The Greening of the Swedish Innovation System

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Introduction
From most viewpoints, not least from the political perspective, a “greening” of innovation is highly desirable. Most countries, as well as many businesses, wish to excel in being increasingly “green” in technologies, processes and products, logistics, raw materials and waste handling, and so forth. From a social scientist’s perspective, however, the dominating problem is how to be able to investigate what actually has been accomplished and what are the likely prospects in this area. First of all, many of us have problems already in defining a “greening” of innovation: how can “green” be defined among the products and processes in innovation systems? Second, the problem is one of data: are there any ways we can estimate the development of our innovation systems regarding green versus conventional innovations? Only on the basis of existing data one might then, thirdly, consider measuring, modeling, estimating, explaining and perhaps even forecasting and suggesting policies and firm-level strategies for such greening of innovation in our innovation systems (Freeman 1988, Lundvall 1988, 1992 ed., Nelson 1993).

In order to study and assess greening of innovation systems one has to have reliable data stretching sufficiently far back in time. One may of course initially make a general mapping of both environmental orientation of production of goods and services over the whole economy or its sectors and branches. But the grading system is critical for such data gathering. Is for example an environmentally oriented improvement of traditional production and processes measurable with the same scales as production of recycling services? One may also ask which economically rather than environmentally motivated modifications in existing production processes, say energy saving, may qualify as “green” innovation. Can any production or process be considered “green” or “conventional” from the fact that they affect the environment more or less? These
questions point to the problems in defining “environmentally sound”, ”green” or ”eco-efficient” production or processes. It also means that 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. Rather, it means that one should focus, as social scientist, on what is measurable, what actually has been measured, and start in those questions that actually can be answered.

When presenting empirical research results based on necessarily controversial definitions and measurements it is critical however to stress what these results are not saying as much as what they are saying. In particular any results on the ratio between green and conventional sectors or innovations of the economy have to be presented with detailed definitions on what they exactly measure in the greening by new products, new processes or innovations.

This preliminary plan in the proposed project is an investigation of existing official and total organizational population data merged with data on the Sweden’s environmental product sector and data on types of energy used and environmental protection measures taken in industry. However, these data will to a large extent be transformed into variables of changes from one year to another in practices of different kind. Since we do not have any variables of innovations themselves each year, we will instead define innovation at organizational level as change from one year to the other in variables that are related to the Schumpeterian definition (1947: 153) of innovation as change in products, processes, raw materials, markets or organization. All changes among all organizations and institutions with respect to these changes in Sweden are then simply considered to equal the national innovation system. The innovation system is therefore defined somewhat differently than in the classic texts above as it is operationalized for direct use in statistical and mathematical analysis. The unit of the innovation system analysis is thus change in organizational activities and institutions, rather than the population of organizations, individuals as agents of change or institutions as such. A change in orientation from traditional into environmentally friendlier production, more eco-efficient types of energy use or larger amounts of environmental protection measures among organizations are considered “greener” innovations in the Shumpeterian sense. Considering change as the fundamental unit in a system makes it natural to model the evolution of changes and interactions between them over time. Our
focus is thus 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, along with institutional change, can be extracted, modeled and analyzed, along with factors believed to influence innovation. Some of these factors may be found at work-force, individual level, thus requiring a model connecting industry and production sector, organization and individual level variables. From the results of these analyses, we can then later discuss more complicated aspects of forecasting, policy measures and firm-level strategies.

**Swedish official 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 form of data is covering the whole population of cases – individuals, organizations and so forth - of the system, and variables should of course be those that are included in the model. When dynamics is in focus, time series data structure is essential. It is always critical that data is of high quality, i.e. the values of the variables should correspond to actual conditions. Other types of data are often based on samples of the organizational population in which the larger organizations of the population are covered completely, while smaller organizations are randomly selected. This is the case with other interesting datasets such as the Eurostat CIS data set which provides comparable data for EU countries on innovation, including environmentally oriented innovations.

In this case, where we focus on Swedish environmental innovation as change in environmentally significant activities of organizations, there is one data set option that one must consider superior to all the rest, namely the official register data on all organizations in Sweden in a time-series structure (Swedish statistics’ so-called FAD-data set). This dataset can also be expanded with variables available on organization level, such as environmental product data and data on industrial use of various types of energy sources and environmental protection measures.

