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Windfall Gains or Eco-Innovation?

‘Green' Evolution in the Swedish Innovation System

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Abstract

This paper looks closer into climate gas emission and the shift to non-fossil energy use in Sweden. This includes what types of organizations are behind the observed shift to non-fossil energy use, what are the relative effects on emissions, to what extent can these interactive dynamics be considered eco-innovations, and if so, can they be related to specific institutions and policies? Analyses in this paper are based on time-series data. Methods include statistical survival analyses, in particular Cox regression. These analyses inform us why energy sources shift. Results indicate that wood fuel and solid waste increase as sources of energy while fossil oil have decreased between 2003 and 2010. This result is in line with industrial and environmental policies of the Swedish governments that present these facts as institutionally and policy related ‘green innovation'. However, our analysis contests such a conclusion and it is noticed that the shift to non-fossil sources of energy has not led to verifiable decreases in green-house gas emissions. Results instead suggest that ‘green’ innovation of non

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fossil energy was mostly the effect of low-tech innovation in public organizations with no fundamental effect on CO₂ emissions.

Keywords: innovation, fossil, non-fossil, energy, Sweden

JEL classification: Q 42, Q 48, Q 51, Q 53, Q 55, Q 58
1. Introduction

In theory, innovation processes lie behind the evolution of national systems as they create interacting dynamics among organizations (Bergek et al., 2010; Edquist, 2011; Freeman, 1988; Lundvall, 1992; Lundvall, 1988; Nelson, 1993). Institutions and policies are considered means for influencing these interactive dynamics, such as shifting innovative focus from traditional to environmentally oriented production, more environmentally friendly types of energy use, or environmental protection measures, products or services (Bergh, 2007; Chaminade and Edquist, 2010; Freeman, 1992; Kemp, 1997; Sandberg, 1999). Institutions and policies can thus be considered drivers or incentive structures of change in technologies, processes, markets, raw materials or organizational forms—the five classic types of innovation according to Schumpeter (Schumpeter, 1947). Given such a definition of institutions and their function as drivers (“sticks”) or incentive structures of change (“carrots”) in technologies among organizations, one would expect to find institutional changes behind most, or at least many, of the technological changes that reduce environmentally unfriendly effects if these changes do not also imply economic advantages. One would also think that public and private organizations might be affected somewhat differently by institutions. Institutions created and modified within the framework of the political and economic system are typically formulated in a way that distinguishes between public and private ownership and therefore also how public organizations are managed versus how private corporations are handled. This is particularly true for mixed market-oriented welfare states with strong
political and governmental structure and public organizations managed at national, regional and local levels, such as Sweden (Carlsson et al., 2010; Cooke, 2012). Political history has shaped the industrial structure of any innovation system, and in Sweden’s case, the industrial and organizational structures have emerged mostly during Social Democratic governments (1932-1976, 1982-1991, 1994-2006, and 2014-). However, Sweden experienced a shift in government to an “Alliance” of rightist parties (2006-2014), which is noteworthy in relation to industrial, environmental and innovation policies in which central and governmental influences were rolled back in favor of more entrepreneurial and liberal principles. The “Alliance” gave the impression that their policy of reducing fossil fuel use and replacing it by non-fossil energy was environmentally friendly and an example of “green innovation” in line with the recommendations from the Intergovernmental Panel on Climate Change (IPCC) (Energimyndigheten, 2013; IPCC 2007a). One empirical question is of course whether it was true that there was a shift and if so, whether the shift was of environmental and technological significance. The question of climate effects of increased non-fossil energy use in different forms is therefore not the topic here.² Instead we focus on the actual energy source innovations made in Swedish organizations, the question whether the increasing use of non-fossil fuel actually reduces the levels of CO₂ emissions, and what factors can explain this shift from a time dynamic and evolutionary perspective. We think the answers to this question, presented in this article, should be of wider interest especially for OECD nations that take pride in green innovation and shifts toward sustainable technologies. It should also be of

