Acta Universitatis Agriculturae Sueciae

Doctoral Thesis No. 2020:48
Faculty of Natural Resources and Agricultural Sciences

Organisation and Governance of Agri-food Systems

Implications of Intellectual Property Rights in Plant Biotechnology

Chrysa Morfi

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SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

DOCTORAL THESIS
Uppsala 2020

Acta Universitatis agriculturae Sueciae
2020:48

ISSN 1652-6880
ISBN (print version) 978-91-7760-614-7
ISBN (electronic version) 978-91-7760-615-4

Print: SLU Service/Repro, Uppsala 2020

Organisation and Governance of Agri-Food Systems

Abstract

This thesis examines the question of organization, governance and choice of seeds in Swedish agriculture. It consists of four papers: Paper I investigates the evolution of plant breeding industry in Sweden. The results suggest that the establishment of intellectual property rights (IPRs) schemes creates power in the seed value chain in Sweden and has therefore been a major driver of mergers and acquisitions, together with changes in domestic agricultural policy as well the country´s entrance to EU. Based on nationwide survey among farmers, papers II and III examine the impact of IPRs and specifically the implications of the enforcement of Plant Breeders Rights on farmers´ choice between certified versus farm saved seed (FSS). Paper II uses transaction cost theory and logistics regression to examine empirically the governance structure of farmers choosing certified or FSS. Farmers´ assessment of the quality seed in terms of the genetic purity of each channel has no impact on their choice while personal relations with their upstream partners, investments in the farm as well as delivery contracts affect their procurement strategy. In paper III, spatial autoregressive models are used in order to analyze the transfer of "know-how" between farmers, and the spillover effects of social learning in farmers´ choice of seed channel. Farmers are distinguished between neighbors, based on their relative distance; and peers, based on membership in farmers' cooperatives. The results indicate the existence of spatial dependence on Swedish farmers' choice of seed channel. Paper IV evaluates the impact of farmers' social networks on their decision to be involved in the governance of the agricultural cooperative. The findings suggest a relationship between network characteristics and farmers' involvement in the governance that persists over a long period.

Keywords: seed systems, intellectual property rights, transaction cost theory, Bayesian econometrics, social networks, cooperative governance, cooperatives

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Dedication

"To the little pine tree
now long gone,
right bellow my window view,
astonishing us all,
with his willingness to live and grow."

and my parents!

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Morfi, C. (2020). The Wizards of Svalöf. *Agricultural and Food Science*, 29 (1), 29-42.

II. Morfi, C., Karantininis, K. & Andersson, H. (2020). Save or Buy? Insights from farmers ‘choice of seed input. (*Manuscript*)

III. Morfi, C., Karantininis, K. & Andersson, H. (2020). Spatial Seeds; Peer and neighbor effects on farmers’ choice of seed channel. (*Manuscript*)

IV. Morfi, C., Nilsson, J., Hakelius, K. & Karantininis, K. (2020) Social networks and member participation in cooperative governance. *Agribusiness.* (*In press*)

Papers I and IV are reproduced with the permission of the publishers.

The contribution of Chrysa Morfi to the papers included in this thesis was as follows:

I. Planned the paper, collected date, performed analysis and wrote the paper.

II. Designed the survey together with co-authors, planned the paper together with co-authors. Carried out data collection and estimation of econometric models. Wrote the paper together with co-authors.

III. Designed the survey together with co-authors. Developed hypotheses, performed econometric analysis and wrote the paper.

IV. Planned the paper and developed hypotheses together with co-authors. Performed econometric analysis. Wrote the paper together with co-authors.

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Abbreviations

CPVO	Community Plant Variety Office
EU	European Union
FSS	Farm Saved Seed
GDP	Gross Domestic Product
GM	Genetically Modified
IPRs	Intellectual Property Rights
LRF	The Federation of Swedish Farmers
MLC	Multinational Corporations
M&A	Mergers and Acquisitions
PBRs	Plant Breeders Rights
PVP	Plant Variety Protection
R&D	Research and development
SBA	The Swedish Board of Agriculture
SFO	The Swedish Seed and Oil plant Growers Association
SpmO	The Association of Swedish Cereal Growers
SVUF	The Swedish Seed Trade Association
TCT	Transaction Cost Theory
UAA	Utilized Agricultural Areas
UPOV	International Union for the Protection of New Varieties of Plants

1. Introduction

1.1 Thesis overview

This thesis covers issues related to organisation and governance of agri-food systems with emphasis on seed systems. Seed is the only physical matter with the ability to duplicate itself which is subject to Intellectual Property Rights (IPRs). IPRs affect not only the evolution of the plant breeding industry but also farmers´ seed choices. Hypothetically, if a holder of a smartphone could plant the phone and harvest more smartphones in subsequent periods, there would be a series of questions to be asked. Who is the owner of the second generation smartphones; the tech-phone company who invested in the embedded and protected technology or the user? Who decides who the owner is? Should the user pay for the use of the second period smartphones? Will the user repurchase new smartphones or will she continue using the second period phones? Will her peers and neighbors affect her choice? This thesis attempts to provide answers to some of these questions in the context of seed.

Paper I reviews the evolution of plant breeding in Sweden and the impact of IPRs on the development of the industry. Papers II and II examine farmers´ choice of seed and specifically the choice between certified and farm saved seed (FSS). The use of FSS not only can push the prices of the formal seed system down, it can also act as a parallel seed channel safeguarding the stock of seed input required for the domestic agricultural production. Additionally, as more and more patents on widely adopted varieties are expiring, understanding farmers´ preferences and behaviors towards these two seed channel becomes increasingly relevant. Papers III and IV examine the link between social networks embedded in cooperative membership in relation to farmers' seed choices and farmers' involvement in the governance of their cooperative. In Sweden, the cooperative movement has a long history and has helped the country transformed to a highly industrialized country. Table 1 provides an overview of the papers examined.

Table 1. Overview of the papers included in the thesis

No.	Title	Aim	Keywords
I	The wizards of Svalöf; Intellectual property rights and consolidation in plant breeding industry.	To map the evolution of plant breeding industry in Sweden.	biotechnology, UPOV, seed industry, seed system, value chain
II	Save or buy? Insights from farmers' choice of seed input.	To examine farmers choice of seed input; why some farmers opt for certified and others for FSS.	transaction cost theory, trust, seed perception, IPRs
III	Spatial Seeds; Peer and neighbor effects on farmers' choice of seed channel.	To investigate how farmers affect each other in their choice of seed channel as well as impact of perceptions about IPRs and cooperative membership.	spatial econometrics, Bayesian econometrics, seed systems, intellectual property rights, cooperative membership
IV	Social networks and cooperative members' willingness to be elected representatives.	To explore the impact of social networks on farmers' willingness to be elected representatives and their involvement with the governance of their cooperative	board of directors, social capital, nomination committee, cooperative governance

The remainder of the thesis is organized as it follows; two additional subchapters in the introduction provide general information about the agricultural sector in Sweden as well the domestic formal (certified) and informal (FSS) seed supply chain. Chapter two reviews the two main IPRs regimes and their economic implications as well as the literature conducted related to farmers´ seed choices. Chapter three attempts to provide an overarching perspective of the papers included in the thesis. Information about the data used in the analysis of the papers can be found in chapter four. Section five discusses the main findings of the papers and it is followed by the last chapter which consists of the summaries of the appended papers.

1.2 Swedish agriculture in numbers and figures

Sweden has three million hectares of land available for agriculture, of which two and a half million hectares are cropland. About 40% of the country's cropland is allocated to the production of cereals which corresponds to 1.8% of the total EU(28) land for cereal production. Sweden has a share of 5.5% in EU's fodder and forage production and 2.2% of the union's dry pulses (Eurostat, 2016). Approximately twenty thousand hectares are allocated for the production of fresh vegetables and berries while two thousands hectares are used for the production of fruits (Eurostat, 2016).

As illustrated in Figure 1, the acreage of agricultural land and cropland has decreased during the past decades; in 1961 the land for agricultural production amounted to 4.2 million hectares. This corresponds to approximately 30% loss of agricultural land in the past seven decades. Much agricultural land has been turned into forestland in the northern and mountainous parts of the country, especially after the national agricultural policy was abolished in 1990 whereby the financial support to farmers in disadvantaged areas decreased.

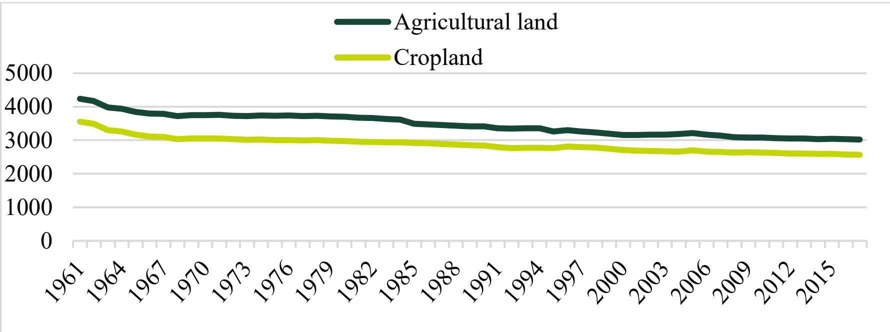

Figure 1. Agricultural land and cropland area in Sweden during 1961-2017 (in 1000 ha). Source: FAOSTAT (2020)

The number of agricultural holdings has decreased by nearly 4,000 in 2013 compared to 2010. This corresponds to a 6% decrease; from 71,091 holdings in 2010 to 67,146 three years later. The declining trend has been ongoing for decades (Eurostat, 2017). Figure 2 displays the distribution of holdings and utilized agricultural area (UAA) in 2013. The figure shows that larger units (with 100 ha UAA and more) cultivate more than half of the country´s UAA. Approximately 1150 holdings are involved in the production of certified seed.

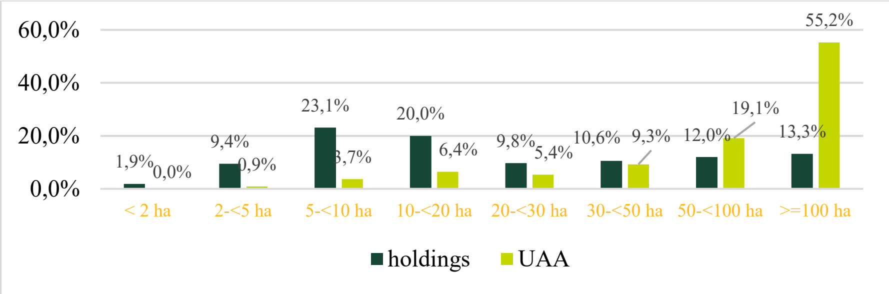

Figure 2. Number of holdings and utilized agriculture area by UAA size classes, 2013 (%). Source: Eurostat (2017)

Cereals have historically been one of the biggest crops in terms of production volume. The most common cereal crop is wheat with almost half a million hectares grown, followed by barley and oats. The share of land allocated to the production of different crops has been relatively steady the past 40 years. An explanation to the negative trend in some crops (see Figure 3) is the fact that less productive agricultural land has turned into forestland.

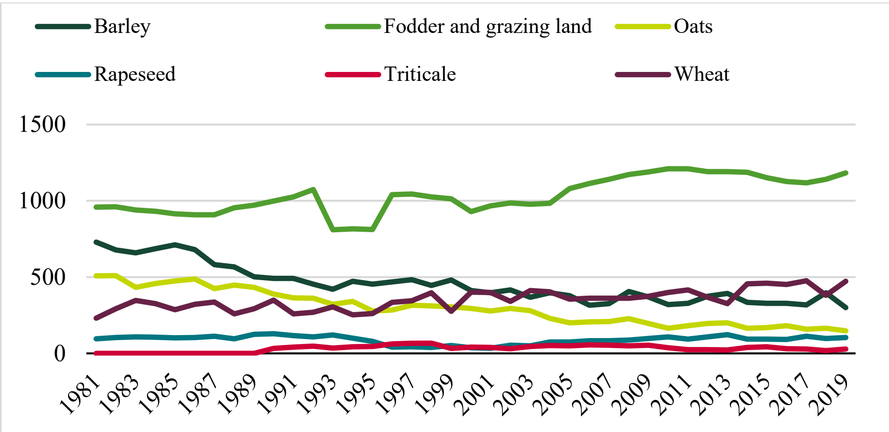

Figure 3. Filed areas for selected crops in Sweden 1981-2019 (in 1000 ha). Source: SBA (2020)

Figure 4 and Figure 5 display the annual production volume and corresponding yields for selected crops respectively. Both figures display notable annual fluctuations with a drastic change in the year 2018 when Swedish agriculture experienced a dramatic loss of production due to the extreme warm and dry summer.