FAD is compiled from yearly so called Labor Market Register Data (“RAMS”) - information from organizational, sub-unit level (“arbetsställe”) as well as employee level. All organizations, their sub-units (separate plants and the like, with own addresses), and all employees, are included
with case identification on these three levels (!). FAD is thus a time-series of these RAMS data and is therefore of demographic character. It means that using FAD you may study “births” and “deaths” of organizations and their sub-units as well as mergers and splits over a period of several years, depending on variables. Data quality issues are addressed systematically.¹

Swedish statistics also collects data on types of environmental production of goods and services and volume in percent of that particular environmental production on organization level. FAD and environmental register data can be merged, which is one of the ideas on which this project is based. The definition of various environmental products (goods as well as services) in the environmental products data set is made with reference to the OECD and Eurostat manual The Environmental Goods & Service Industry – Manual for Data Collection and Analysis (1999 and later). The definition is formulated in the following way:

“Environmental goods and services industry consists of activities to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and ecosystems. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use.”

Note that the definition includes environmentally oriented production of goods and services rather than adaptation to environment of not environmentally oriented production. This means that, say, green innovations in the automotive industry is not included. However, recycling of chemicals is, as environmentally directed service production. In 2009, Eurostat published another edition of the handbook. Swedish statistics participated in preparation of this book and it will be used in the further build up of statistics. The definition of environmental organizations is the same, however. One problem for comparability with other national systems of organizational statistics is that the classification systems may still differ. The Swedish system (SNI) is national, but gradually adapted to international standards.

What data gives us is a definition of those organizations, their subunits and employees that are directly, not indirectly, providing environmentally friendly goods and services, such as environmental “core industries” consisting of NACE 25.12 ”Retreading”, NACE 37 ”Recycling”,

¹
NACE 41 "Collection, purification and distribution of water”, NACE 51.57 "Wholesale of waste and scrap” and NACE 90 "Sewage and refuse disposal, sanitation and similar activities”. In addition, manual search of organization involved in the provision of environmental goods and services are added by SCB into the data base, including historic data. Thus, time-series data are continuously updated retrospectively. This makes it possible to report comparable time-series in three broad categories: pollution management, cleaner technologies and products, and resource management.

Using recent classification, the following categories of environmental production have been used (under short descriptive headings):

***Box 1 around here***

In the description of their data, Swedish statistics (SCB) states that time series data sets have been created in a way that makes temporal comparison possible. Each year the entire data set is checked with the purpose of making variables reliable over time (SCB 2008). The classification made in the time series data Swedish statistics provides for the period 2003-2008 are shown in the figure below:

*** Figure 1 around here***

Combining environmental product data with FAD one obtains a data set from which it should be possible to make authoritative conclusions about the number and variety of environmental product organizations there are in Sweden, its regions and branches. It is also possible to add individual-level variables such as: age of the individual, education, level of education, employment status, region where the individual lives, labor mobility, occupational code, sex, wage, number of employees, wage costs, and so on. Public organizations are also included in the data set. It means that publicly and privately owned organizations can be compared in various branches. A comparison between activities of private and public organizations is often interesting from a public policy point of view and will of course be presented as background to modeling of change in these variables.
To make analyses comparable with international research, and also from a descriptive point of view, it would also be interesting and important 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.

Some of the “greening” aspects of innovation of various kinds suggested by Arundel and Kemp under “eco-innovation” and “eco-efficiency” can perhaps never be measured validly in their entirety on a comparative national level, even if they may well serve as basis for policy formulation. However, certain aspects of the energy use in relation to output variables such as production volumes, profits, and value added can be combined with FAD and environmental product data. This means that we may also be able to come closer to a measurement of eco-efficiency (ibid.) or ”sustainable added value” (Figge and Hahn 2004), in that case defined as the ratio between product and service value added and environmental impact terms such as energy and material inputs and waste output and change in these values. This can be made using the energy source data for Swedish industry that also can be merged with FAD. Among energy types coded, we find everything from different types of coal, oil and gas to electricity and bio-fuel. In addition there are also output variables available, such as waste volumes of different types, some of which are calculated on input data on energy consumption.

