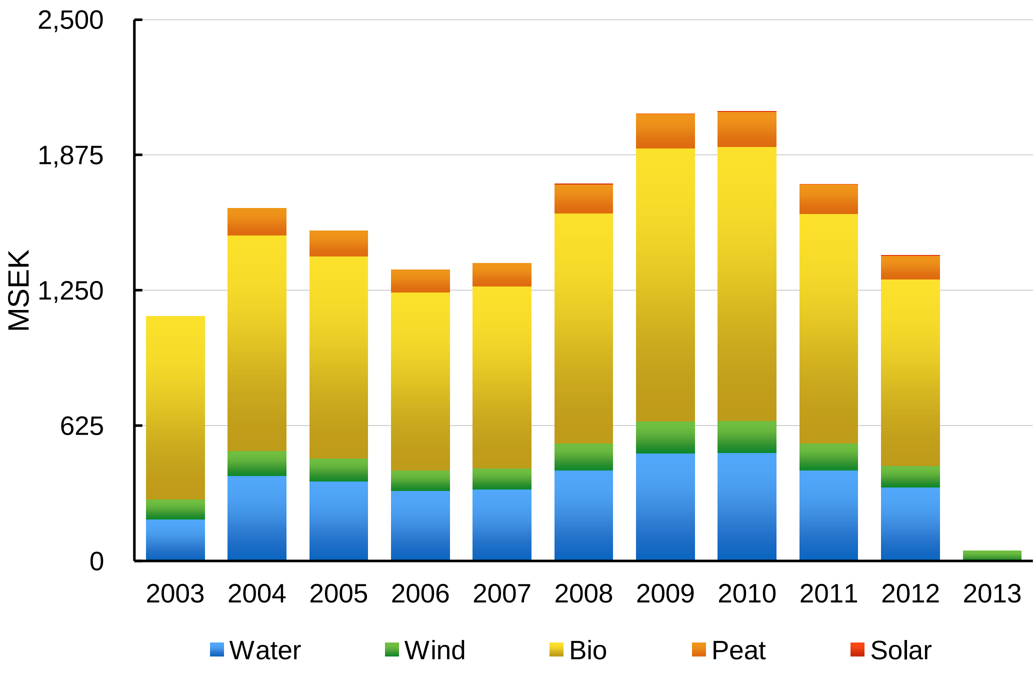

Figure 5.4 Distribution of Type I Ren
Source: Own calculation

Table 5.2 and Figure 5.4 clearly show the distribution of Type I rent by energy source. Only wind power is still gaining some Type I rent in 2013, while production from other sources have phased out. Biofuel constitutes a large share of the total Type I rent the whole time before phasing out. Even at the last year in 2012, it still covers more than 60% of the rent. In fact, the existence of Type I rent is already not equitable for Elcertifikatsystemet, such high share of biofuel in the rent furthermore reveals the inequality among old plants, if using different energy sources. Similar to the trade-off between old and new plants as discussed in the last section, now it is the trade-off between old and new industries. Again, industries that need more incentives to grow, such as wind power and solar power, are not gaining enough rent in comparison with biofuels who is actually facing lower marginal cost.

We also have made two estimations for biofuel as shown in Figure 5.5. It shows similar trend and conclusion from the previous estimations for Type I rent. As the main contributor for easily accessible production, biofuel gains almost double sized rent in the second estimation, indicating the huge benefit from easily accessible productions of CHP plants.