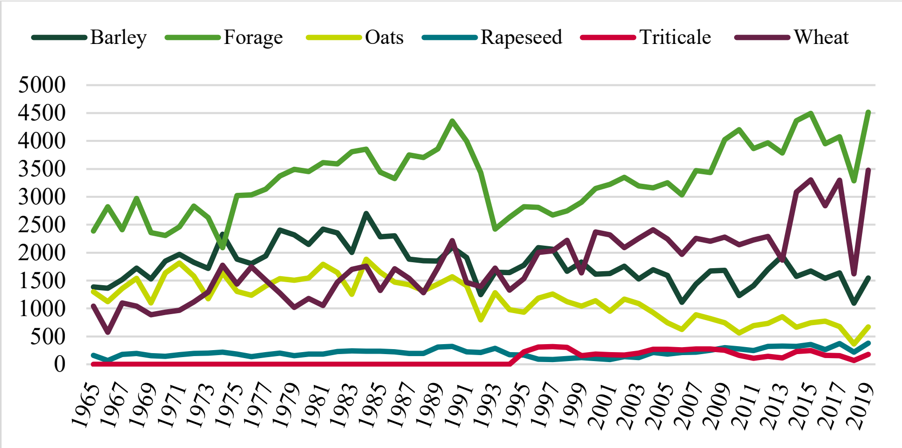

Figure 4. Production volume for selected corps in Sweden (in 1000 tones). Source: SBA (2020)

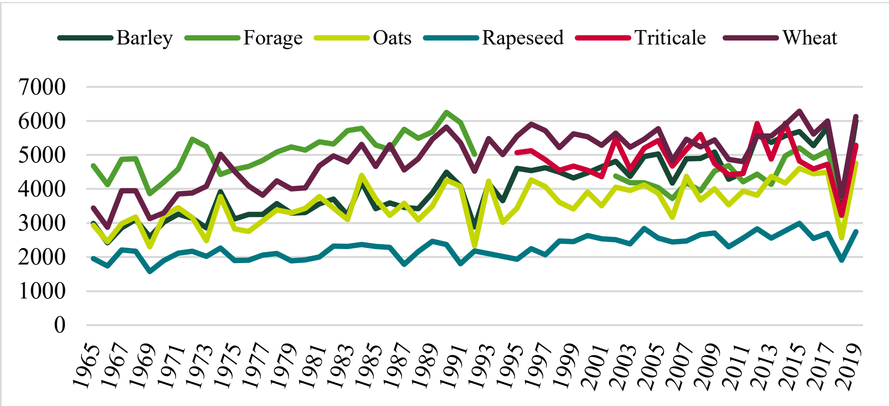

Figure 5. Yields for selected crops in Sweden (in kg per hectare). Source: SBA (2020)

Figure 6 illustrates area grown for specific crops for the production of certified seed. The arable acreage for the production of seed for cereals fluctuates with a negative trend. Arable areas for the production of oilseeds and pulses has been steady since 1997 while the area for forage corps almost doubled during the same period.

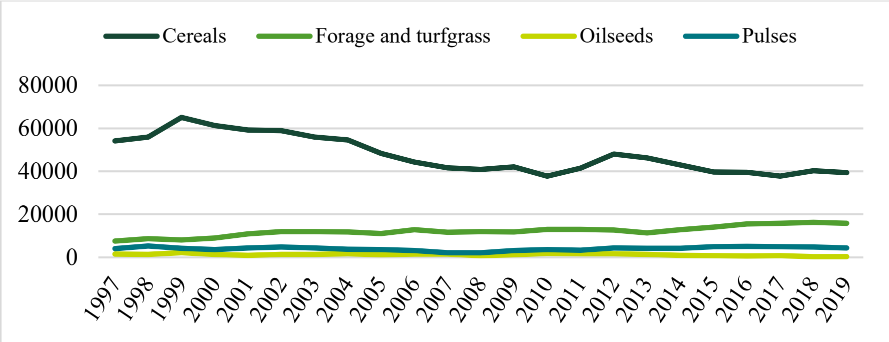

Figure 6. Field production area for seed for aggregated species in Sweden 1997-2019 (in ha). Source: ESCAA (2020)

1.3 Seed supply chain[1]

The term *seed supply chain* refers to all the actors involved and the processes required before a farmer can obtain the most valuable input from the formal seed markers. Even though in most countries, including Sweden, this chain is highly integrated, two industries can be distinguished, namely plant breeding and seed production. This distinction is based on the objective of each industry. Plant breeders aim to develop new varieties or to improve existing ones while seed producers aim to multiply and market the final product. Figure 7 describes the major stages involved in the production, processing and distribution of seed.

[1] The information provided in this section is based on a working paper (Morfi and Karantininis, 2018). The data used for the analysis are collected mostly via interviews, governmental reports as well as additional anecdotal sources.

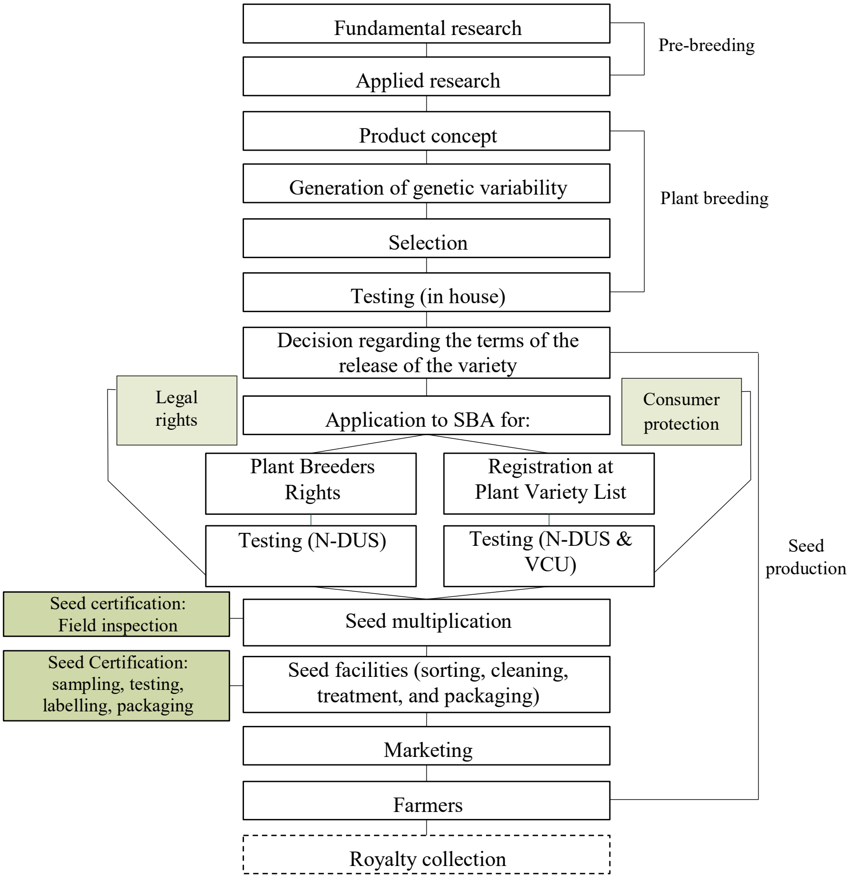

Figure 7: Steps and processes involved in plant breeding and seed production

1.3.1 Pre-breeding and plant breeding

The term plant breeding refers to the upper part of the chain (Figure 7) and it includes fundamental and applied research which are often referred to with the term pre-breeding. Pre-breeding can be described as *genetics and mathematical statistics combined with plant physiology, and (bio)chemical analysis, supplemented by a number of molecular biological concepts and techniques in plant breeding* (Louwaars et al., 2009, p.9). Thus, pre breeding -the link between genetic resources and breeding programs- is an essential part of plant breeding. Generally, the term refers to all processes and activities leading to germplasm domestication but it is not uncommon for pre-breeding programs to include research on the development of breeding methods for the shortening of the breeding process.

There are four primary stages in plant breeding: i) development of product concept and formation of the breeding objective; ii) creation and/or management of genetic variation; iii) selection; and iv) testing, risk assessment and finalization of the variety for the market.

The process starts when the breeder determines the breeding objective: a new improved variety, which will exhibit specific traits with one or even more purposes such as higher yield, improved quality, disease and insect resistance, changes in agronomic characteristics, etc. Once the breeding objective is determined, the breeder searches for parental plants with the desired traits. In doing this, the breeder selects promising genes, from the available genetic resources (gene bank accessions, segregating populations, forward/reverse genetic systems). There are several ways to create genetic variation. The most common approach is by making artificial and deliberate crosses selected for specific traits. Another method is the use of artificially induced mutations or changes in the DNA sequence of the plant (Ceccarelli et al., 2009). Introduction of germplasm, which is the genetically distinct variants of a species, is also a primary source of variation (Suslow et al., 2002).

The breeders' own stock, genetic stock developed by other firms, genebanks and *in situ* locations are some of the most common sources for breeders to obtain access to genetic stock and native or genetically modified traits, in order to generate genetic variability (Smith et al., 2016). This means that a breeder - or more accurately a breeding company- depends at least partially on development and genetic stock owned by competitive firms.

Through selection, the breeder aims to utilize and narrow down the large diversity of breeding materials to a number of lines which best exhibit the desired combination of traits. There are various techniques for selection depending on the mating system of the crop (self-pollinating, cross-pollinating, vegetative multiplication) and the selected traits. Conventional selection, marker assisted selection and genetic engineering are three broad ways for selecting plants with the best genetic make-up. In conventional selection, the breeder develops the new variety, commonly by using the germplasm directly or incorporating it into already existing varieties. The techniques that are used in Sweden to improve germplasm for the development of commercial varieties are conventional and marker assisted selection. So far, genetic engineering in breeding programs is used in academic institutions for research purposes.

1.3.2 Processes related to production of certified seed in Sweden

Once the breeding activities have been successfully completed, the variety release processes begins. The term "variety release" refers to all decisions, procedures and actions required from the moment a breeder develops a new variety until that time when the variety is available for commercialization. Sweden, as member state of the EU, must comply with the European regulations on seed and plant propagating material. The EU requirements can be classified in four categories:

i. Registration of the variety in a national or EU list
ii. Certification and inspections which aim to safeguard the quality of marketed seed
iii. Marketing regulations (seed classification, homogeneity of lots, packaging, sealing)
iv. Equivalence of seed harvested outside EU with seed harvested inside EU with respect to quality criteria.

The above standards are translated into several stages and activities along the chain of seed production. The Swedish Board of Agriculture (SBA), in accordance with the EU Directives, states that in order to be permitted to sell seed and other propagating material of regulated agricultural plant and vegetables species, the varieties must be approved/registered and follow specific requirements[2]

First, a decision must be made on the terms of the variety release; how to proceed in the multiplication stage and launch the new variety into the market(s). Not all varieties are released by the breeder or the variety owner. The breeder might decide to apply for PBR in specific territories and select another company as their successor for other states. Alternatively, the breeder can decide to apply for Community Plant Variety Rights which cover the wider EU territory. This is a common feature of the seed sector in many countries. The organization that owns the rights of a variety can reach an agreement with another party, in order to allow production and/or distribution of plant materials, especially in cases where the owner company

[2] EU Directives on marketing of fodder plants (66/401/EEC), beet seed (2002/54/EC), seed of oil and fibre plants (2002/55/EC) are incorporated in SBA statute SJVFS 2016:46. EU Directive (Directive 66/402/EC) on marketing of cereal seeds is implemented through statute SJVFS 2016:21.

cannot reach the market in a satisfactory way through existing market channel.

There are two types of licenses: distribution license that gives the licensee the right to market and sell the variety; and production license which in addition to distribution rights, includes the right to multiply and produce seed (Nilsson, 2007). Typically, when the involved parties agree upon the terms and conditions of the release of the variety, the multiplication procedures begin. However, there is always the possibility for the breeder, to proceed with both multiplication and marketing of the seed, when the breeder has expanded the scope of its business operation (vertical integration). In Sweden, the agricultural cooperative Lantmännen is an example of a fully integrated system. The parties involved must also reach an agreement regarding the exclusivity of the rights. A common practice is the licensee to be granted exclusive rights when the organization undertakes the cost of registrations (VCU and DUS testing).