Using this kind of statistics for extraction of change over time, the evolution of the Swedish environmental goods and services, eco-innovation in terms of change in energy use and eco-efficiency, as well as change in environmental protection measures can be modeled in relation to conventional sectors. In addition, the evolving green sector or green energy innovators can also be described in absolute and demographic figures at organizational level, i.e. change or innovation variables can be tied to the organizational demography dynamics.
**Analysis in terms of “eco-innovations”**

A unit of change, a transition, from being (classified as) conventional to green organization can be interpreted as a “green innovation” in a wide sense of the word, i.e. as a change in how one produces goods and services with an environmentally benign significance in accordance with definitions specified above. This also implies that one without complicated modeling can make statistical analyses of which factors on individual and organizational sub-unit level increase the likelihood - or odds ratios - of such a transition (by means of logistic regressions). For instance, one can test hypotheses of effects of employees’ education, or threshold values of critical amounts of such experts, on organizational and sub-unit innovations and the time lags for such effects. In an initial analysis it is important to see how various factors on individual and sub-unit level influence outcomes in terms of green innovation at organizational level and with what likely delays. One may also describe trends in competition among industrial branches between green and conventional actors. Even simple descriptive results will be pioneering due to the previously unexploited data set.

**Theory for choice of models and research questions**

As was mentioned earlier the preferred data is of organizational-demographic or organizational population character. This means that the population of organizations and sub-units are “born”, “die”, merge and split. The number of cases in the data set thus varies depending on transitions each year. At the same time green innovations are being diffused in this population. This means that the data structure is suited for a population ecological analysis, but also for an “epidemiological” analysis. In many cases, this means the same thing, model-wise, since innovation will give “birth” to another type of organization or sub-unit. Likewise, the type of organization one was before the transition will be analyzed as a “death” event of one case of the previous as conventional-type organization.

Innovations may most likely work as splitters of sub-units so that innovating sub-units may split up into a pair, of which one unit is coded as green, the other conventional and potential candidate for a merge with other conventional sub-units of an organization. The population of organizations and subunits may thus be analyzed as an evolving system of two main evolving stocks – one green and one conventional - and time dependent flows between those stocks under the additional influence of in- and outflows of emerging, disappearing, merging and splitting
units into these two stocks. This means that the changes in flows, our units of analysis, can be measured and modeled in interaction and influence of parameters measured in the data set.

Classic references to the population-ecological approach include Hannan and Freeman (1993) *Organizational Ecology*, Aldrich (1999) *Organizations Evolving*, and Carroll and Hannan (2000) *The Demography of Corporations and Industries*. Especially in the first and last titles there are a variety of models and estimations of them that are well suited for the type of data FAD with environmental variables offer. One can think of a number of angles from which this material can be modeled. One is organizational “life histories”, such as birth ratios of organizations and sub-units of green character. Survival functions, giving the probability of an event such as emergence, disappearance, merge or split of a green organization or sub-unit not to happen before a certain point in time.\(^2\) Survival analysis can of course describe which share of the population environmentally oriented organizations and sub-units or their characterizing innovation still exist each year, and among those that still exist, with what rates the eventually will disappear, but can also be used to correlate with factors affecting these survival rates.

A critical question is the transition itself from being a conventional into being a green organization or sub-unit of an organization. One important detail is the step-wise versus saltational change in organizations and sub-units, i.e. the structure of variable values between being conventional and being green: does this change constitute small steps during several years or is it generally a sudden leap from one year to the other from one stock into another stock of units? What factors determine whether an incremental or step-wise versus a sudden or saltational innovation will occur? Does that differ between branches and categories of units? Will one type of transition make green organizations, sub-units or innovations survive longer than other types? Probabilities of survival of green organizations, sub-units or innovations can be estimated as a function of transition time; the more the longer time-series are being cumulated. It is important in the long run to establish how long transition periods of organizations need to be in order to gain long-term survivability.

Mathematics from survival analyses originates from medical and population-ecological research. The latter has its origin in the rather simple models of diffusion that originally were developed
by mathematicians and naturalists in the 19th Century. From these early models, epidemiological model arose. Some diffusion models are well-known from Rogers Diffusion of Innovations (2003 and earlier editions). Malthus model of exponential growth is well known as it inspired Darwin to his theory (or law, rather, on evolution as a consequence of variation, selection and retention). Gompertz and Verhulst (1825 and 1838) had already improved Malthus model, however, to include density dependence. Density dependence is of course critical in any application to diffusion of innovations in a population of organization or on a market. Rogers’ lectures and book also inspired Frank Bass to formulate an analogy to diffusion of innovation, the Bass-model (1969). An overview over the last decades’ advances in the area of diffusion models are presented in an article by Meade and Islam (2006).