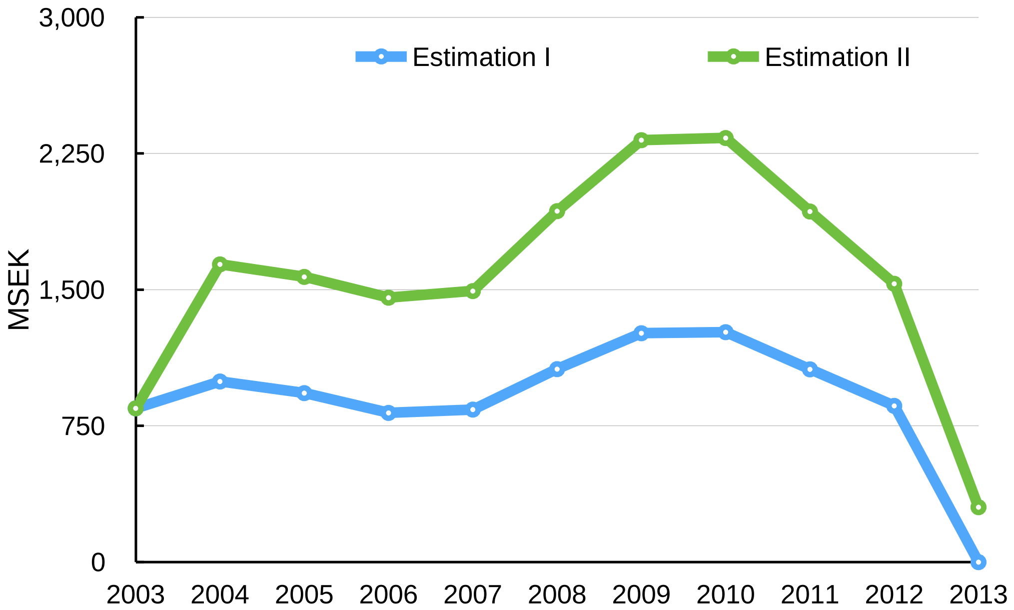

Figure 5.5 Type I Rent for biofuels (Two Estimations)
Source: Own calculation

5.1.4 Discussion

The result from up-to-now rent generation shows a very concerning picture for the Swedish TGCs, because the equity criterion among renewable electricity producers are obviously not achieved.

- Elcertifikatsystemet is designed to encourage new production of power from renewable electricity producers. However, if more than half of the total payment goes to old plants who are already commercially viable when the system established, new plants do not receive enough incentives and can not expand as expected, which directly leads to less investment opportunities and other shortcomings. This suggests that the phasing-out schedule for old plants should have been more carefully designed to lessen the ignorance of new plants.

- Renewable electricity production is sensitive to many constraint factors, such as location, weather, timing, etc. In terms of timing, Elecertifikatsystemet has been giving too long certificate entitlement to old plants. High level of Type I rent is in place for so long, that the new plants are more and more discouraged to grow. It will also be rather difficult for new plants to achieve the equivalent level of production as old ones, because better locations, lower cost opportunities, and other advantages have already been taken. Therefore, Elcertifikatsystemet should consider the effects that timing issues may cause on newly established plants.
- If justified, considering Type I rent as an incentive for old plants to expand their production, it is still not equitable among producers in different industries with different levels of marginal cost. The allocation of the rent shows that old biofuels (mainly existing CHP plants) are given unreasonable high proportion of rent, while these plants have limited potential in production expansion and lower marginal cost. The old plants of other energy sources, although rent receivers as well, could not get equivalent opportunities to grow. Although technology-neutral, the impacts of Elcertifikatsystemet has brought on plants with different renewable energy sources are not technology-neutral. In the policy design, heterogeneity of energy sources should have been given more attention.
- Existing CHP plants are the biggest beneficiary of Elcertifikatsystemet, while the new biofuels plants, and plants using other energy sources, either old or new, could not obtain the benefits they are supposed to receive. Since most of the CHP plants have already been phased out of the system, the rent obtained by them is sunk. However, this is a hint for future policy design, which should be aware of the actual beneficiary of the policy and make sure it matches the goal of the policy.

In conclusion, the analysis of up-to-now rent shows the following facts: Elcertifikatsystemet is not able to stimulate new production equitably because of the existence of Type I rent. Type I rent’s high proportion in total payment and the long duration in the system discourage new plants. What’s more, equity criterion could neither be met among rent receivers, because a large part of the rent goes to producers with low marginal cost.