Once the breeder decides how to reach a specific market, the new variety must be submitted for official testing in order to be granted Plant Variety Rights and to be registered in a National or Community List of Plant Varieties. The applicant should have a sufficient amount of genetically uniform and stable pure seed (nucleus seed) which will be later used for technical examination and further multiplication. An applicant can alternatively decide to submit a variety for testing at another EU authority, assuming that the submission fees and costs of testing are significantly lower than in Sweden.

For a variety to be eligible for the protection, it has to establish that is new and i) distinct from other existing varieties; ii) uniform in its characteristics within the population; and iii) stable, meaning that maintains the same characteristics after successive stages of multiplication. The above test (DUS), is run in accordance with the Community Plant Variety Office (CPVO) guidelines where it is determined what morphological characteristics should be tested and how. The technical examination is carried out by examination offices appointed by the CPVO Council, after considering the geographical origin of the variety, the country of the applicant, the practical experience of the examination office and the opinion of the breeder. The examination office in Sweden is responsible for DUS testing in sugar beets. If the results from the trials are satisfactory and the variety meets the requirements, the official committees register the variety in the national or EU variety list and exclusive marketing rights are granted for a period of 25 to 30 years. Plant Variety Protection rights cannot be renewed or prolonged.

Registration in the national or EU variety lists aims to safeguard the quality of the varieties released in the national or common EU market. For a variety to be admitted in these lists it has to be submitted for DUS testing and meet specific standards on its Value for Cultivations and Use (VCU test). The aim of the VCU test is to assist farmers in the selection of varieties; farmers should not be dependent on promotion activities of breeders but rather on an independent comparison of agronomic characteristics such as yield and quality among different varieties. This test ensures that a new variety is better in one or more of its characteristics than the varieties already existing in the Swedish or common EU catalogue. What VCU test typically examines is field attributes such as yield, resistance to common plant deceases and time of maturity. It also provides an assessment of the quality of the seed after harvesting. The duration of this test is 2 to 3 years and SLU is the responsible agency.

Registration at the national or common EU variety list does not grant Plant Variety Protection, hence doesn't secure the legal rights of the owner. Similarly, PVP is an intellectual property protection system. Like any other protection scheme, owning the rights of a plant variety does not imply that is legal to propagate and market the variety. Thus, registration of the variety on the PVP cannot substitute registration on the national/EU variety list and vice versa. For conservation varieties and amateur varieties different regulations are applied[3].

Multiplication is the intermediate stage where the new genetic material is transitioning from laboratories and research farms towards the final destination: agricultural use. The process of seed multiplication begins with the decision of an organization, to multiply the seed of a variety in order to launch it on the market or license it out to another organization. In some cases, the multiplication phase begins when the variety is still under official testing. The initial amount of pure seed is multiplied through various classes and stages and classified from higher to lower grade, based on classification scale provided by SBA.

[3] Statute of approving the conservation varieties of agricultural plant species and on the production and marketing of seed of such varieties (SJVFS 2016:18), Statute of conservation varieties and amateur varieties of vegetable species (SJVFS 2016:17).

The genetic and physical purity of breeders and pre-basic seed is 100%. The multiplication procedures of the first three classes are usually taking place in laboratories and research farms. In Sweden, Lantmännen is typically engaging seed growers in two cycles of multiplication stages, where the first cycle is characterized by higher seed purity and offers a higher profit margin for the farmer however, farmers cannot chose which cycle of the multiplication stage they will enter. Seed companies base their decision upon assessment of the capability of each grower to deliver clean and non-germinated seed. During this time, growers are inspected (field controls) to verify the compliance with certification guidelines.

Once the seed is collected from the farm, it is transported to facilities where it is subjected to moisture testing, drying, pre-cleaning, fine-cleaning, sorting, treatment, and packaging. Some growers have invested in seed facilities thus cleaning and drying can be performed at the farm level. During this time the sampling and labelling, the next steps of certification processes takes place.

Certification is one of the main EU marketing requirements: only seed that has been certified can be sold within EU. The aim of certification is to guarantee the identity, health and quality of seeds before entering the market. The certification process includes pre-harvest as well as post-harvest procedures such as field inspections, sampling, testing and analysis, labelling and packaging. The certification criteria at the crop level usually are based on the farms' cropping history, the minimum distances from neighboring pollen resources and the potential presence of harmful organisms. The criteria at the seed level include controls of the identity and purity of the variety, germination rate, content of seed of other plant species and presence of harmful organisms.

Field inspections and sampling are conducted either by SBA personnel or by an authorized person, provided that this person has education in agricultural science and has successfully completed a course offered by SBA. SBA proceeds with random control of at least 5% of the crops that have been inspected or sampled by authorized personnel. What is typically controlled during field inspections for most species is the cropping history of the seed field, the appropriate distance and isolation from other species and/or varieties when necessary, and the presence of weeds and wild oats. The objective of sampling is to obtain a sample of a size suitable for tests, in which the probability of a constituent being present is determined only by its level of occurrence in the seed lot.

The aim of testing and analysis is to determine the health of the sample and by inference the health of the seed lot. The analysis is operated by the seed unit of SBA or by Frökontrollen Mellansverige AB. Alternatively, a seed company can use an authorized by SBA laboratory to conduct the analysis. In this case, SBA randomly controls at least 5% of the examined seed sample. What is typically examined is the varietal purity and identity, the accepted level of which varies from one crop to another.

The last steps in the certification process are labelling and sealing processes. Once the seed has been controlled by the certification authority and the quality, health, identity and purity of the seed has been verified, the seed can be packaged and labelled in accordance with the national regulation and finally reach the market.

1.3.3 Plant breeders and producers of seed borne plants in Sweden

Lantmännen, MariboHilleshög Research AB, Secobra, Findus and Svalöf Consulting are the main breeders focusing crop varieties of seed-borne plants. Additionally, Sveaskog, Holmen, Stora Enso and Bergvik Skog focus on tree breeding and SLU at apples and berries.

Lantmännen is one of the largest groups within the food, energy, and agricultural industries in the Nordic region. It is a cooperative organization owned by approximately 20,000 Swedish farmers. Initially co-owner of the breeding organization Svalöf AB, which was later merged with Weibull AB and formulated SW Seed. This subsidiary was integrated in Lantmännen's agricultural operations in 2011. Currently Lantmännen owns breeding programs in winter wheat, oats, barley, triticale, summer rape and willow. The cooperative employs three breeding stations; two in Sweden (Svalöf, Lännas) and one in the Netherlands (Emmeloord). Svalöf station focus on breeding of spring barley, wheat, oats, spring rape, forage grass and salix. Lännas station focuses on spring barley and fodder legumes and the breeding station in Emmeloord on potatoes and triticale.

Secobra is a French breeding company, which acquired the spring barley program for the southern Sweden from SW Seed during autumn 2014. The company operates based on service contractd with personnel from Lantmännen. **Svalöf Consulting** runs a breeding program on turning rape (Brassica Rapa). **Maribo Hilleshög**, former Syngenta SE, has its origins in

Hilleshög AB. The company was established in 1907 focusing on breeding of sugar beets. Most varieties of certified sugar beet in Sweden are bred at the company´s breeding station in Landskrona. Findus, in collaboration with Bjuv municipality will continue to run the breeding program of peas after its acquisition by the British Nomad Foods.

Lantmännen and **Scandinavian Seed** are the main seed suppliers. Lantmännen was among the top twenty fodder producers in the EU with production that reached twelve million tonnes in 2013. Scandinavian Seed is an umbrella organization for Forsbecks AB, Skånefrö AB and Svenska Foder AB. Scandinavian Seed tests varieties developed in other EU countries and markets varieties that best fit the climate conditions in Sweden. Table 2 illustrates the volume of certified seed produced during 2015-2016 by respective seed company for selected crops. While Scandinavian Seed represents exclusively foreign varieties, Lantmännen markets varieties developed by SW Seed as well varieties licensed from other European breeders.

Table 2. Percentage of produced volume of certified cereal seed in Sweden for Autumn 2015 – Spring 2016 by seed company.

Organization	Seed class	Barley	Oats	Durum wheat	Triticale	Wheat	Rye
Lantmännen	Sum	69%	75%	100%	50%	62%	45%
Lantmännen	A	33%	56%		86%	65%	
Lantmännen	B	33%	38%		53%	21%	
Lantmännen	C	69%					45%
Lantmännen	C1	65%	74%	100%	64%	65%	
Lantmännen	C2	69%	76%	100%	48%	62%	
Lantmännen	F	40%	100%		68%	49%	
Scan. Seed	Sum	31%	25%		50%	38%	56%
Scan. Seed	A	67%	44%		11%	35%	
Scan. Seed	B	66%	62%				100%
Scan. Seed	C				47%	79%	55%
Scan. Seed	C1	28%	26%		36%	34%	
Scan. Seed	C2	31%	24%		52%	38%	100%
Scan. Seed	F	52%	0%		1%	43%	96%
Syngenta SE	Sum	0%					
Syngenta SE	A	0%					
Syngenta SE	B	2%					
Syngenta SE	C	31%					
Syngenta SE	C1	7%					
Total vol (ton)	Sum	49475	26759	335	4397	70914	1369
Total vol (ton)	A	63	20		73	56	
Total vol (ton)	B	442	161		55	689	22
Total vol (ton)	C	35					1331
Total vol (ton)	C1	2738	1665	78	172	3381	
Total vol (ton)	C2	46013	24841	257	4037	66640	10
Total vol (ton)	F	184	73		61	148	6

Note: Classes F, A and B correspond to nucleus, pre-basic and foundation seed, and C, C1, C2 and C2 to certified seed. Source: own calculation based on publications from the Swedish Board of Agriculture (2016) and information received by SVUF

In addition to these major seed producers, there are a few small local suppliers spread across the country[4]. Furthermore, there are approximately thirty seed processing companies approved by SBA, which are registered seed units and about one hundred smaller unregistered facilities. Although these facilities vary in size and operation, their main operation is to process seed (clean and sort) for neighboring growers.

1.3.4 Farm saved seed (FSS) channel

An alternative to buying certified seed for the farmer is to save and replant seeds. This is a substantial channel considering that for cereal crops farm saved seed (FSS) historically accounts for approximately 20 to 25% of total seed. Figure 8 displays the origin of seed used in agricultural production for the years 2016, 2017 and 2018 as it has been estimated by SVUF in terms of seeded areas (hectares of land). In Sweden, it is legal for a farmer to use FSS of varieties protected by Plant Breeders Rights, provided that the farmer declares the use and pays the corresponding fee (remuneration). There exist several laws and statutes[5] that regulate the collection of payments for the use of home-produced, non-certified seed of protected varieties. The Swedish Seed Trade Association (SVUF) is the responsible agency for the collection of the remunerations.

[4] The Dutch company Barenbrug and the Danish DLF represent in Sweden grass varieties. .Additionally Agrico Nordic AB, Bjälbo Trädgård AB, Munke & co, Stubbetorp potatis HB, are representatives of potato varieties.

[5] Council Regulation (EC) No 1782/2003, 2100/94, Commission Regulations (EC) No,1768/95, 2605/98, 795/2004 and 796/2004, The Swedish Plant Variety Rights Act (SFS 1997: 306).

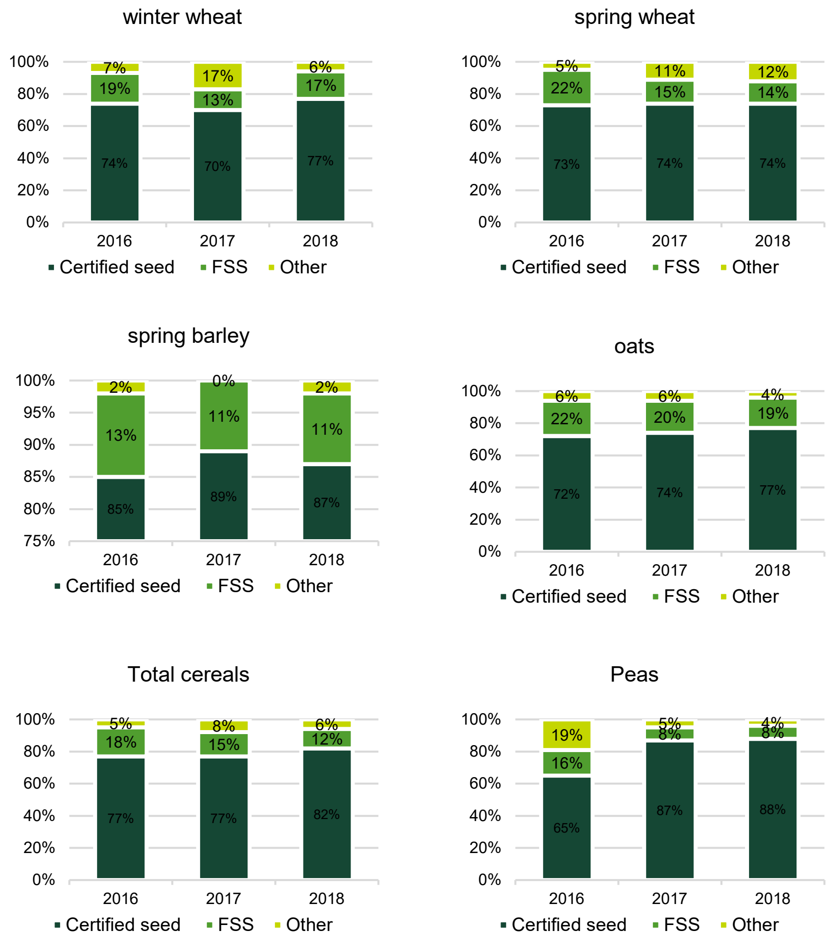

Figure 8. Share of seed used in agricultural production from different seed channels in Sweden for the years 2016, 2017 and 2018.