² See instead IEA 2010 and Zetterberg 2011 on this important topic.
interest for environmental technology policy makers of other nations. However, not only are facts and figures important. In this context, it is also important to use adequate statistical techniques that can reveal why certain technologies are replaced by others over time, as they are measured in time series data sets. We propose here, in a spirit of evolutionary analysis of technological change (Aldrich, 2003; Carroll and Hannan, 2000; Colombelli et al., 2013; Dosi, 1981; Hirschleifer, 1977; Mokyr, 1991; Sandberg, 1999, 2006; Silverberg, 1988), in which some technologies “die” and others “are born” among organizational “hosts”, to apply a statistical survival analysis. Survival analysis, we will argue, has several advantages in cases where there is time series panel data, i.e. data for many units of analysis over time, and the dependent variable is a binary indicator of categorical change in the time series.

This is why we address the analysis of the shift from fossil to non-fossil use of energy in Swedish organizations as technological change, where we look for explanations in terms of changed institutions and policies and their resulting eco-innovations (Arundel and Kemp, 2009; Halila and Rundquist, 2011; Hörte and Halila, 2008). This paper therefore looks closer into climate gas emission and the shift to non-fossil energy in Sweden and therefore asking the questions:

- what types of organizations are behind the shift to non-fossil energy use, what are the relative effects on emissions, to what extent can these interactive dynamics be considered eco-innovations,
- do these effects vary between public and private organizations, and if so,
- can they be related to specific institutions and policies?
2. Background

From most points of view, not least from the political perspective, a “greening” of production by means of innovation is highly desirable. Most countries wish to excel by being increasingly “green” in technologies, processes and products, logistics, raw materials, waste handling and so forth. From a social scientist’s perspective, however, the dominating problem is how to be able to investigate what has actually been accomplished and what the likely prospects are in this area. First of all, many of us already have problems in defining a “greening” of innovation. Secondly, the problem is one of data: are there any ways we can estimate the development in our innovation systems regarding green versus conventional innovations? Only on the basis of existing data we might, thirdly, consider measuring, modelling, estimating, explaining, and perhaps even forecasting such greening of innovation in our systems.

In order to study and assess development in this area, one has to have reliable data stretching sufficiently back in time. One may, of course, initially make a general mapping of both the environmental orientation of the production of goods and services over the whole economy, or its sectors and branches. But at the same time the grading system is critical for such data gathering. For example, is an environmentally oriented improvement of traditional production and processes measurable on the same scale as the production of recycling services? One may also ask which economically, as opposed to environmentally motivated, modifications in existing production processes, for example energy saving, may qualify as “green” innovation. Can any
production or process be considered “green” or “conventional” by the fact that they affect the environment somewhat? These questions point to the problems in defining “environmentally sound”, “green” or “eco-efficient” production. It also means that the measurement of “green” innovation, or “eco-innovations” in technologies, products or processes become difficult or controversial. This does not mean, however, that such attempts should be avoided. Instead, it means that one should focus, as social scientist, on what is measurable, what has actually been measured, and begin with the questions that can be answered.

When presenting empirical research results based on necessarily controversial definitions and measurements, it is therefore critical to emphasize what these results are not saying as much as what they are saying. In particular, any results on the ratio between green and traditional sectors or innovations of the economy have only to be presented with detailed definitions on whether they depict the greening by new products, new processes or innovations. The innovation system is, in this case, understood as all changes in values from one year to the next in the registered parameters of activities of all organizations included as measured variables in the merged official time-series data set. The fundamental outcome of the innovation system is, therefore, changes in activities, such as the rise of non-fossil energy use and the fall of fossil fuel use, such as a change in orientation from traditional to environmentally oriented production, more environmentally friendly types of energy use, or larger amounts of environmental protection measures, types of innovations Schumpeter was the first to define (Schumpeter, 1934). Considering change as the fundamental unit
in a system makes it natural to model the evolution of changes and interactions between them over a length of time. Our focus is, therefore, to study such evolution of greener innovations in the Swedish innovation system. This, of course, requires time-series data from which changes in organizational activities can be extracted, modelled and analyzed. The aim of this article is thus to make some initial explorations in this direction using adequate statistical techniques for the analysis of such change.