A classic way to depict logistic diffusion of innovation is to use Fischer and Pry transforms, i.e. log linear analysis of substitution. In this case it would mean conventional versus green innovations or organizations in the populations or sub-populations such as sectors of the economy. It is interesting to compare diffusion of several of the “green” innovations among organizations and sub-units in different branches and regions of country or along other dimensions in the material, but Fischer-Pry transforms should most probably not be over-interpreted cybernetically as prediction devices.

**Interacting diffusion processes**

As we can see there are at least two related approaches to studying diffusion processes within populations. One is more influenced by the same population ecology mentioned above, the other more statistic. The first can help us understand the dynamics between different changes in interacting organizations. The other can help us understand which variables are the most important for the occurrence of diffusion of greener innovations among cases of organizations. In both cases we should focus on change from one year to another, rather than presenting yearly absolute values.

The population ecological analysis provides a way to mathematically model the interaction between organizations and sub-units in relation to diffusion among them. The Fischer-Pry transform was mentioned above. Such an equation can be elaborated into a system for how two diffusion processes interact. They would correspond to the population-ecological modeling of
interaction between populations competing for the same resource, so-called Lotka-Volterra equations. It would be particularly interesting to study time-series changes in the equilibrium within such a system of two competing groups of organizations, sub-units or innovation-types, green and conventional, across sectors and branches but also diffusion of improved eco-efficiency and environmental protection. Lotka-Volterra equations can also be elaborated into Lotka-Volterra systems with n groups of organizations, sub-units or innovation competing.

There are reasons to emphasize that the dynamics of such a system, the interacting populations of organizations, sub-units and innovations, create incentives to evolution in the sense of further product, process, market, raw material and organizational innovation. Minor differences may give selection advantages, and therefore survival as capacity of a competitor. Innovation as “doing of new things or the doing of things that are already being done in a new way” (Schumpeter 1947: 151) can thus create conditions that provide evolution at innovation level in a Darwinian sense (even if evolution at innovation selection level was never understood by Schumpeter7). Both customer preferences and the society’s policies and institutions respond and therefore interact with the variants of innovations being diffused among organizations. This is why we nowadays often speak of co-evolution between institutions and innovations, not the least in the environmentally oriented innovation studies (Sandberg 1999, Van Der Berg et al. 2007, Faber and Frenken 2009). Questions to put in the current case are what interactive processes one can detect among organizations in the environmental sector in relation to the conventional sector and if effects of policy and institutional changes can be observed as diffusion responses among organizations. Again, such changes in the institutional environment may be introduced as factor in a statistical analysis of innovation as change if the time series is sufficiently extensive.

These questions on co-evolution of policies, institutions and innovations are more open-ended than the previous. The reason is that they to a greater extent are motivated by theory and previous empirical studies of this type are scarce or non-existent, including on the Swedish material. But as we see it, it is an intriguing way of trying to understand “how the national system of innovation actually works” and how evolution within it can be understood and studied as interaction between various types of change. The more one gets to know the interaction and
the co-evolutionary patterns between institutional change and innovation by successful modeling, the more likely one may propose forecasting methods.

In forecasting as well as in statistical analysis of actual innovations, factors in interaction with these diffusion processes are critical to understand. To be able to analyze them in closer detail, one may also use multi-level analysis. This would mean to analyze diffusion processes among branches of industry at organizational level and then include the parameters of those micro models into a linear regression on macro level. Statisticians call it multi-level analysis (Hox 2002), but normally the micro level analyses are also linear. In our case, we would rather compare logistic models at micro level and then include parameters of them in linear regression on branch or sector level. One idea would be to include the flows of qualification in terms of education at individual level as factors for the diffusion of green innovation at firm-level and sub-unit level, thereby estimating the network in which greener ideas flow between organizations. Thereby a multi-level analysis might reveal some of the diffusion patterns for greening of the Swedish innovation system.

**Summary**
The proposed project is an investigation of some of Swedish Statistics’ official data of all registered organization in country that can be merged with other data sets on the environmental product sector, energy consumption and environmental protection measures in industry. The innovation system is in this case understood and operationalized as all changes in values from one year to another in the variables of activities of all these organizations included in the merged official time series data set. The basic unit in the proposed analysis of the innovation system is thus *change in activities*, rather than the amounts and populations of organizations and individuals as agents of change each year in a sequence. A change in orientation from traditional into environmentally oriented production, more environmentally friendly types of energy use or larger amounts of environmental protection measures among organizations are considered “greener” innovations in the Shumpeterian sense of change in technologies, processes, markets, raw materials or organizational forms. Considering change as the fundamental unit in a system
makes it natural to model the evolution of changes and interactions between such innovations over time.