Note: "other" refers to the estimated usage of illegal use of FSS or unprotected varieties. Source: SVUF

During June 2015, SVUF and the Federation of Swedish Farmers (LRF) signed an agreement concerning the fees for the use of farm-produced non-certified seed of protected varieties. This collaboration has contributed to a unique institutional environment: breeders are effectively protected from potential free riding behavior of farmers. The agreement was published in the official gazette of CPVO and specifies fees (remunerations) for each variety as a percentage of the current licensing fee for certified seed of class

C2. The level of the fee is negotiated annually between SVUF, LRF, the Association of Swedish Cereal Growers (SpmO) and the Swedish Seed and Oil Plant Growers Association (SFO). Currently it is set to be 70% of the royalty level on certified seed. Additionally, farmers who fail to report their use of farm saved seed face a penalty fee based on their total farm acreage. According to the breakup analysis of seed price (Figure 9) provided by SVUF, a farmer that uses farm saved seed, can reduce the price of seed input at least by two thirds compared to the alternative of buying certified seed.

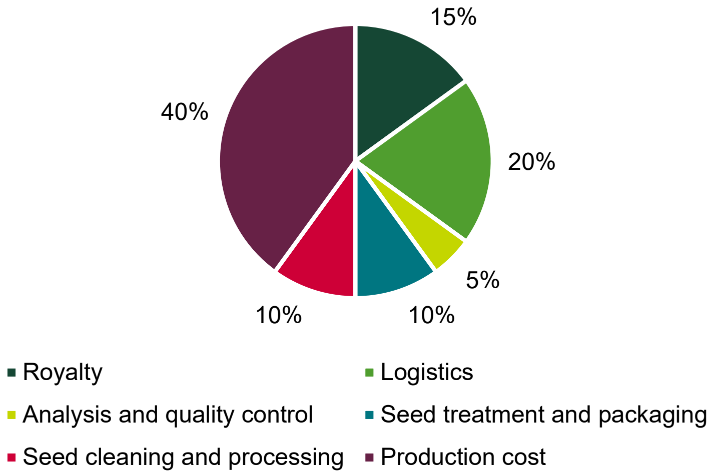

Figure 9. Breakup analysis of the price of certified seed. Source: SVUF

Small-scale farmers are exempted from paying remuneration fees[6]. These are farmers with capacity to produce at most 92 tons of cereals per year (and 185 tons of potatoes per year). In the Swedish legislation this translates to farmers with 23.7 ha acreage of arable land for cereals on the holding; or 4,2 ha for potatoes. Considering the farm structure in Sweden, approximately 55% of the holdings are exempt from the regulations on FSS which amounts to 12% of total utilized agricultural area.

To collect the fees, every year SVUF sends information and declaration forms to farmers. A small percentage of farmers typically ignores the reminders and thereby they may obtain a competitive advantage viz-á -viz

[6] European Commission Regulation EC 1768/95

those farmers who declare FSS and pay the fee. SVUF using information from the Single Farm Payment Register and in collaboration with processing facilities and seed producers is able to estimate the non-reported quantities of seed. Since the harvesting period of 2015, SVUF and LRF agreed to charge farmers that fail to report the use of FSS, with a fixed rate of 90 SEK per hectare.

This resulted in the collection of an additional 2 million SEK for the year 2015 with a total collection of 16.8 million SEK (declared use: 14.8 million SEK, undeclared use: 2 million SEK). The accounting of FSS royalties for the year 2016 shows a decrease in the total payments for the use of farm saved seed: 16.4 million SEK (declared use: 15 million SEK, undeclared use: 1.4 million SEK). As it is evident, the compulsory acreage fee on the non-declared use of farm saved seed has contributed significantly to breeders' income. Additionally the decline in payments from undeclared use of seed shows a switch in farmers' behavior; since the royalties from declared use of FSS increased only by 0.2 million SEK, it is rational to assume that some farmers switch to certified seed.

2. Literature review

2.1 Intellectual Property Rights in plant biotechnology

2.1.1 Patents and Plant Breeders Rights

Institutional arrangements such as the establishment of Intellectual Property Rights (IPRs) have had, and continue to have, a strong impact on plant breeding. IPRs are defined as *Rights granted by a state authority for certain products of intellectual effort and ingenuity* (Prifti, 2015, p.31). Plant varieties, gene traits, and breeding technologies can be protected by IPRs. The most commonly used IPRs in plant biotechnology are patents and Plant Variety Rights, also known as Plant Breeders Rights (PBR). In Europe, new varieties are predominantly protected by PBRs.

The United States was the first country to introduce patents on asexually produced plants (vegetative crop varieties) in 1930 through the Plant Patent Act as a means to bust the horticulture industry. The establishment of plant patents was the result of a long held view regarding utility patents and their statutory scope that believed to prohibit patenting on biological innovations. However, in 1980 in the famous Diamond v. Chakrabarty[7] case the US court ruling paved the way for the patentability of virtually any biologically based invention that is obtained through human intervention. A second ruling in 2011[8] confirmed the right to file utility patents for sexually and asexually reproducing plant seeds and plants traditionally bred or through genetic engineering (Clancy and Moschini, 2017).

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7 J.E.M Ag Supply, Inc. v. Pioneer Hi-Bred International, Inc.

8 U.S. Supreme Court, Diamond v. Chakrabarty, 447 U.S. 303 (1980)

Utility patents in USA are comparable to standard patents that are granted in Europe. The EU Biotechnology Directive[9] opened the way for the patentability of plant-related innovations, despite criticism from the EU parliament. One essential difference between USA and EU patent laws is that the later do not allow the patenting of varieties. Native traits are not eligible for patenting either, although in the case of transgeneric traits patentability can be considered (Smith et al., 2016).

Plant Breeders Rights is a *sui generis* form of intellectual property protection based on The International Convention for the Protection of New Varieties of Plants (UPOV Convention). The convention was initiated by European breeders and took place in Paris in 1957. This resulted in the establishment of the International Union for the Protection of New Varieties of Plants (UPOV) and the first Act of UPOV in 1961. The 1957 UPOV was later revised in 1972, and 1978 with the last adaptation taking place in 1991. The purpose of the 1991 Act was to protect new plant varieties by ensuring to the breeders' property rights using a set of uniform and clearly defined principles. Currently, there are 120 member- countries of UPOV. Sweden became member of UPOV in December 1971 and became party to the 1991 Act in 1998.

There are several significant differences between PBRs and patents with respect to the subject of protection, the eligibility criteria, the scope and duration of protection. A major difference regards exceptions: utility patents in essence do not permit any exceptions, while PBRs allow for two exceptions: *breeders exemption* and *farmers' privilege*.

Breeders exemption. According to this exception, a breeder that has been granted PBRs cannot act against another party that uses the protected variety for further research and development of a new variety. In the case of coexistence of two IPRs schemes, the EU Biotechnology Directive stipulates that when *a breeder cannot acquire or exploit a plant variety right without infringing a prior patent, he may apply for a compulsory licence for non-exclusive use of the invention protected by the patent* (Chapter 3, Article 12, Paragraph 1). This compulsory licensing is not included under current US patent laws.

Farmers privilege. The second optional provision, enables each member state to recognize a common practice of farmers saving own seed for the

[9] Directive 98/44/EC of the European Parliament and of the Council of 6 July 1998 on the legal protection of biotechnological inventions

purpose of re-sowing, and decide whether farmers should be allowed to use farm saved seed of protected varieties exclusively on their own holdings. Due to the inclusion of these two exemptions, PBRs offer weaker protection compared to patent rights.

2.1.2 Impact of Intellectual property rights on social welfare, growth and innovation

The optimal level of intellectual protection for plant varieties has been a prominent issue in international debate. Weaker IPRs might diminish the economic incentive to invest in new technologies, however stronger IPRs restrain access to germplasm, slow down innovation pace and decrease spillovers in research and development (S. H. Lence et al., 2016). The form and the extent of the optimal IPRs is still an open question as there are no clear patterns predicting the relationship between IRPs and innovation and growth in the context of plant biotechnology (Alston and Venner, 2002; Lence et al., 2005; Moschini and Yerokhin, 2007a; Ambec et al., 2008; Perrin and Fulginiti, 2009; Clancy and Moschini, 2013; S. H. Lence et al., 2016; Baudry and Hervouet, 2017; Gray et al., 2017).

Several empirical studies suggest that the relationship between IPRs and growth depends on the stage of the economic development of a country (Galushko, 2012; Campi and Nuvolari, 2015; Campi, 2016). A study on the impact of the strength of IPRs for plant varieties on GDP per capita shows a strong positive effect only for developed countries and a significant correlation between strengthening of IPPs and agricultural added value (Campi and Nuvolari, 2015). The UPOV had a significant effect on USA seed trade for developed countries (Galushko, 2012). The impact of IPRs on yield varies by a country's GDP: there is positive link between strengthening IPRs and yield productivity for low and high-income countries, but no significant effect is found for middle-income countries.

Most of the theoretical studies on the impact of IPRs schemes on welfare and the optimal level of adoption focus on the ability of other breeders to use protected material (ex. research and breeders exemptions). However, the results are highly heterogeneous and sensitive to model assumptions. Alston and Venner (2002) develop a Stackelberg competition model to examine the impact of PBRs on breeders' incentives to innovate. The authors argue that the research effort and the quality of the new variety increases along with the ability of the innovator to detect and collect royalties of the seed companies producing and selling the developed variety (appropriability).

Lence et al. (2005) develop a single country vertical market equilibrium model where the strength of intellectual property protection is measured by the degree of appropriability extracted by the innovator. The authors argue that there is a tradeoff between breeders and farmers surplus, however below a certain threshold of intellectual property protection both groups can benefit from increasing the level of appropriability. A policy maker can only justify high levels of appropriability only by attaching greater weight for the welfare of research and development firms as opposed to consumers and farmers.

Moschini and Yerokhin (2007) develop a game theoretic model to study the effect of research exemption on breeders' economic incentive to innovate which captures the tradeoff between static and dynamic efficiency existing in different IPR regimes. Stronger IPRs provide stronger ex ante incentives for firms to invest in R&D however weaker IPRs "*ensure a larger pool of* innovators *for follow up inventions*"(pg.16). The authors argue that breeders will always prefer stronger IPRs protection such as patents as they suffice that in any given level of cost in R&D there is a range of the returns which ensure the viability of firms in order to participate in the first period of R&D contest. In addition, the rate of return under patents is higher compared to the rate of return under PBRs.

Moschini and Yerokhin (2008) further their analysis in order to examine not only breeder incentives but also societal welfare. The model illustrates two competitive firms, a leader and a follower who compete in a dynamic context aiming to develop the next dominant product. The authors showcase again that the two competitive firms will always prefer full patent protection ex ante. From a social welfare perspective, either regime (PBRs vs patents) can be optimal given that the outcome depends on relative magnitudes of the costs of initial innovation and improvement. The authors argue that full patent regime is most likely to dominate when research costs are relatively high since research exemption often fails to provide adequate incentives for the firms to invest.

Lence et al. (2016) develop a non-stochastic infinite horizon dynamic model where each firm decides the optimal level of investment in order to compare societal welfare under PBRs and patents. The results depend on two key parameters: research complexity and the rate at which genetic improvement deprecates. When the depreciation rate is 100% (example short lived commercial varieties) PBRs is preferred to patents for all levels of research complexity. Both systems generate the same genetic improvement and amount of social welfare. They authors argue that there is a tradeoff between incentives to innovate and technological diffusion. While PBRs leads to faster diffusion, patents incentivize breeders to invest in complex long lasting research programs.