5.2 Future Rent Prediction

5.2.1 Retail Electricity Supply (Estimation)

In Chapter 4.3, we have talked about a few possible situations of the retail electricity supply curve, as well as the certificate supply curve. In general, if certainly identified, they will show the trend of retail electricity price and the certificate price as the demand of electricity goes up, and furthermore indicate the level of Type II rent that could be possibly generated in the future. However, due to the uncertainty of policy agendas for off-shore wind power in Sweden, we are not sure about the supply curves now. However, we can plot the historical data to see the trend so far, and make relevant predictions on that. The future rent prediction here is Type II rent.

Based on the data from 2003 to 2014, the retail electricity price p^*, certificate price p_c and quantity Q of each year are plotted in the axis. The trend line is also generated given different values of α, thus shown as linear, concave, and convex in Figure 5.6. It is worth mentioning that the horizontal axis is δQ, recalling the equations for p^* and p_c in **4.3.2**.

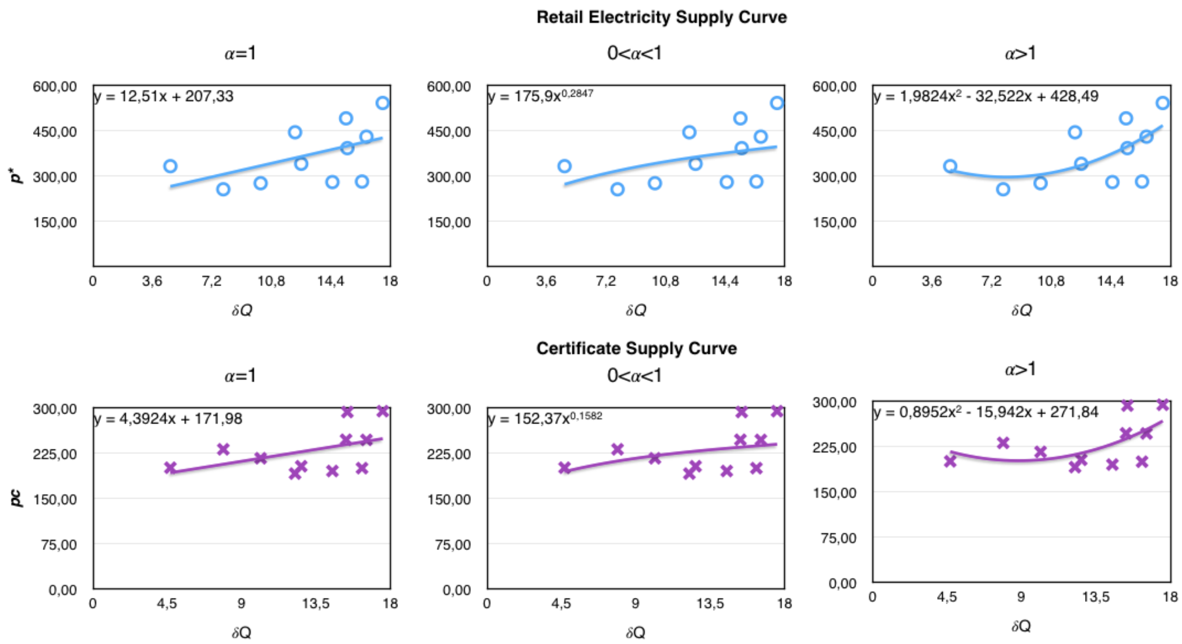

Figure 5.6 Plotted supply curve of retail electricity and electricity certificate

Source: see Appendix II.

In Figure 5.6, retail electricity supply curve is shown above and certificate supply curve is below. The plotted graph confirms our discussion on F.O.C in **4.3.2**, that **i)** As the total demand of electricity goes up, retail price of electricity will definitely go up, as well as the conclusion from $m=0$ in **ii)** As the total demand of electricity goes up, the certificate price will increase. As for the shape of the supply curves, the graph shows how the linear, concave, and convex supply curve may look like under the case of $\alpha=1$, $0<\alpha<1$, and $\alpha>1$. The next step of the prediction is to speculate values of other parameters (*m, m'*), and the exact value of α. As seen in each small graph, the equation is easily obtained, which could be used as reference for the speculation. The rest of the predication is worthy of further research, which, however, will not be discussed here.