In a dataset available from official Swedish statistics, the total number of organizations and employees, including values on a number of critical variables, can be combined with the register data of the environmental sector, i.e. the sector in which goods and services are produced, as well as data on type of energy used and investments made in environmental protection. The resulting data set would thus become a total set of all organizations, their employees and variables both from these two levels and variables of environmentally-oriented production of goods and services, as well as energy use and investments in environmental protection in industry. From 2003 we would have a complete time-series data set of all these variables including both individual and organization level data.

As the data set provides a “demography” of organizations in Sweden, with “births”, “deaths”, mergers and splits in a time series, we intend to apply an organizational ecology and demography approach to the study of dynamics in the Swedish innovation system. The data set provides us with many testable hypotheses about why some changes in organizations grow faster than others and how they interact.

As we can see there are at least two related approaches to studying diffusion processes within populations. One is more influenced by the same population ecology mentioned above, the other more statistic. The first can help us understand the dynamics between different changes in interacting organizations. The other can help us understand which parameters are the most important for the occurrence of diffusion of greener innovations among cases of organizations. In both cases we should focus our study on change from one year to another, rather than deal with yearly absolute values.

The more one gets to know about the interaction and the co evolutionary patterns between institutional change and innovation by successful modeling, the more likely one may propose forecasting methods. In forecasting as well as in statistical analysis of actual innovations, factors in interaction with these diffusion processes are critical to understand. To be able to analyze
them one may also use multi-level analysis. This would mean to analyze diffusion processes among branches of industry at organizational level and then include the parameters of those micro models – including flows of expertise at individual level - into a regression on macro level. From these exercises we would be able to come somewhat closer to answers on critical questions about what factors at national and organizational level promote diffusion of greener innovations in the innovation system.
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Data Collection and Analysis

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Box 1. The Swedish environmental goods and services sector

<table>
<thead>
<tr>
<th>Pollution management (Grouped domain)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air pollution control</strong></td>
</tr>
<tr>
<td>Goods and services for treatment or removal of exhaust gases and particulate matters from stationary and mobile sources. This class also includes environmentally less-damaging specialised fuels. A typical establishment in this class produces and sells air filters for different applications, for example exhaust filtering.</td>
</tr>
</tbody>
</table>

| **Wastewater management**            |
| Goods and services for the management of wastewater. This class includes all establishments within NACE 90010 and those who produce goods and services for collection, treatment and transport of wastewater. Many of the establishments work both with wastewater and water supply, making the boundary to the domain Water supply somewhat indistinct. A typical establishment in this class is a waste water system installer. |

| **Solid waste management**           |
| Goods and service for the management of solid wastes, collection, treatment and transportation). For example all establishments within NACE 37 (Recycling), NACE 5157 (Wholesale of waste and scrap) and NACE 90021-90030 (Collection and treatment of other waste through Sanitation, remediation and similar activities) are included. Establishments producing containers for waste and trucks aimed at transportation of waste and transport companies are typical for this class. |

| **Remediation and clean-up of soil, surface water and groundwater** |
| Good and services to reduce the pollution of soil and ground water. For example establishments providing absorbents or cleaning up systems. Establishments providing protection for soil and groundwater, for example oil spill protection, are also included. |

| **Noise and vibration abatement**    |
| Goods and services that protects against disturbing noise from sources outdoors. Typical establishments are those which provides noise fences or noise isolation. |

| **Environmental monitoring, analysis and assessment** |
| Goods for monitoring and analysis and services within education, research, and consultancy. Typical establishments are environmental consultancy firms, educational firms and establishments performing analysis and monitoring. |

<table>
<thead>
<tr>
<th>Cleaner technologies and products (Grouped domain)</th>
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<tbody>
<tr>
<td><strong>Cleaner/resource efficient technologies and products</strong></td>
</tr>
<tr>
<td>In this area we have previously included establishments active in reducing the impact from production or use of products. Included here has been the production of equipment, technology, specific materials or services. However, this environmental domain has been difficult to follow of</td>
</tr>
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</table>
many reasons and therefore it has been removed as a separate domain since 2005. Instead, it will be included as a new classification declaring if each environmental establishment, no matter if primary or secondary, is using a cleaner and/or resource efficient technology. All establishment previously included in this domain have been distributed among the two other grouped domains.