Some research attempts have been made to capture the impact of farmers´ privilege. Galushko (2008) argues that a breeder who selects a durable good strategy and charges a higher price, prefers the protection offered by PBRs compared to patents. Ambec et al. (2008) partially share Galushko's view. In their analysis, they incorporate the level of fee for the use of farm saved seed and argue that when the fee is low, the durable good payoff dominates the non-durable good. However as the fee increases the monopoly payoff from nondurable good strategy exceeds the durable good payoff.

Hervouet and Langinier (2018) build on Galushko's (2008) and include in their model taxes collected from farm saved seed. They argue that when replanting is highly efficient and the level of taxation relatively low, the breeder will opt for a durable good strategy. The level of investment that maximizes society's welfare can be achieved under PBRs when both regimes coexist. Specifically, breeders may prefer to allow farmers replanting their varieties if they have the ability to charge a higher price in the first period; a common strategy for durable goods. Ultimately, a patent system helps to prevent under investment even though it does not rule out replanting all together; when only PBRs are available *the optimal investment levels are lower than if both patent and PBR regimes are available, therefore PBRs and patents regime intensify research investment* (Hervouet and Langinier, 2018, p.23). However, the authors exclude from their analysis "breeders' exception" which allows other breeders to reproduce a fairly similar variety.

Arzandeh(2017) examine three distinct cases of IPRs settings, allowing for farmers' exception, breeders' exemption and full IPRs protections with both exemptions. In a Cournot duopoly they develop scenarios where breeders are equally efficient in conducting R&D or asymmetric. They argue that in case of symmetry, research exemption generates the highest surplus for the breeder while farmer's exemption is the least favorable.

In conclusion, there is a diverse set of intellectual protection schemes in plant biotechnology with the major ones being utility patents and PBRs. Internationally, the scope and the strength of both regimes has been increasing while research shows a heterogeneous impact of strong IPRs on social welfare and innovation.

2.2 Farmers´ seed choices

As illustrated in the previous section, there are numerous studies on the impact of intellectual property protection regimes on measures of social welfare such as farmers and breeders surplus, growth and innovation. IPRs are often identified as one of the major drivers behind consolidation in the plant breeding industry. The establishment of IPR schemes is the starting point and central to Paper I where it is argued that IPRs create power asymmetry in the seed value chain and have therefore been a driver of consolidation in plant breeding industry in Sweden.

Papers II and III examine the impact of IPRs on the lower part of the seed supply chain; specifically on farmers´ choice of seed. There is a vast literature focusing on seed choices typically in the context of technology adoption (Foster and Rosenzweig, 1995; Munshi, 2004; Conley and Udry, 2010; Maertens and Barrett, 2013; Maertens, 2017; Beaman et al., 2018). Farmers need to decide between opting for high yielding varieties, often genetically modified, and traditional varieties. In developing countries, the widespread adoption of seeds with significant varietal improvements is not always accomplished (Almekinders et al., 2019; Eriksson et al., 2018; Hoogendoorn et al., 2018). Issues related to the institutional, socio-economical environment as well as to local agronomic and climate conditions, have been identified as major factors driving the prevalence of certain seed types (Singh and Agrawal, 2019). Additionally, the literature on attitudes of farmers living in developed (Furtas, 2016) as well as developing economics (Maredia et al., 2019) towards the quality of certified and FSS is sparse.

Both papers II and III examine seed choice not in the context of the embedded technology of the varieties, but by focusing on the farmers' preferences of seed channel. To the best of my knowledge, no prior study has investigated empirically the impact of farmers' perceptions on the usefulness and fairness of the PBRs fees, on their seed choices and specifically with a focus on developed economies. A reason for this can be the widespread adoption of genetically modified and biotech crops cultivated in non EU developed countries. For instance, the United States is not only a top global producer of transgenic crops but also a top adopter of GM plant biotechnology (Pechlaner and Otero, 2008). This in practice means that the adoption of agricultural technologies protected by patents, combined with the strong IPRs enforcement mechanisms do not allow farmers to save and reuse their seed. However, as more and more patents on varieties that are still widely used expire, a better understanding of farmers' preferences regarding their choice of seed channel becomes of increasing relevance.

3. Conceptual framework

In his classic work *Taking Stock, Looking Ahead,* Williamson (2000) highlights the importance of institutions in the function of the markets. Williamsons develops a four-level social analysis of the economics of the institutions where both formal and informal institutions are taken into account (see Figure 10). The first level of analysis refers to unofficial, unwritten institutions such as social norms, customs and traditions. The second level focuses on *the rules of the game* which are formal institutions such as laws and formally written rules. The third level refers to the *play of the game* and how actors given the existing laws and contracts align governance structures with transactions. The last level is associated with the neoclassical paradigm as it deals with resource allocation. Each of the levels is not independent but rather constrained by the levels above it; resource allocation is constrained by laws and regulations, which have been shaped by the culture and norms. Additionally, each lower level can provide feedback to the level above and therefore affect it. The rests of the section provides a more detailed view of each level and positions the articles in this thesis in relation to them.

The first level of the analysis, embeddedness, contains informal constraints such as norms, customs and traditions that hold a strong impact over the long-term character of economies (North, 1990). The concept of embeddedness relates to the ongoing network relations that ultimately constrain behavior and institutions (Granovetter, 1985). Papers III and IV examine farmers´ decisions in relation to their respective social networks. For instance paper III attempts to untangle farmers' seed network relations and its underline assumption is that seed savings is a practice narrowly connected to community knowledge (Breen, 2015). *The seeds being sowed, the knowledge of how to grow and save them, the methods and tools used,* *and uses of seeds … are always changing and exist always in relation with others* (Phillips, 2016, p.3). Stated otherwise, considering that economic action is embedded in ongoing social ties, social networks should also be present in farmer´s seed choices. In fact, farmers networks have historically been an important channel for the transmission of information related to crop varieties, their agronomic requirements, yields etc. (Coomes et al., 2015).

The second level of analysis, the institutional environment, refers to formal rules such as constitutions, laws and property rights. According to Williamson, designing the instruments of the level (executive, legislative, judicial functions) although crucial it is hardly possible to be achieved without major irruptions, as it is an ongoing process. This level of analysis highlights the importance of property rights; once they have been defined with enforcement mechanisms in place, the government may step aside as markets take over. This is the focus of paper I, which examines the evolution of plant breeding in Sweden. This paper acts as a prequel to papers II and III as it acknowledges that that former decisions have an impact upon current settings (Schreyögg and Sydow, 2011). Paper I focuses on the changes in the domestic and global organizational, political and regularity environment, such as the establishment of IPRs, and their impact on Swedish breeding programs and organizations. Whether farmers opt for certified or farm saved seed and to what extent is not a decision that happens in a vacuum; contrary, it relates to stipulations of IPRs regimes in place and their ongoing revisions. In the latest revision of UPOV (Act of 1991), *farmers' privilege* became an optional provision for each country member to decide upon. Countries may opt to allow replanting as long as the farmers pay royalty fees to the breeders. Internationally, various stakeholders argue that this provision neglects the historical contribution of farmers in plant breeding and limits their rights. Examining the interplay between seed choices (certified vs fss) and IPRs in Sweden (Papers II and III) becomes an necessary case study, as the major commercial plant breeder is an agricultural cooperative with a vast membership; in a country with less than 21.000 full time farmers, Lantmännen is owned by 20.000 Swedish farmers.

The third level of social analysis, governance, goes beyond property rights and focusses on the governance of contractual relations. The unit of analysis is the transaction and the objective is to conduct a comparative examination of the relative transactions costs entailed in different governance structures and opt for the structure that minimizes the sum of production and transaction costs (Williamson, 1985). Until today four scholars have been awarded the Nobel Memorial Prize in Economic Sciences, for their contributions in institutional economics and its most prominent branch transaction cost economics: Ron Coase (1991), Douglas North (1993), Oliver Williamson and Elinor Ostrom (both in 2009). As the theory and applications to the theory of transaction costs count for more than eight decades (since Coase's seminal paper in 1937) of ongoing research, it seems improbable the idea of a novel contribution to the literature. To the best of my knowledge, the choice of seed framed as make or buy decision (paper III) has never been investigated before.

Level	Objective	Paper (s)
L1:Embeddedness; informal institutions, customs, traditions, norms	Informal constrains with pervasive influence often linked with complementary institutions	III & IV
L2: Institutional Environment; formal rules of the game- esp. property (polity, judiciary, bureaucracy)	Getting the institutional environment right. 1st order economizing	I
L3: Governance; play of the game- esp. contract (aligning governance structures with transactions)	Getting the governance structures right. 2nd order economizing	II
L4: Resource and allocation and employment (prices and quantities; incentives alignment)	Getting the marginal conditions right. 3rd order economizing	

Figure 10: Economics of institutions. Adopted from Williamson (2000)

4. Data

4.1 Paper I

Both primary and secondary sources of data were used for the analysis presented in paper I. First, I constructed a dataset using data available from the Plant Variety Database of UPOV (Pluto) and the National Listings Data and Common Catalogue Data (NLI) combined them with statistics regarding the production of certified seed published by the SBA. In cases of inconclusive information from the above databases, I consulted with SVUF.

To perform content analysis, I used both primary sources: interviews with stakeholders; as well as secondary material such as annual reports, presentations for shareholders, conferences presentations, seminars, public debates, newspaper articles. The interviews were conducted in several locations across Sweden; SLU campus Ultuna, SLU camplus Alnarp, Lantmännen and SVUF facilities in region Skåne. Most of the interviews were conducted in the autumn of 2016. The interviews started with professors in plant breeding within SLU who later introduced me to industry stakeholders.

4.2 Papers II and III

Papers II and III are based on primary data obtained through a questionnaire. The collection of primary data is a time consuming method with inherent risks; there is a long preparation stage before the actual data collection with no guarantee for the outcome. The design of the questionnaire started during December 2018 and the survey was finally distributed during

June - July 2019 to all farmers´ in Sweden that have registered an email address to the Swedish national database of owners of agricultural land. Prior to the data collection, in depth interviews with farmers were conducted and thereafter the survey was reviewed by representatives of LRF, SVUF and SpmO. The survey was also tested on students of the agronomy program at SLU in two face-to-face sessions. Lastly, the final online version was tested by a selected group of farmers. The latter group was not randomly selected, but rather based on their availability to provide feedback during a specific period.

One of the most unforeseeable troubles with the data collection regarded a very technical aspect of the distribution; how to send out 35.000 emails without compromising network security. To achieve this and in close collaboration with the IT department of SLU, a webpage nested at the official departmental webpage was developed. Farmers could find the link to the online survey as well as information about the research project and the group of researchers responsible for it. The distribution of the first email invitations to participate in the survey took place from 24th to 28th of June and reminders were send three weeks afterwards. This process lasted for approximately two months and it was the first time that SLU attempted to contact via email 35.0000 individuals external to the institution.

An alternative to this approach, was to outsource the data collection to the Swedish Board of Agriculture. However, a direct implication of this would had been a massive reduction of the sample size. After consultation with the SBA, we decided to proceed without the SBA´s involvement. It is broadly accepted that SLU has built a strong network and good reputation among Swedish farmers as many have studied themselves or their children at SLU. Additionally, there are no –at least perceived- misaligned incentives or conflicts between Swedish farmers and SLU, which is a situation that may occur between the farmers and SBA

In total, 2508 completed and 992 uncompleted participations were recorded, including missing values. This corresponds to at least 10% response rate. The exact response rate has not been possible to calculate due to the presence of incorrect email addresses in the registry. The average age of farmer in the sample is 55 years and 83% of the participants are male. Figure 10 shows the distribution of the farms in the sample based on their location (n=3002).

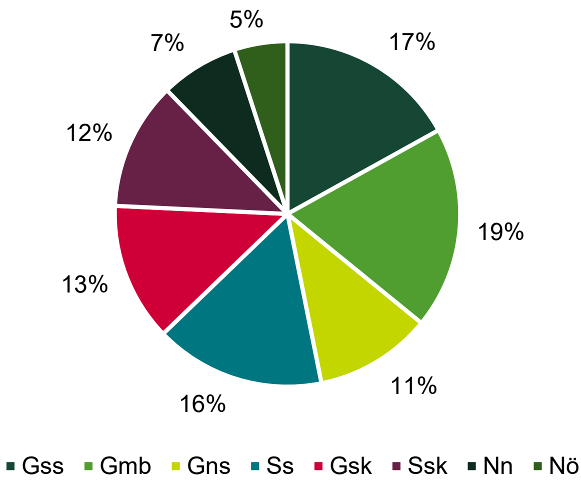

Figure 11. Farmers' participation in the survey by area division followed by national agricultural statistics (complementary map with explanations of the abbreviations exists on the Appendix).