3. **Swedish National Register Data**

Data sets can have different structures and be more or less suitable for testing different kinds of models that can help us understand the dynamics of an innovation system. The best selection of data naturally covers the whole population of cases – individuals as well as organizations – in the system, and variables should be those that are included in the model. When dynamics are in focus, a time-series data structure is essential. It is always critical that data is of high quality, i.e. the values of the variables should reliably correspond to actual conditions. Other types than such total sets of data are often based on samples of the organizational population in which the larger organizations of the population are completely covered; while smaller organizations are randomly selected. This is the case with other interesting data sets, such as the Eurostat CIS data set, which provides comparable data for European Union member states on innovation, including environmentally oriented innovations.

In this case, where we focus on Swedish environmental innovation as changing environmentally significant activities of organizations, there is one data
set option that one must consider superior to all the rest, namely the national register data of all organizations in Sweden in a time-series structure (Swedish Statistics’ so-called ‘FAD’ data set, ‘data on enterprise dynamics’ or ‘demography’). This data set can also be merged and expanded with variables available at an organizational level, such as environmental product data and data on the industrial use of various types of energy sources and environmental protection measures (with the exception of electric energy). There is also data on the use of various types of energy sources among Swedish organizations and their emissions (see table 1).

FAD is compiled from yearly Labor Market Register Data (“RAMS” register data on the labor market) – information from organizational and sub-unit level as well as employee level. All organizations, their sub-units (separate plants etc., with their own addresses) and all employees are included on these three levels. It is important to emphasize that the data are structured in three levels, so that organizations, their sub-units (“arbetsställe”), and all their employees, are included in separate and yearly files that can be aggregated at lower levels and, by means of codes, merged with higher level data sets. FAD is, therefore, a time series of these RAMS data and demographic in character. It means that by using FAD you may study ‘births’ and ‘deaths’ of organizations as well as their sub-units, including mergers and splits, over a period of several years, depending on the variables. Data quality issues are addressed systematically. Uniquely, RAMS data also includes education data on all employees at disaggregated level. For example, in this study, data on the number
of employees having at least undertaken undergraduate education in at least one course is used for company level aggregation, as is the number of employees with an environmental education of any type. The company-level aggregates are then used in the further analysis of company and organization behavior in terms of energy use.\(^3\)

//Table 1 around here//

**Table 1** Number of cases in two mergable Swedish register databases 2003–2011 on individual employees and all registered organizations

In a separate file, ‘the coal file’, data on both energy use and emissions of various kinds are given for industrial organizations in Sweden, both private, state or municipally owned or administered (Statistics Sweden, 2010). Among the energy types coded we find e.g. solid fossils (coal and coke), liquid fossils (oil), fossil gas, gasoline, non-fossil solids and non-fossil liquid gas, solid waste, and wood fuel (for details, see figure 2 below). This implies that types of fuels are easily grouped

\(^3\) In the documentation from Swedish Statistics (SCB), the quality of RAMS is discussed in “Årlig regional sysselsättningsstatistik 1988:7 and “Kvalitetsdeklaration av den årliga regionala sysselsättningsstatistiken 1991:1”, Statistics Sweden.
into fossil and non-fossil fuels. In addition, emission data is also included, such as emissions of carbon dioxide and a series of other gases. Omitted are other energy users than industry, such as households. The production of electric power by power plants is not deducted from the consumption (we realize that energy is never consumed, but still use this term.)