**Resource management (Grouped domain)**

**Indoor air pollution control**

Includes all establishments that treats or renews indoor air in order to remove pollutants. An establishment must have their primary business in cleaning air rather that in air condition in order to be classified as primary. Since many establishments are active in both of these activities, an estimation of its operation usually has to be made in order to classify them as either primary or secondary establishments. The boundaries in this domain are hard to draw. Examples of establishments are producers of air filters, smoking rooms and units for smoking rooms.

**Water supply**

Includes all establishments active in collecting, purifying and distributing drinking water. This class also includes establishments working with conserving and reducing water. All establishments classified as NACE 41 (*Collection, purification and distribution of water*) are included. If they treat wastewater they are found in the domain Wastewater management. However, many of the establishments work both with wastewater and water supply, making the boundaries somewhat indistinct. The main NACE code decides which domain the establishment is classified as.

**Recycled materials**

In this domain all establishments active within NACE 25.12 (*Retreading*) are included. This includes all establishments active in rubber tires, vulcanisation and rubber repairs. It also includes producers of new materials or products, separately identified as recycled, from recovered waste or scrap or preparation of such materials or products for subsequent use. Energy recycling is excluded. An example of establishment, except for those active in NACE 25.12, is one producing for example a package or product from recycled plastic.

**Renewable energy**

In this domain most of the establishments active in the area of renewable energy are included. However, this domain is very closely related to the domain Heat/energy saving and sometimes the difference is difficult to point out. Renewable energy should include establishments producing equipment, technology or specific materials, or designs, constructs, installs, manages or provides other services for the generation, collection or transmission of energy from renewable sources. Solar energy, hydropower energy, wind power energy and energy from biomass sources are therefore included, as well as their subcontractors if they can be discerned. Peat is not considered to be a renewable source in Sweden, nor is waste. Heat and/or power plants using biomass fuels are included if they use a share of renewable fuels to produce the heat and/or power (the share determines the classification). Also establishments producing and delivering wood, wood chips, chips, pellets and briquettes are included in this domain, since they provide the fuel to generate energy. At the moment most network companies are not included in the database, except for in the few cases when they mainly deliver environmentally produced electricity.
### Heat/energy saving and management
This domain should include establishments working with energy efficiency improvements or reduced heat and energy loss. In the case of Sweden this implies for example producers, distributors and installations of technology which saves energy, such as for example pellet heaters, heat pumps and heat meters. It also includes establishment that works with technology or systems in order to minimize the use of energy. Advisors and consultants in this area are usually included in the domain Environmental monitoring/analysis and producers of renewable fuels in the Renewable energy domain. Since many producers both sells for example pellet as well as heaters, an usually rough estimation of which of these activities is the largest will decide in which domain the establishment will be placed.

### Sustainable agriculture and fisheries
In this area, establishments that reduce the impact of agriculture and fishery are included. For agriculture this translates to organic farming in Sweden. We use the register from an association called KRAV in Sweden from which we receive yearly information about organic farmers, their organisation number (if available), type of organic activity and if they are entirely shifted or not. Entirely shifted becomes primary and not entirely shifted becomes secondary. A typical establishment in this area is therefore for example an organic farmer or, for Sustainable fisheries, an establishment active in fishery care.

### Sustainable forestry
In this domain programmes and projects for reforestation and forest management on a long-term sustainable basis are included. One example of establishment in this domain is plantations, which cultivates and plants forest plants.

### Ecotourism
Establishments in this area provide services or education for eco-tourism. In Sweden we include establishments which have been classified as Nature’s best as primary and those classified as eco-tourism according to the Ecotourism association becomes secondary.

### Other resource management
In this domain establishments involved in nature conservation, biodiversity and other are placed. One example in this group is an establishment that works with liming of lakes.