5.2.2 Policy

According to a report by Swedish Environmental Institute and WWF Sweden in 2011, Wind power will increase to 20 TWh in 2020, 30 TWh in 2030, and reach 45 TWh in 2050. According to the long-term forecast of the Swedish Energy Agency, electricity generation in Sweden is expected to total 175 TWh with electricity exports of 24 TWh in 2020 and 23 TWh in 2030. However, there is no clear policy inclination that has been shown to introduce off-shore wind power in Sweden. In a recent meeting for Elcertifikatsystemet, it has been pointed out that greater transparency of the policy is required, "the Swedish Energy Agency should be tasked to provide information on the planned expansion of facilities in the electricity certificate system…". It is said that relevant information will be published in quarterly report in May 2015.

5.2.3 Rent Generation

Recalling that the goal set in 2012 was to increase renewable electricity production by 13.2 TWh between 2012 and 2020. Based on that, we can actually make a rough estimation on the certificate price. In 2012, the renewable electricity production □Q was 16,29 TWh, so an additional 13,2 TWh will lead to 29,49 TWh in 2020. In the three situations, the speculated certificate price will be 301,51 SEK, 260,26 SEK, and 580,23 SEK, which is consistent with our analysis that a convex supply curve indicates higher Type II rent, and a concave supply curve indicates smaller Type II rent. When the supply curve is linear, the rent is in between of the two situations. With the data of certificate price, it is not difficult to calculate Type II rent, given other parameters. We will not discuss further here.

5.2.4 Discussion

The volume of Type II rent will be largely dependent on the shape of retail electricity supply and certificate supply. These two supply curves are not certainly identified at the moment, however, predictions could be made by speculating the values of a few parameters. It is confirmed that concave supply curve indicates a much lower Type II rent generation than convex or linear supply curves, and when the policy intention is clearer and more certain, it will not be difficult to identify the potential volume of Type II rent, thus evaluate the equity performance of Elcertifikatsystemet in the future.

In all three situations, the existence of Type II rent and conclusions from the analysis of Type I rent, could shed some light on the policy design or adjustment of Elcertifikatsystemet in the future. The heterogeneity of renewable electricity producers should be given enough attention to, which directly leads to the equity issue between old and new plants, as well as among different renewable energy sources.

6. Conclusion

This paper is an exploration of the rent generation issue in the Swedish TGCs system Elcertifikatsystemet, and aims to evaluate the system from the equity perspective. We start from knowing the policy, agents involved and how exactly it works. We also went over the criteria usually used for renewable energy policy evaluations. After that, we start our evaluation for Elcertifikatsystemet.

Following Bergek and Jacobsson's analysis in 2010, the excessive payment for renewable electricity producers are categorised into two types, Type I rent from the overcompensation for existing plants before the implementation of the system in 2003, and Type II rent from higher certificate price driven by the introduction of more expensive technologies into the system. According to the policy formulation, the first type of rent will end by the end of 2014, because all those plants will be phased out of the system by then; and as for the second type, the estimation is not in exact numbers but the trend in the future.

Based on the analysis for Type I rent, Elcertifikatsystemet failed to meet its goal to encourage new production of power from renewable electricity producers. The reasons are a few: more than half of the total payment goes to old plants who are already commercially viable when the system established, while new plants do not receive enough investment opportunities; unreasonably high Type I rent exists for almost ten years, which largely affects the timing of renewable energy projects to take better locations, lower cost opportunities, or other advantages; existing CHP plants with limited potential to grow are the biggest beneficiary of Elcertifikatsystemet, while the new biofuels plants, and plants using other energy sources, either old or new, could not obtain the benefits they are supposed to receive. Although Type I rent finally ends by 2014, the effect it has placed on the renewable electricity producers could not be easily ignored. The rent has shaped the current structure of renewable electricity supply, which is not easily adjustable. It has also influenced the expectations on the market, where new renewable energy power plants are more cautious in entering. In a word, the huge amount of Type I rent and long duration in place have caused negative impacts on renewable electricity producers, and the impacts are not technology-neutral.