In describing its data, Statistics Sweden (SCB) states that time-series data sets have been created in a way that makes temporal comparisons possible. Each year the entire data set is checked to ensure that the variables are reliable (Statistics Sweden, 2008). The classifications made in the time-series data for the period 2003–2011 are shown in figure 1.

By combining environmental product data with FAD, one can obtain a data set from which it is possible to make authoritative conclusions about the total number and variety of environmental product-oriented organizations in Sweden, its regions and branches. It is also possible to add individual-level variables, such as: age of the individual, type of education, level of education, employment status, region where the individual lives, labor mobility, occupational code, sex, wage, number of employees, and so on. To some extent, hypotheses of networking effects on eco-innovation (Halila and Rundquist, 2011; Hörte and Halila, 2008) can be tested on this kind of data. Public organizations are also included in the data set. This means that publicly and privately owned organizations can be compared in various branches. A comparison between

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4 Fossil fuels are well known to be the main contributors to CO2 emissions (IPCC, 2007b).
activities of private and public organizations is often interesting from a public policy point of view, and will, of course, be presented as a background to change modelling and analysis of time-series information of transitions to non-fossil energy.

To make analyses comparable with international research, and also from a descriptive point of view, it would also be advantageous to be able to define and operationalize “eco-innovation” on the basis of variables in this data set. “Eco-innovation” has been defined by Arundel and Kemp (2009: 5) as something much wider than environmental products only:

> the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.

In particular, in this paper, we will look closer into the reduction of CO₂ aspect of eco-innovation, and the factors affecting this aspect of greener innovation (Arundel and Kemp, 2009; Figge and Hahn, 2004). This research therefore touches upon a number of issues, such as: energy transitions and innovation dynamics (Ghisetti and Quatraro, 2013; Gilli et al., 2013; Safarzynska, 2013; Schmidt et al., 2012), the “Porter hypothesis” that environmental standards can trigger innovation offsets (Porter and van der Linde, 1995), functions of innovation systems (Hekkert et al., 2007; Tukker, 2008), CO₂ emissions in
Swedish manufacturing industries (Bergquist and Söderholm, 2011; Guziana, 2011; Pardo Martínez and Silveira, 2013), country case comparison in the shift from fossil to non-fossil fuel (Armstrong and Blundell, 2007; Costantini, 2013; Costantini et al., 2012; Lincoln, 2012; Wang et al., 2012), responses to the global climate change (Witthaus, 2012), and more generally, models of evolutionary environmental economics (Bergh, 2007; Faber and Frenken, 2009). Since education indicators are used in the statistical analysis, our results should also be interesting for those who investigate aspects of knowledge versus formal education in relation to innovation (Colombelli et al., 2013; Jensen et al., 2007).

The paper unconventionally follows a cultural evolutionary approach to studying population dynamics in industry performance and the ecology (interaction over time) of organizations’ behavior (Sandberg, 2006) rather than an organizational-ecological focusing on firms themselves as units (Aldrich, 2003; Carroll and Hannan, 2000; Hannan and Freeman, 1989). The units of analysis or cases in the matrix are therefore the *usages* of various practices in organizations (Sandberg, 1999, 2006); in this case various energy sources. What matters is therefore the survival time of usages or types of energy use. Survival analysis, or more specifically Cox regression, is adequate to the structure of time series data in our material on how use of various energy sources change – emerge, transform and vanish - over time in organizations.

4. **Energy Use and CO₂ Emissions**

Among the datasets mentioned in table 1 above, the “coal file” covers energy use and emissions. The sample of this data set is less than two thousands enterprises
each year but covers all the largest organizations in Sweden and a sample of the rest structured in terms of both branches ("SNI", a Swedish organizational taxonomy) and sectors (private, public, etc., see table 1). Data from the coal file can be used to explore fundamental trends in Swedish energy use (for a description of the data set, see Statistics Sweden, 2010) at the level of energy use of each organization. The data set includes organizations involved in: agriculture, fisheries, wood processing, industry, construction, transport, public organizations, housing, and private services. An overview of the energy use by these different types of organizations is given in figure 1.