Source: SCB 2006.
Figure 1. The green products sector: sub-organisational units in various branches

Source: SCB 2008
Notes:

1 In the documentation from Swedish statistics- SCB, the quality of RAMS is discussed in "Årlig regional sysselsättningsstatistik 1988:7", "Kvalitetsdeklaration av den årliga regionala sysselsättningsstatistiken 1991:1" (SCB) and in "RAMS, Beskrivning av statistiken" (all in Swedish). SCB notes that the largest effort is devoted to finding the correct sub-unit for the employees. It is on that particular point that quality problems primarily may arise. Employers with more than one organisational sub-unit have been given sub-unit control figures since 1985 from the tax authorities. These control figures should be tied to the address of the sub-unit and be included in the organisational registry data set. If the data entry is incomplete or incorrect, this may of course give quality problems. But the organisations are contacted in order to extract the correct data.

2 Namely that i does not happen before time t:

\[ S(t) = \Pr (T>t) \] (1)

Where survival S at a certain point in time t is defined as the probability Pr for "death" or disappearance of the greening innovation from an organisation or sub-unit to appear after time t.

3 Some examples of classic diffusion models also follow the history of mathematics. Gompertz’ equation (1825) elaborated Malthus’ exponential model (1798) but included a saturation level for diffusion:

\[ \frac{dN}{dt} = rN \ln\left(\frac{K}{N}\right) \] (2)

which in this context means change in number of N adopters of a certain innovation equals the growth factor r times the number of organisational sub-units gånger times ln of the saturation level K/N. The solution to this equation is for example used in the analysis of information technology diffusion in Taiwan (Chow 1967).

The logistic equation defined by Verhulst (1838):

\[ \frac{dN}{dt} = rN \left(1 - \frac{N}{K}\right) \] (3)

denotes that the change in the growth factor r times the organisational sub-units times the share of the population N that has not yet reached the saturation level for the innovation. The equation has been used for prediction of diffusion of telegraphy (Gilliches 1957).

Both the Gompertz’ and the Verhulsts equations are still used in some of the available softwares for curve estimations and prediction, along with others (Mead and Islam 2009).

Bass was inspired by Rogers and formulated the equation for how an innovation is spread in a population in the following way (1969):

\[ \frac{f(t)}{1-F(t)} = p + q / M \ F(t) \] (4)
where f(t) is the likelihood to adopt something at the time t, where F(t) is the fraction of the maximum saturation of the market M that has been reached at time t, and p is the innovation coefficient and q the coefficient of imitation. What Bass introduces is thus a distinction between innovation as an effect of being first with a novelty and innovation as an effect of imitating others who are first with a novelty.

The equation has an analogy in discrete form, which might be more realistic in predicting innovations, and which is applicable on the number of adoptations of a technology. This equation is particularly useful in estimation and forecasting of diffusion data. On the Bass institute’s home page on can download excel add-ins for the purpose of forecasting and model estimation on one-och more-generational diffusion data.

In a survey article, Meade and Islam (2006) list a large number of additional models that have been proposed in the last decades, both for estimating diffusion of single and generations of innovations. Their conclusion is that models for prediction from fewer observations are being developed, as well as models used for multigenerational diffusion.

If f is the share of the market in percent the green organizations gain, then the rest of the market is of course 1-f. Fischer-Pry logic states that that the ratio of the two, f/(1-f), plotted in a semi logarithmic scatter, becomes linear:

\[
\log \left( \frac{f}{1-f} \right) = a + b \ t
\]

in which t is time and b is the slope coefficient (the effect of one year on the 10-logarithm of the market share), and a is the intercept. The equation makes it easy to compare diffusion rates b between various innovations in the population or sectors of it.

4 Innovation rates (change in cumulative number of adopters per time unit) is one thing, saturation level another. An innovation can be spread quickly, yet fade to low levels of saturation. Therefore it is critical that factors affecting the rates as well as the saturation levels are considered.

5 Lotka and Volterra's equations of competition are defined as:

\[
\begin{align*}
\frac{dN_1}{dt} &= r_1N_1\left(\frac{K_1-(N_1+\alpha N_2)}{K_1}\right) \\
\frac{dN_2}{dt} &= r_2N_2\left(\frac{K_2-(N_2+\beta N_1)}{K_2}\right)
\end{align*}
\]

where \( N_1 \) and \( N_2 \) are the two competing populations, in this case of green and conventional innovations. \( K_1 \) and \( K_2 \) are the saturation levels in the system for the two populations, \( r_1 \) and \( r_2 \) are the growth factors, \( \alpha \) and \( \beta \) their coefficients of competition. Equilibrium in the competition is reached when \( N_1=K_1-\alpha N_2 \) and \( N_2=K_2-\beta N_1 \).