The majority of the farmers (19%) are located in Götalands mellanbygder (Gmb). More than half of the sample size observations (63%) are located in the wider region of southern and central Sweden´s plains (Södra och mellersta Sveriges slättbygder). Figure 12 displays the number of holding in the sample by size of agricultural area. Comparing it with the national level information (Figure 2), it appears that there is an over representation of large-scale farmers in the sample. However, the national catalogue of agricultural holdings includes also owners of agricultural land that are not involved in agricultural production (non-farmers), while the survey was answered exclusively by farmers.

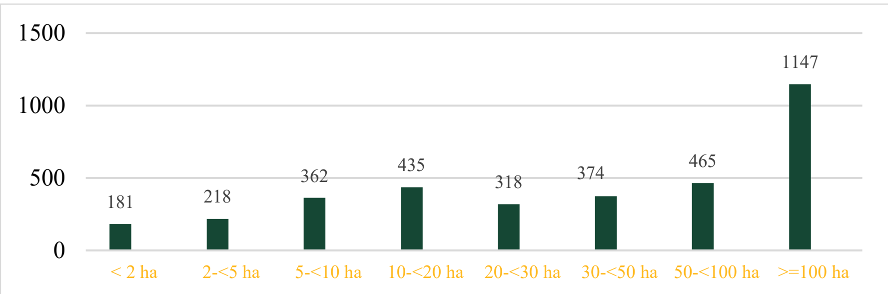

Figure 12. Number of holdings by farm size

Figure 13 displays the number of farmers using exclusively certified seed or certified seed together with farm saved seed. This figure has similarities to Figure 8, which is based on nationwide data, however there are three major differences. First, the percentage shares provided by SVUF are based on seeded areas (hectares of land seeded by certified or FSS) while figure 13 displays share of farmers using the alternative seed channels. Second, we distinguish between farmers using exclusively certified seed and farmers using both certified and farm saved seed. Third, SVUF distinguishes between legal and illegal use of FSS. Therefore, a direct comparison of the two figures is misleading.

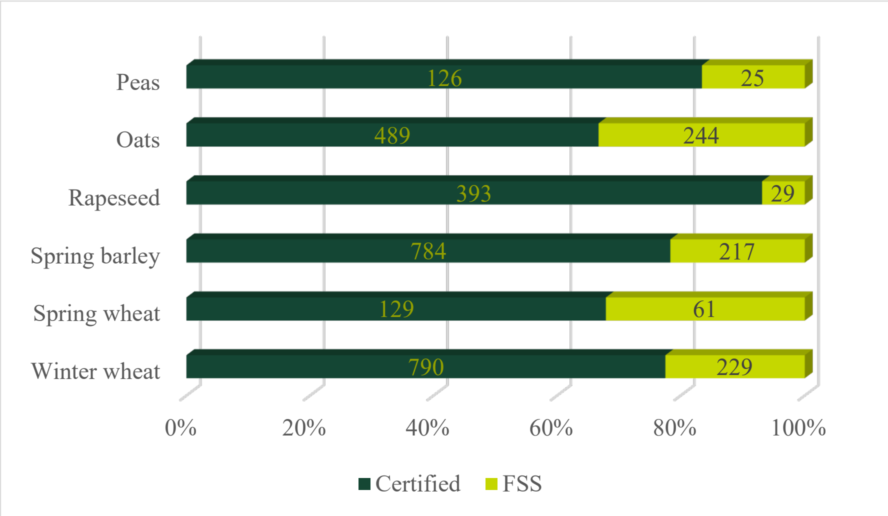

Figure 13. Number of farmers using certified or FSS by crop

4.3 Paper IV

The data required for the analysis of the last paper are also based on primary data collection and specifically based on repeated cross sectional survey. The first round took place during 1993 with two subsequent rounds with 10 year intervals. Unlike the rest of the papers, I was not involved in the data collection process.

5. Results and discussion

5.1 Paper I. The wizards of Svalöf

The aim of this study is a twofold; first to map the evolution of plant breeding in Sweden and explore changes in the domestic and global organizational, political and regulatory environment and second to calculate the ratio of domestically vs foreign bred varieties in Sweden. Overall, the main argument of the article is that IPRs are a major force that lead Sweden to lose its position in the global arena.

There are two points to further deliberate upon, which are not currently included in the discussion of the published article. First, an objection to the main argument that could be made is that with weaker IPRs schemes disincentivise licensing agreements, as firms might be reluctant to license and opt for M&A in the fear of IP theft. This would imply that stronger IPRs reduce the need for mergers and acquisitions (M&A) and therefore act against consolidation. While this is a hard to dispute claim generally, when examining plant breeding in Sweden as a case study, I did not find evidence supporting it. Contrary, in one of the interviews with a former director of SW seed, it was explicitly stated that it was the dependence on licensing agreements that drove SW to search for collaborations with the "big" seed multinational corporations. The partnership with BASF and the formation of BASF Plant Science was a response from the SW Seed management to the increased dependencies on licensing agreements. Even though theoretically, licensing could help a firm maintain its independence while still enables the firm to gain access over protected materials, in reality transaction costs such as legal uncertainties, limited patent experience and costs related to contracts and negotiation of license fees, could lead a firm to opt against licensing.

Whether the absence of strong IPRs, would generate greater waves of M&A is a hypothetical question, beyond the scope of this article.

A second issue to be discussed is the relevance of patent protection in the Swedish context. PBRs are mostly used to protect varieties bred with traditionally breeding techniques while patents are associated with GM technology and traditionally bred hybrid varieties. It is also true that in Sweden, GM crops are cultivated only for research purposes. Since in PBRs regime, the ‘breeders’ exemption’ ensures that protected varieties can be used to breed new varieties, it would be rational to argue that IP protection does not restrict the use of protected genetic material. However, SW Seeds was active in GM breeding with varieties that were bred in Sweden and produced and marketed in Canada. Additionally, it is not uncommon for a variety protected with PBRs to contain DNA-constructs protected by utility patents. This double protection of plant varieties creates an interface issue, as the exemptions provided by one regime do not limit the rights of the other. In other words, a breeder cannot exercise breeders´ exemption without the risk of a patent infringement.

5.2 Papers II and III. Certified *versus* farm saved seed

Papers II and III examine the factors that influence Swedish farmers´ choice of seed and any potential relation between royalty fees related to PBRs and farmers’ choices. Both articles are based on the same survey data but differ in terms of the econometric approach taken, the theoretical framework as well as variables included in the respective models.

The title of paper II “Save or Buy” is a wordplay on make-or-buy decisions. The later refers to a strand of literature in organizational studies the beginning of which can be traced to the classic paper by Coase (1937). The transaction cost approach was selected for the empirical investigation of the research question (certified vs FSS). An alternative approach could had been the resource based view (Barney, 1991). According to this theory, a firm would prefer to outsource the production of inputs non-critical to the firm’s competitive advantage. However, the resource-based view is less relevant in this specific context, considering that the majority of farmers in Sweden use certified seed and that that seed is a crucial factor for the success of farmers’ agricultural operations.

The theoretical framework of the papers was partially developed while building up the survey. The interviews with farmers during the preparation stage, revealed a tradeoff in farmers' choice of seed channel; they would either have to invest in their own facilities and skills (and therefore avoid dependence on upstream partners) or be confident in their personal relationship with their seed suppliers or processors. The farmers were in essence describing Williamson´s argument (Williamson, 1985); transaction characteristics such as asset specificity and uncertainty combined with actors own limitations (meaning bounded rational individuals subject to/with propensity to opportunism) determine which transactions will be executed internally and which will be procured in the market. Paper II attempts to disentangle the impact of these transaction specific characteristics while Paper III examines the impact of spatial relations with other farmers on their seed choices.

A major distinction between the two papers regards the construction of the dependent variable. In paper II three governance structures are examined based on transaction costs economics typology in the context of farmers´ selection of seed procurement strategies; vertical integration (self-clean FSS), market transaction (certified seed) and a hybrid form (custom clean FSS). Additionally, in order to control for the impact of different crops on the selection of different seed strategies farmers are repeatedly sampled for each level of the various crop varieties (panel structure). Paper III goes beyond transaction characteristics, and examines seed choices in the context of social learning and networks. We distinguish only between farmers that use exclusively certified seed for the total acreage and farmers who mix certified with FSS. In this paper, the impact of different choice of seed across crops is not examined. The underlying assumption here is that the knowledge related to seed savings is not dependent on the crop characteristics. That is to say if a farmers is knowledgeable in seed saving practices for wheat, it is assumed that this farmer will also be knowledgeable is seed saving practices for barley.

In paper II we find that farmers´ assessment of the quality seed in terms of genetic purity of each channel has no impact on their choice of seed while personal relations with their upstream partners, investments in the farm as well as delivery contracts affect farmers´ procurement strategy. Paper III further investigates the impact of personal relations on farmers' choices and finds evidence of neighbor effects. The findings of the two papers are complementary; the choice of governance depends on the costs of transaction and the choice is also embedded in structures of social relations (Granovetter, 1985).

Lastly, with respect to royalty fees for the protected varieties, we find the following. First, farmers who are subject to the property rights fee are less likely to outsource the processing of FSS. This is not surprising, assuming that there is a small minority of farmers who seeks to "free ride" and avoid the payment of the fee. The agency responsible for the collection of royalty fees in Sweden (SVUF), acquires information from seed processing facilities across country and controls the information provided by farmers. In this way, farmers who do not report their use of FSS (or report zero use), yet process seed are identified and charged. Second, we find that farmers´ perception regarding the fairness of the fees doesn´t affect their choice of seed channel.

5.3 Papers III and IV. Social networks and agricultural cooperatives

Papers III and IV examine the impact of social relationships in two distinctive areas; the choice of seed channel and farmers involvement in the governance of their agricultural cooperatives. In paper III, social relationships are disentangled using a combination of farmers´ spatial proximity with belongingness to the same cooperative organizations. Paper III provides evidence on non-spatial randomness on farmers´ procurement decisions and the results of article IV indicate strong relationship between social networks and farmers' propensity to participate in cooperative governance.

Both papers III and IV are based on primary data collected via surveys. In paper III, every farmer with a registered email address in the national registry had the opportunity to respond to the survey (as explained in Section 3.2.2) while a representative sample of farmers was selected for paper IV. Another approach commonly used in social network analysis is the "Snowball Method". To collect data, the researcher starts with a core group of individuals and their connections and later reach out to these new connections and collect information on their connections and so on. This method has the benefit of high degree of control over the collected data however is requires abundance of resources and it leads to biased results and therefore has not been selected.

The focus on research related to cooperative membership is motivated by the structure of the domestic agricultural sector. Historically, the contribution of agricultural cooperatives in Sweden's industrialization processes has been significant (Nilsson et al., 2012). Today, the country's biggest agricultural organization is cooperative (Lantmannen) with more than 20.000 farmers-members. This is a vast membership base considering that there are 21.000 full time farmers nationwide. Several studies suggest that social relationships are important in cooperative membership (Mensah et al., 2012; Feng et al., 2015) and cooperative membership is highly related to farmers' procurement decisions (Bernard et al., 2010; Abebaw and Haile, 2013).

6. Summary of appended papers

6.1 The Wizards of Svalöf; Intellectual property rights and consolidation in the plant breeding industry

This paper focuses on the evolution of plant breeding in Sweden. We identify the establishment and enforcement of IPRs along with changes in domestic agriculture and Sweden´s entrance in EU as major factors of the structural changes the industry has undergone during a period of 130 years. This study contributes to the strand of literature that investigates the impact of IRPs on consolidation by analyzing the Swedish plant breeding industry as a case study. Additionally we extend the work of Solberg and Breian (2015) by providing an index of foreign versus domestically bred varieties. To the best of our knowledge this study is the first to explore changes in global and domestic organizational, political and regulatory environments and their impact on the evolution of the Swedish plant breeding industry through the lens of the global value chains.