//Figure 1 around here//

**Fig. 1** Total energy use (apart from electricity) by Swedish organizations 2003-2011 (terajoules)

At least three important conclusions can be drawn from figure 1. One is that wood fuels have rapidly been increasing its share, in particular in the years 2003-2010. This is also true for solid waste. These two types of non-fossil energy are behind the shift from fossil to non-fossil energy during these years; as a consequence of the reduction of fossil oil and solid fossils. However, fossil gases are second in terms of energy consumption. “Green innovation” in Sweden, therefore, is largely a matter of replacing fossil oil and solids with wood and waste, in combination with an increasing use of fossil gas. If the various types of
energy use are collapsed into two major groups of sources, fossil vs. non-fossil, we can see that the shift around 2006 becomes very clear (see figure 2).

//Figure 2 around here/

Fig. 2 Fossil vs. non-fossil use of energy among Swedish organizations (sums in terajoules)

Figure 2 describes the shift from fossil to non-fossil fuel as the source of energy among Swedish organizations in the simplest graphic form. Fossil fuels decrease as the non-fossil fuels increase as an energy source. Taken together in total, energy consumption in total decreases during the last years of the period measured, which is in line with what Statistics Sweden reports (Statistics Sweden, 2010) and partly an effect of GDP figures. Our question is if this also implies a “greening” of Swedish industry and other organizations in the sense that CO₂ emissions decline as a consequence of this shift. Looking at figure 3, we understand that this is not the case.

//Figure 3 around here/

5 The decrease in emissions and consumption registered in the last year of their series could be related to the sharp slowdown of the economy in 2009, which is linked to the global economic crisis of that year.
The shift from fossil to non-fossil energy in Sweden has had the consequence that non-fossil users are responsible for increasing CO$_2$ emissions (figure 3). The shift between 2006-2007 is dramatic and mirrors the consumption figure. As the emissions mirror consumption, the increasing CO$_2$ emissions arise as a consequence of increasing, not only consumption of the energy from primarily wood fuels, but also solid waste, while fossil oil in particular is declining as the origin of carbon dioxide. The gap between fossil and non-fossil energy closes as a consequence of increasing total consumption, particularly in 2010.

5. **Survival analysis of “eco-innovations”**

Survival analysis is a statistical technique in which we are concerned about the time duration until a specific event occurs. It is a technique that requires time-series data of the type we have here. The event can be, for example, when an organization changes from fossil to non-fossil fuel use. Typical of the survival analysis of time-series, is that some cases never reach the analyzed variable value (the event of change into non-fossil energy use), and are therefore ‘censored’. Since such a variable with censored cases does not follow a normal distribution, a times-series, event history or survival analysis is required. In this paper we will use a Cox regression, since it produces predictions (of an death event) at survival time $t$ as a function of baseline survival taken to the power of
an expression that contains predictors we wish to include as co-variates or factors behind the shift to non-fossil energy sources.