As for Type II rent, it is not easy to predict the volume of rent generation without a certain picture of whether more expensive renewable electricity production might be included into the system. However, if the shape of retail supply curve could be identified through further research on the unknown parameters, the volume of Type II rent could be anticipated in numerical terms, thus we can also make conclusions on whether equity criterion has been met.

The analysis of Type I rent and Type II rent also reveals the fact that enough consideration should be taken on the heterogeneity of renewable electricity producers, including old and new plants, as well as plants based on different renewable sources. The reason is the equity issue discussed in this paper. In practice, it could be shortening the time for old plants to be in the system, making entitlement of certificates based on operational level, or different certificate prices for different energy sources, and etc. This was not covered in this paper, but the conclusions we get from the research could shed light on the future policy design or adjustment of Elcertifikatsystemet.

Although the research made in this paper endeavours to be detail-oriented, it can not be thorough and there are limitations. The categorisation of Type I and Type II rent, above all, is not the only way to carry out research on equity issues. During the analysis, some values chosen are not accurate enough due to lack of data, such as the average marginal cost in existing CHP plants, easily accessible production, etc. This paper did not take a closer look at the consumers, who are important agent in the system as well. More information on the consumer cost will help interpreting our results furthermore. There are indeed a lot to improve in further research. Other than overcoming the shortages listed above, the shape of supply curves is worthy of exploration. With the conclusion from both Type I and Type II rent analysis, a more complete picture could be presented in terms of the equity performance of Swedish TGCs — Elcertifikatsystemet.

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A: Appendix I: Quota Adjustment

Table A.1 Quota Adjustment of policy changes from 2003 to 2015

Year of policy changes	2003	2006	2010	2014	2015
2003	0,074				
2004	0,081				
2005	0,104				
2006	0,126				
2007	0,141	0,151			
2008	0,153	0,163			
2009	0,16	0,17			
2010	0,169	0,179	0,179		
2011		0,156	0,179		
2012		0,161	0,179		
2013		0,089	0,135		
2014		0,094	0,142		
2015		0,097	0,143		
2016		0,111	0,144	0,230	0,231
2017		0,111	0,152	0,246	0,247
2018		0,111	0,168	0,262	0,270
2019		0,112	0,181	0,276	0,291
2020		0,112	0,195	0,266	0,288
2021		0,113	0,190	0,250	0,272
2022		0,106	0,180	0,235	0,257
2023		0,094	0,170	0,222	0,244
2024		0,09	0,161	0,205	0,227
2025		0,083	0,149	0,184	0,206

Table A.1 Quota Adjustment of policy changes from 2003 to 2015 (Continued)

Year	2003	2006	2010	2014	2015
2026		0,075	0,137	0,161	0,183
2027		0,067	0,124	0,140	0,162
2028		0,059	0,107	0,124	0,146
2029		0,05	0,092	0,108	0,130
2030		0,042	0,076	0,091	0,114
2031			0,061	0,071	0,094
2032			0,045	0,053	0,076
2033			0,028	0,037	0,052
2034			0,012	0,021	0,028
2035			0,008	0,013	0,013

B: Appendix II: Data for Plotting

Table B.1 Data for plotting supply curves (2003 to 2013)

Year	Certificate Price (SEK)	Nord Pool price in Sweden (SEK/MWh)	Nord Pool system price (SEK/MWh)	Quota	Total demand for electricity (TWh)	□Q
2003	200,81	333,00	334,90	7,4%	63,3	4,6842
2004	231,38	256,30	263,90	8,1%	97,4	7,8894
2005	216,5	276,40	272,50	10,4%	97,6	10,1504
2006	191,13	445,40	449,80	12,6%	97,1	12,2346
2007	195,4	280,20	258,70	15,1%	96	14,496
2008	247,21	491,60	431,20	16,3%	94	15,322
2009	293,20	392,80	372,20	17%	90,6	15,402
2010	294,57	542,50	505,90	17,9%	98	17,542
2011	246,96	430,80	423,50	17,9%	92,5	16,5575
2012	200,15	281,90	272,20	17,9%	91	16,289
2013	203,3	340,80	329,00	13,5%	93,4	12,609