The global value chain typology (Gereffi et al., 2005; Gereffi and Lee, 2012) is used to illustrate the seed value chain in Sweden. In the upper segment of the chain, which is the focus of the paper, a few Swedish plant breeders are dependent on Life Science Multinational Corporations that determine the distribution of profits along the chain (Lee and Gereffi, 2015; Hendrickson et al., 2019). IPRs are a major source of the above power asymmetry and can increase consolidation in the industry in the two following ways; first by prohibiting new firms to enter the market (Kalaitzandonakes and Bjornson, 1997; Louwaars et al., 2009) and second by providing incentives for vertical integration, strategic alliances, contracting and various types of licensing agreements among existing firms (Lesser, 1999; Shi, 2009; Maisashvili et al., 2016).

In order to untangle the evolution of plant breeding in Sweden and identify the factors that contributed to a series M&A of Swedish organizations, content analysis has been performed (Cho and Lee, 2014). Interviews with stakeholders, scientific literature on the subject as well as material from annual reports, presentations for shareholders, conference presentations, seminars, public speeches and newspapers have been reviewed. This analysis resulted in a formation of a map that illustrates the establishment of early plant breeders in 1880s and the subsequent major M&A that took place in the Swedish seed industry.

We find that a major part the country´s history on plant breeding can be traced to the origins of the formerly known breeding organization SW Seed (now integrated into Lantmännen´s operations). The organization was the outcome of a merger between Svalöf AB; a 50% state supported cooperative and W.Weibul; a family owned company. At the time of the merger, the two former companies jointly owned 17 subsidiary companies 14 of which were located in Europe and North America. The international presence of Swedish plant breeders and their path breaking research earned them the title of "Wizards of Svalöf". During 1990s, increased dependencies on license agreements led the management of the organization to seek partnership with a major multinational corporation. The consequent formation of BASF plant science did not generate the anticipated results and combined with a switch in the attitudes relating to international ambitions in plant breeding in the management of cooperative, led to gradual disinvestments; today there are only three breeding stations owned by the cooperative. In recent years, acquisition of the breeding station in Germany by Syngenta and the collaboration with Secobra in 2014 were enacted as a means of enabling Lantmännen to access material and technologies protected by IPRs and owned by Syngenta and Secobra (Gertsson et al., 2014).

Changes in the domestic agricultural policy and Sweden's entrance into the EU have also shaped the evolution of the industry. At the beginning of the 1990s the stated reduced the land allocated for agricultural production and withdrew the financing from Svalöf AB (Kuylenstjerna 1997).

Lastly, we provide a proxy for the level of dependence on foreign-bred varieties by calculating the percentage of production of certified seed originating from Swedish bred varieties. To do this, we combined data on production of certified seed for the years 2014, 2015 and 2016 with data from the Community Plant Variety Office and PLUTO database regarding information on the origin of the breeding station of each cultivar. We find that wheat and oats are the two crops with a relatively high presence of Swedish-bred cultivars. There is still a limited amount of Swedish bred-varieties on the market for winter rye. For the remaining cereal crops, almost all winter barley, spelt, spring durum wheat, spring triticale and maze cultivars were not bred in Sweden.

6.2 Save or buy

The choice of seed is an essential decision for agricultural production. A farmer has to decide upon the varieties to sow and whether to buy certified varieties every year or use his own farm saved seed (FSS) in subsequent periods. If the farmers opts for the later, he also has to decide whether to process the seed in the farm, or outsource the processing to a third party. Thus, there are three alternative options; *buy* certified seed, outsource the processing of FSS (*pseudo make*) or process in own facilities (*make*).

In Sweden, FSS accounts for typically around 20% of the seed used in the production of grains. The implementation of PBRs regime in country allows farmers to use protected varieties as long as they report their use and pay royalty fees. The amount of the fee is negotiated annually among the Swedish Seed Trade Association (SVUF), the Swedish Board of Agriculture (SBA) and two farmers' interest organizations (LRF & SPMO). Farmers with operations less than 23.7 hectares are exempt from the fee. Additionally, farmers who misreport or fail to report the use of farm saved are subject to a penalty fee based on their total farm acreage. This is a unique arrangement that has mostly eliminated free riding among farmers who costume clean their FSS.

This paper aims to examine the factors that influence farmers' choice of seed, and specifically why some farmers buy exclusively certified seed while others use both certified and FSS. A special aim of the paper is to explore whether the enforcement of the of royalty fee affects farmers 'choices. The literature on farmers choice of seed, with respect to the embedded technology (advanced vs traditional varieties) is extensive however to the best of our knowledge no prior study examines farmers choice of seed channel.

We use of one of the most prominent theories examining make or buy decisions which was originally developed by Nobel Prize laureates Ronald Coase (1937) and Oliver Williamson (1975, 1985). The choice between buying certified seed (buy), produce and process in-house FSS (make) or produce and contract an external processor of FSS (pseudo-make) has been framed as a save or buy choice following transaction cost theory (TCT) logic Farmers are assumed to make –bounded- rational choices that economize the sum of transaction and production costs. According to TCT, transactions differ according to their attributes, namely asset specificity, uncertainty and frequency. We distinguish between physical asset specific and relational asset specific and identify sources of uncertainty (input and output uncertainty) in order to develop hypotheses that link transaction attributes to governance structures.

We test the hypotheses using data obtained from a nationwide survey conducted during summer 2019. We focus on six crops and with the use of random effects models we identify the factors that drive farmers seed strategies. Factors associated both with asset specificity and uncertainty were found significant. Access to farm equipment with lower level of asset specificity (dryers) increases the probability of using farm saved seed almost three time as much compared to assets with higher level of asset specificity (cleaner and treatment equipment). Additionally relational capital (trust) with the processors and seed suppliers was found to have a significant impact. Delivery contracts are often used between farmers and their buyers and it is a common way for farmers to tackle price and output uncertainty. As our theoretical framework predicts, delivery contracts increase the likelihood of a farmer to use certified seed, which is a common stipulation in such contracts. Contrary, we find that farmers' assessments regarding the varietal purity of seed, had no impact in their choices.

6.3 Spatial seeds

Swedish farmers can use farm saved seed as long as they report its use and pay the corresponding royalty fee in accordance with PBRs stipulations. Previous research has shown that trust developed between farmers and their upstream partners is a important factor for their choice of seed channel (Morfi et al., 2020). In this paper, we relax the conventional assumption of independent observations in order to investigate the presence of neighbor and peer effects in farmer´s choice of seed channel.

Seed savings is a practice as old as agriculture. It enables farmers to retain independency from seed suppliers and reduce the cost of agricultural inputs (Furtas, 2016; Mascarenhas and Busch, 2006). However malpractices in proper seed savings processes can result in seed with lower viability and varietal purity compared to certified seed and thus lead to a significant yield reduction (Khazaei et al., 2016; Peltonen-Sainio et al., 2011; Reddy et al., 2000). This is because the use of FSS requires both capital investments and knowledge. The farmer must be able to select seed based on the performance of parental lines and in conjunction with the local agronomic and climatic conditions. The farmer must also be knowledgeable regarding the proper storage conditions (Khazaei et al., 2016). This knowledge not only enables farmer to retain independence and a potential to reduce their costs, but can also act as parallel to the formal seed channel safeguarding access to seed in cases of unpredictable disruptions in the formal value chains.

There is a plethora of research examining farmers´ choice of seed, examined commonly as a choice between different agricultural technologies (ex. genetically modifies vs traditional varieties) (Asfaw et al., 2011; Asrat et al., 2010; Shiferaw et al., 2008). Several studies focus on network effects on farmers´ uptake of agricultural technology (Conley and Christopher, 2001; Conley and Udry, 2010; Maertens and Barrett, 2013) while some studies examine specifically the role of social learning (Foster and Rosenzweig, 1995; Munshi, 2004; Maertens, 2017; Beaman et al., 2018). This article examines the impact of social learning in farmers' choice of seed channel. In this way, the notion of knowledge in embedded in the practice of seed savings. In addition, the choice of seed channel is not subject to correlation effects arising from similarities in agronomics-climate conditions among neighboring farmers.

The second objective of the paper is to examine the impact of farmers' opinions regarding royalty fees on their choice of seed channel. To the best of our knowledge, no prior research exists on the topic. This is a significant aspect of the paper as it is often assumed that farmers are inherently against the collection of fees for the use of second generation seed. Lastly, we distinguish between neighbor and peer effects by constructing weight matrices not only based on location but with additional control of cooperative membership. We define peers as farmers who belong to the same municipality and are members of at least one of the same cooperative organizations.

The data used for the analysis are based on an online survey that was conducted during summer 2019 and was addressed to 34.000 farmers in Sweden. These are farmers with a registered postal and email address and the national catalogues of agricultural firms. We received at least 10% response rate included surveys with incomplete responses and missing values. To test for spatial randomness, as a first step, we employ Moran´s I statistics and Geary’s C statistics based on both join count statistics as well as Monte Carlo simulations of join count statistics (Moran, 1948; Geary, 1954). To do this, we construct weight matrices based on nearest neighbors within a fixed radius of 1, 5 and 10 km as well as based on farmers 3, 5 and 10 nearest neighbors.

As a next step, we analyze the choice of seed channel using spatial autoregressive (SAR) probit models and with the use of Bayesian Markov Chain Monte Carlo estimators (LeSage and Pace, 2009). Bayesian inference implies that by a sufficiently large sample from any distribution we can in essence calculate the whole distribution without having to rely on asymptotic approximations (Gilks et al., 1995). Additionally, SAR models allow us to capture direct and indirect effects with the latter being the effect of a change on farmer´s i explanatory variable on farmers j´s decision to opt for a certain type of seed channel (Behrens and Thisse, 2007).

Based on the statistics tests we fail to reject the null hypothesis of spatial independence for farmers within a 10 km distance threshold. Similarly, we fail to reject the null hypothesis for the 3, 5 and 10 nearest neighbors. Contrary, the existence spatial independence arising from peer effects depends on the selected test and approach. Similar results were obtained from the SAR probit models; neighbor effects are significant within an 1% statistical significance level and 10% for the peers. The neighbor effects are robust to the choice of model, after comparing within results obtained from Spatial Durbin Probit models however this was not the case for peer effects.

Lastly, we find that farmers who experiment and make their own trials of seed varieties are less likely to depend exclusively on certified seed. These farmers affect their neighbor’s choice of seed channel. With respect to IPRs opinions, we find that farmers opinions regarding the royalty collection has no impact on their choice of seed channel.

6.4 Social networks and member´s participation in cooperative governance

There are numerous ways for cooperative members to participate in the governance of the organization. General assemblies, district councils, boards of directors, supervisory councils, advisory councils, nomination committees are some of the governing bodies in which the members can actively participate provided that their fellow members entrust them with their vote and elected them (Bijman et al., 2013; Chaddad and Iliopoulos, 2013; Bijman et al., 2014). The objective of the paper is to investigate underlying differences with respect to their social networks between elected and non-elected representatives as well as their willingness to participate in the governance. The relationship between active participation in the governance and social networks is examined during a time span of 20 years. This enable us to examine the impact of social networks as the economic, political, and social conditions change.

Previous studies have shown that active participation in cooperative governance increases in organizations where the culture and values facilitate this process and the collective incentives outweigh the individualistic ones (Romero and Pérez, 2003; Birchall and Simmons, 2004). Member participation is higher among farmers who are emotionally bonded to their cooperative (Barraud-Didier et al., 2012) or older farmers who aim to pursue a political carrier (Cechin et al., 2013). According to a recent study among Swedish farmers, motivational factors such as sense of cooperative belongingness and appreciation by other farmers increase farmers' involvement (Morfi et al., 2018). Several other studies examine farmers behavior in relation to the their agricultural cooperative (Barraud-Didier et al., 2012; Arcas-Lario et al., 2014; Hakelius and Hansson, 2016) but no study has been conducted linking social networks to farmers willingness to be elected representatives. To do this we break down the impact of farmers 'social networks in personal, professional networks as well as the extend of influence of social networks on farmer´s involvement in the governance of the agricultural cooperative.

The data used in the analysis covers three distinct time periods; 1993, 2003 and 2013. Prior to 1995, when the country joined the EU, Swedish agriculture was shielded from foreign competition and was at large under strict political control. The political climate allowed agricultural cooperatives to develop regional monopolies which inevitable weaken domestic competition (Micheletti, 1987). After Sweden´s entrance in the EU, the country faced fierce competition from imported food. Domestic agricultural cooperatives were forced to lower their prices ending up with huge financial loses for their members. The upcoming years, cooperatives responded to these new challenges by waves of mergers. During 2003, Swedish cooperatives were in a state of flux. By 2013, the number of cooperatives has decreased substantially and the agricultural sector was transformed to a sector characterized by large-scale units and commercially oriented farmers (Nilsson and Lind, 2015).