The Cox regression is developed for purposes of biostatistics, such as the analysis of survival among cancer patients in relation to treatment. This means that survival in relation to an illness condition may correspond to, with respect to our data, either the event of innovating into non-fossil sources of energy or the reverse event, analyzed in the next step below. However, the Cox regression is not only used to actually study survival and hazard ratios among patients, but is also used in the analysis of clinical trials examining time to disease resolution (i.e. in the study of the “survival of the disease” or its symptoms); something which perhaps is a more easily acceptable analogy for the analysis of a “pathological” usage of fossil energy. In a Cox regression, the hazard ratio represents the hazard that a treated patient will resolve symptoms before a control patient. The relation of the hazard rate in the two groups is called the hazard ratio. Stated the analogous way, for any randomly selected pair of organizations’ use of fossil energy, one from the ‘treatment’ group (in our case an organization that was affected earlier by specific conditions likely to enhance the likelihood of earlier transition to non-fossil use), and one from the control group of fossil user organizations (without such conditions). The hazard ratio in our case is therefore the ratio of the ‘hazard’ that the time to ‘healing’ (an advantageous transition to non-fossil use) is less in the nation from the group of organizations affected by a hypothesized factor than in the organizations of the control group.
Survival of fossil use among organizations can be analyzed using Statistics Sweden ‘coal file’, merged with data on employee education programs and levels, provided by the Swedish Statistics labor market data base (RAMS), if aggregated at organization level and tied to the organizations (see table 1). This way, data on the organizations’ ownership, degree of market orientation, energy consumption, economic added value, operational profit, and revenues, can be combined with the factor of the general level of education of their employees and degree tind of (at least undergraduate level) environmental program education. The effect of all these factors on the ‘survival of fossil energy use’ can then be made using Cox regression, and also separately for various types of industrial branches. The model used here lists the hypothesized variables that affect the likelihood of the survival of fossil use among Swedish industrial organizations. Column B indicates first the direction of how these factors influence the event of non-survival of fossil energy use; minuses indicate that these factors negatively affect the likelihood of the event of transition to democracy. Column Exp (B) gives the predicted change in the hazard for each unit increase in the covariate (the factor). When the Exp (B) value is 1.0, the covariate makes no difference in predicting the event of the transition to non-fossil energy. The more the hazard ratio exceeds 1.0, the greater the relative hazard of the ‘death’ of fossil energy use—related to a change in a factor or covariate. An Exp (B) value of 1.1 for any the covariates would mean that a positive value of the factor in question would be associated with a 0.1 (10%) increase in the hazard rate for an innovation into the use of non-fossil energy. The further the hazard ratio is below 1.0, the greater the covariate’s contribution to decreasing the hazard of ‘death’: in this case decrease
in the ‘hazard’ of innovation into non-fossil energy use. We test the hypotheses of the effects of the employees’ education, the ratio of environmentally educated to all educated at undergraduate level in organizations, on green innovations and the time lags for such effects, along with control factors such as: consumption levels, turnover, value added, and operating profits as indicators of the economic situation of the organizations. We are also interested in the fact that some organizations are public, while others are private.

Note that the sample of the ‘coal file’ is not randomized, but comprised of the largest enterprises and organizations. This means that the test of statistical significance in the Cox regressions should be treated accordingly, i.e. since the sample is not randomized; the hazard ratio Exp (B) describes actual values. However, levels of statistical significance in the form of p values are normally presented even in analyses of total samples.

6. Survival Analysis of Fossil Energy

A survival analysis is first made on the already described set of industrial organizations, their energy use, a set of economic variables (the coal file) combined with the aggregated values of the numbers of employees with environmental education and at least a minimum of undergraduate level education, as well as the ratio between them (the yearly RAMS files).

//Table 2 around here//

**Table 2** Survival of Fossil Energy Use in Swedish Industry: a Cox Regression
Fig. 4 Cumulative Hazards for Fossil Energy Use in Public, Private and Other Organizations

The Cox regression shows, first, that neither private ownership, value added, nor the number of environmentally educated employees significantly affect the likelihood of the survival of the fossil energy use (p>0.05). Since energy consumption, net turnover and operational profit all have Exp (B) values of 1; we can say with statistical accuracy that these factors do not influence the survival of fossil energy use. The factor environmentally educated has a slightly lower Exp (B) value than 1, indicating in fact that the employment of environmentally educated personnel increases the chances of the survival of non-fossil use among Swedish organizations. This is an unexpected result. Maybe these organizations have been in situations in which environmentally trained employees are needed in order to investigate future energy sources. The final factor in the model, with a strong detrimental effect on the survival of fossil energy use is public ownership; however, publically owned organizations are more likely to innovate from fossil to non-fossil energy. The Exp (B) of slightly more than 2 implies that public organizations have 68 per cent higher probability of reaching the non-fossil energy use than the private organizations (the probability equals the hazard ratio Exp(B) divided by 1 + the same hazard ratio). The cumulative hazards for fossil energy use is therefore higher among public organizations than among private organizations, as figure 4 reveals.
7. Survival of Non-fossil Energy

Similarly, we can look at the reverse analysis, i.e. a Cox regression in which the survival of non-fossil, rather than fossil, energy use is analyzed with the same set of co-variates.

Table 3 Survival of Non-Fossil Energy Use in Swedish Industry: a Cox regression

Fig. 5 Cumulative Hazards for Non-Fossil Energy Use in Public, Private and Other Organizations

In this analysis, we look at the factors influencing the reversal from non-fossil to fossil energy use in Swedish organizations 2003-2011. In this analysis, net turnover, value added, and operational profit are not statistically significant factors for explaining why organizations fail to maintain their non-fossil energy use. Energy consumption and the number of employees with at least an undergraduate education have a hazard ratio of 1, indicating statistical significance of their non-influence on the survival. Organizations with a higher
number of environmentally educated and privately owned organizations are somewhat more likely to continue with the non-fossil use. A statistically significant larger effect is again only found among public organizations as opposed to private, where the Exp (B) value is only 0.515, indicating that being a public rather than a private organization enhances the probability of introducing fossil fuels as energy source by 34 percent. In the figure 5, we can see that the cumulative hazards are lower among public organizations than among private organizations.

8. Discussion

Results from our survival analysis of energy usages among Swedish industrial organizations 2003-2011 on the basis of register data show that neither energy consumption, economic indicators of the organizations or the education levels in general play important roles for why these organizations innovate in the direction to or from the use of non-fossil sources. The Cox regressions cannot find more than one distinct co-variate affecting the likelihood of greener or non-greener innovation in this respect than public versus private ownership. Public ownership of an organization drastically increases the chances for fossil energy users to subsequently and quickly become non-fossil energy users. Public ownership also drastically reduces the hazard that an organization that used non-fossil energy will begin to use fossil energy instead. One reason why public ownership is critical to greener energy innovation is probably a matter of industrial sector. Exactly which types of production state-owned organizations
are hosting the observed shifts to non-fossil energy usage is not easy to reveal from using the register data from Statistics Sweden. What we can see in descriptive statistics (figure 4), is that public organizations primarily use wood fuels, at least until 2010, while private organizations use fossil gases to a substantial degree. Private organizations, more than public organizations, shifted from fossil oil to fossil gases. This is obviously why the ownership factor plays such a crucial role in the survival analyses of fossil vs. non-fossil energy in Sweden. More specific sector studies can be made using other data sets from Statistics Sweden.

Fig. 6 Emissions of CO$_2$ among public and private energy users in Sweden

The result that public ownership is a critical factor suggests that the shift to non-fossil use to a large degree is a question of using wood fuels instead of fossil oil. Two major storms in 2005 and 2007 helped in this respect. Unfortunately this shift does not affect CO$_2$ emissions. Furthermore, the shift is not of high-tech or technological character, or effects of the level of education among employees, but rather a market innovation, if using Schumpeter’s definition (1947). The shifts to non-fossil usage in public organizations were wind-fall gains rather than effects of technical eco-innovations, institutions or policies. Emissions of green-house gases are unfortunately not greatly affected.
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Figure 1. Total energy use (apart from electricity) by Swedish organizations 2003-2011 (terajoules)
Figure 2. Fossil vs. non-fossil use of energy among Swedish organizations (sums in terajoules)
Figure 3. Emissions of CO$_2$ among energy users in Sweden
Figure 4. Cumulative Hazards for Fossil Energy Use in Public, Private and Other Organizations
Figure 5. Cumulative Hazards for Non-Fossil Energy Use in Public, Private and Other Organizations
Figure 6. Emissions of CO₂ among public and private energy users in Sweden