To untangle the relationship between social networks characteristics and cooperative governance first we distinguish between actual involved in the governance and willingness to be involve (potential involvement). For the actual involvement the dependent variable is a dummy controlling for famer´s experience as elected representatives. We estimate three separate logit regressions for each time period. Similarly, three separate ordered logistic regression are estimated in order to examine the impact of social networks on farmers' willingness to participate in the governance. The unpooled models, were compared with pool models (introducing period related interaction terms) in order to test the consistency of the results. Lastly, we constructed a factor using factor analysis and performed ANOVA as an alternative approach that offers greater visualization of the main findings.

We find that the impact of personal network is more important than the impact of professional network on farmers' participation in the governance. In fact professional networks are only significant to the farmers´ aspiration and not for their actual participation in the governance. The relationship between network characteristic and farmers 'involvement in the government is persistent over a period of time when both farmers and cooperatives experienced profound changes.

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Popular science summary

Seed is the only physical matter subject to Intellectual Property Rights (IPRs) with the ability to duplicate itself. IPRs affect not only the evolution of the plant breeding industry but also farmers´ seed choices. Hypothetically, if a holder of a smartphone could plant the phone and harvest more smartphones in subsequent periods, there would be a series of questions to be asked. Who is the owner of the second period smartphones; the tech-phone company who invested in the embedded and protected technology or the user? Who decides who the owner is? Should the user pay for the use of the second period smartphones? Will the user repurchase new smartphones or will she continue using the second period phones? Will her peers and neighbors affect her choice? This thesis attempts to provide answers to some of these questions in the context of seed.

Results from the thesis show that IPRs create power asymmetry between Swedish plant breeders and life sciences multinational corporations. This was a major driving force that spiraled waves of mergers and acquisitions. The results also indicate that changes in the domestic agricultural policy and Sweden's entrance into the EU have also shaped the evolution of the industry; at the beginning of the 1990s the stated reduced the land allocated for agricultural production and withdrew the financing from major Swedish breeding organizations.

Another implication of IPRs regards farmers´ right to use farm saved seed. Farmers in Sweden are allowed to reuse seed they have formerly purchased as long as they pay royalty fees. Historically, farm saved seed (FSS) accounts for 20% of the seed used in the production of cereals. To understand the factors that influence farmer´s decision to opt for a specific seed channel (certified or FFS) a nationwide survey was conducted and distributed to every farmer is Sweden with a registered email address to the national registry of agricultural firms (Lantbruksregistret). The results show that farmers´ assessment of the quality seed in terms of the genetic purity of each channel has no impact on their choice while personal relations with their seed suppliers and seed processors, investments in the farm as well as delivery contracts affect their procurement strategies. Additionally, the results of spatial analysis indicate the absence of spatial randomness and presence of social learning. This means that farmers learn from each other and affect each other regarding the adoption of a certain seed channel.

Lastly, the thesis investigates the relation between farmers' social networks and active engagement in the governance of their cooperatives. The objective of this paper is to investigate underlying differences with respect to farmers' social networks among farmers that have been elected and those who haven't as well as their willingness to participate in the governance. The data used in the analysis covers three distinct time periods; 1993, 2003 and 2013. This made it possible to examine the impact of social networks as the economic, political, and social conditions changed. To do this, social networks are distinguished between personal and professional networks. The results suggest that over time, members have become more willing to be elected when they receive backing from their social networks, with personal networks being more important than professional networks. The professional networks are related only to farmers' willingness to participate and not to their actual participation in governance.

Acknowledgements

I´m fairly convinced a Ph.D. is one of the most peculiar trainings a person can undergo; it is a very long and lonely process yet at the same time*, it takes a village*. This is an incomplete list of my village; the people that helped me complete this journey.

First and foremost, I would like to express my deepest appreciation to my principal advisor Professor Konstantinos Karantininis for his guidance and support. Kostas your comments and feedback transformed the quality of the papers. You believed that I would make it, when I doubted myself. You gave me the freedom to develop my own research ideas. You have shaped the way I think not only as an economist but also as a person. I am very grateful for the journey we have been together, both figuratively and literally, as I am one of the PhD students who had the opportunity to travel the world with their advisors. Through all the ups and downs of the research process, I think of you not as my mentor, boss or supervisor, but as my second father.

Special thanks go also to my assistant supervisor Professor Emeritus Hans Andersson. Hans thank you for comments and advice. Thank you for always having the door to your office open for me. Thank you for taking me to dozens of farms and helping me understand agriculture and Swedish farms. You have shown to me by example how to be the relief pitcher. I would like to express also my heartfelt gratitude to my co-authors Pr. Karin Hakelius and Professor Emeritus Jerker Nilsson; it has been such a great experience working and learning from you! Jerker your contribution to my thesis does not fall short than this of a formal advisor. Thank you for reading all my working papers and providing me with valuable feedback. Knowing that I can always turn to you for advice has made this process a lot easier.

My gratitude is extended to the group leader, Professor Helena Hansson and all the current and past members of the Agricultural Economics group;

Agnes, Assem, Birhanu, Enok, Gaelle, Georgios, Lisa <3, Pia, Stefan, Ruben, Tsegaye and Pr. Yves. Thank you for all the comments and feedback through the years. Helena your joyful spirit and support have created a working environment from which I have greatly benefitted. Special thanks to Professor Emeritus Yves Surry for his valuable comments and guidance. Professor, I deeply appreciate the time you have spent on helping me improve my applied models. I would also like to thank all the other people at the department of economics and specially the administrative staff for responding with kindness to uncountable requests.

Further, I am indebted to my mentor Mrs. Per Henriksson. Per you have inspired me and helped me understand the Swedish seed industry. Your knowledge and support had an immense impact on this thesis. Thank you for always provided me with extensive feedback and for giving me opportunities to advance in this area. I would also like to thank Mr. Anders Nilsson for his valuable feedback and his kindness to share his extensive experience and knowledge of the Swedish plant breeding industry with me.

As a Ph.D. student, I had the opportunity to visit the department of Agricultural and Resource Economics at the University of Saskatchewan, Canada. This had been an extremely valuable experience as I was able to interact with really smart and kind researchers, received feedback for my research and enjoy the awesome social life that surrounds the department. I would like thank Professor Jill Hobbs for inviting me and allowing to participate in her courses, and my half time opponent Professor Richard Gray for his insightful comments and feedback that contributed significantly to the development of this thesis. I´m also grateful to Professor Murray Fulton; participating in the Co-operative Governance School at Centre for the Study of Co-operatives during my stay in Canada, has definitely broaden my knowledge on cooperative governance issues. A big thank you goes to Tanya; first for making sure my transition from one cold country to another would be as smooth as possible and second, for becoming a friend for a lifetime.

At this point, I would like to thank all my current and former Ph.D. colleagues at the department. Abenezer and Andreea you turned so many working late nights from -a tad- boring to delightful. Tobias, Wonde & Abe not only we share a ten-year count of memories for which I´m grateful, but you guys have been like a Google search engine to me. You helped me grow as a person and as a researcher. And just to make clear how significant your contributions have been; I ask perhaps everyday one of you for advice, most often Abenezer. Ida you have been a wonderful office mate. Uliana, Patrycja, wafted Jonathan, Tsegay, Stefan thank you for the deep talks and mostly the hilarious ones. Jacob and George without you maybe I would still be coding on R, thank you so much for your generous help. Shout-out to Agnes, Annie, Bahre, Gaelle, Georgios, Hina, Hanna, Josefina, Julian, Polina; thank you for all the fikas, the exchange of ideas and the supportive climate we enjoy every day. To Aimable, Ashkan, Franklin, George, Justiiiiiiiiiiice, Katarina, Sara, Shyam and Suvi; you all have set the bar so high when you graduated that has inspired to do more.

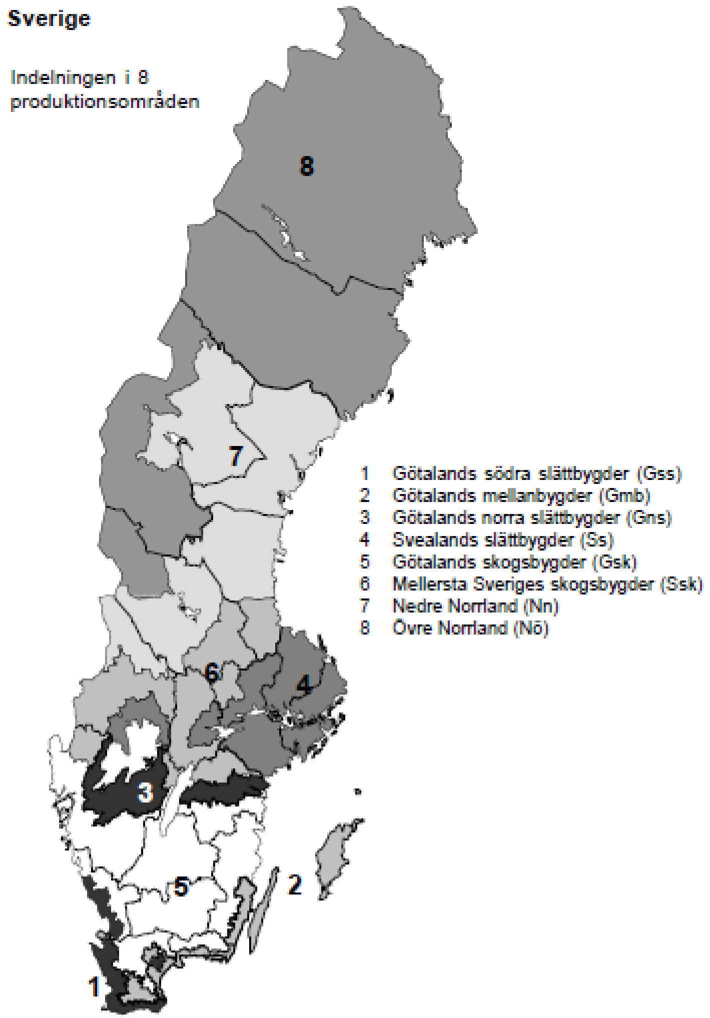
To my former roommates and forever friends Lisa, Kiki, Li and Titti; it is not an exaggeration to say I would be homeless without you. You supported me through very difficult times and I´m not sure, how I could ever repay you. To my Forever_23 crew Maria, Zoi, Vana, Julia that definitely holds the lion´s share of time spent hearing me complain; thank you.

I would not be here if it wasn´t for the support of my family. A special thanks to my parents, Theodoros and Ioanna, for creating a protective net around me and making sure I would get the very best education from a very young age. Knowing that you would be there to catch me if I fall, has enabled me to push forward. To my uncle and aunt, Nikos and Vaso, my brother and his wife, Manos and Anna, and my little nieces, Arguro and Ioanna a big thank you for always cheering me up!

Lastly, this thesis would not have been possible without the contributions of almost 3500 Swedish farmers that were kind enough to participate in my survey (albeit with missing values but that´s a different story). I would also like to express my deepest appreciation to the farmers that through the years welcomed me into their farms and helped me improve my understanding of the topics I was investigating.

Chrysa Morfi
Uppsala, September 2020

Appendix


Sverige
Indelningen i 8 produktionsområden
8
7
6
4
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1 Götalands södra slättbygder (Gss)
2 Götalands mellanbygder (Gmb)
3 Götalands norra slättbygder (Gns)
4 Svealands slättbygder (Ss)
5 Götalands skogsbygder (Gsk)
6 Mellersta Sveriges skogsbygder (Ssk)
7 Nedre Norrland (Nn)
8 Övre Norrland (Nö)

Acta Universitatis Agriculturae Sueciae

Doctoral Thesis No. 2020:48

This thesis explores issues related to the organization and governance of agri-food systems in Sweden, with emphasis on seed systems. Paper I investigates the evolution of plant breeding in Sweden. Papers II and II explore the drivers of farmers' choice of seed input (certified or farm saved seed) in the context of "make or buy" decisions and social learning and network spill-overs respectively. Paper IV studies the relation between farmers´ networks and cooperative governance over time.

Chrysa Morfi obtained her Ph.D education at the Department of Economics, the Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden. She holds an MSc degree in Environmental Economics and Management from SLU and a BSc in Economics from the University of Macedonia, Thessaloniki, Greece.

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Online publication of thesis summary: http://pub.epsilon.slu.se/

ISSN 1652-6880
ISBN (print version) 978-91-7760-614-7
ISBN (electronic version) 978-91-7760-615-4