Effects of Certainty
on Decision Making under Uncertainty:

Using Subsidies to Reduce Production of Environmentally Harmful Products

LARS E. OLSSON

Illustration on title page: Chris Madden (reproduced with permission)

To Mia and Tilda

*"There are risks and costs to a program of action.
But they are far less than the long-range risks
and costs of comfortable inaction".*
John F. Kennedy (1917-1963)

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Abstract

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The present thesis investigates the effects of an environmental policy, with the focus on producers' decision making, which may be used as a means to decrease the production of environmentally harmful products. A subsidy system reimbursing a reduction in sales and/or production is with this aim experimentally investigated by simulating a market. In **Study I**, a price competition between pairs of participants was designed to test effects of a high and a low level of a subsidy, as compared to no subsidy. It was shown that the subsidy led to higher prices and reduced sales, and also inhibited the start of price wars. The results were dependent on the level of the subsidy, suggesting that participants used the subsidy and the opponent's previous price as reference values to guide their behavior. Increased risk taking and/or risk aversion may also have influenced the participants' behavior. In **Study II**, an experiment was performed to determine whether the subsidy decreased competition. The results showed that participants in competitive conditions did not behave collusive or cooperatively and that the effects of the subsidy were the same, yielding increased prices and reduced sales. Since EU prohibits coalitions or cartels it is important that the subsidy system reduced prices and sales while preserving competitiveness. To test the hypothesis that a subsidy makes participants more risk taking, in **Study III** additional experiments were performed focusing on individual production decisions with certain (subsidy) or uncertain sales outcomes. The results showed that participants displayed inconsistent risk taking in that they preferred to diversify between a risky sales prospect and a guaranteed subsidy. Diversifying alternatives were thus rated as more preferable and more attractive, despite not maximizing expected values. The results are explained by that participants make trade-offs between certainty - a guaranteed outcome, and a potential - the highest possible outcome. Taken together, this thesis suggests that although there is a need for refinements and additional studies of the subsidy system, the results are promising in showing that introducing certainty in decision making under uncertainty may be used as part of a mechanism to influence producers to reduce production of environmentally harmful products.

Keywords**:** Certainty, Environmental Policy, Experiment, Individual Decision Making, Interdependent Decision Making, Risk Taking, Subsidy, Uncertainty

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Göteborg, February 2007
Lars E. Olsson

Preface

The thesis consists of this summary and the following three studies referred to in the text by their Roman numerals:

I. Olsson, L. E., Akiyama, M., Gärling, T., Gustafsson, M., & Loukopoulos, P. (2006). Examining the Use of Subsidies for the Abatement of Greenhouse Gas Emissions through Experimental Simulations. *European Environment, 16*, 184-197.

II. Olsson, L. E., & Gärling, T. (in press). Staying competitive while subsidized: A governmental policy to reduce production of environmentally harmful products. *Environment and Planning C: Government & Policy.*

III. Olsson, L. E. (2007). *Diversification leading to inconsistent risk taking: Effects of subsidies in environmental regulation.* Manuscript submitted for publication.

Introduction

Production and consumption are rapidly increasing all around the world. During the 20th century, the motorized movement of people and goods increased more than one hundredfold, while the total human population increased fourfold (OECD, 2000). This has among other things led to a growth of motorized vehicles from 75 million to 675 million over the past 50 years, with a current annual increase of 20 million automobiles (OECD, 1996). Another consequence of the increased production and consumption is increased use of energy. In fact, energy production and consumption levels are growing faster than ever and are currently the highest ever per capita (EIA, 2004). In the wake of these trends, increases in emissions follow at a rate that nature cannot absorb. In fact, in order for the present levels of emissions to be absorbed, the size of earth would need to be at least four times as large as it is. Therefore, the need to develop and implement new and effective environmental policies targeting a sustainable development is indispensable in a nearby future.

As a graduate student of both the interdisciplanary graduate school of Climate and Mobility at the Centre for Environment and Sustainability, and the Department of Psychology, I had the opportunity to develop research that could be argued to lay somewhere in between disciplines. The base is in the psychology of decision making, but, with the relation to the Climate and Mobility program, the practical problems of reducing emissions and overuse of scarse resources was taken as the starting point from which the research progressed. The research conducted in the present thesis experimentally investigates an environmental policy instrument. The policy entails subsidies to reimburse a reduction of sales to influence producers' decision making that they reduce production of environmentally harmful products. However, since the experiments are performed with no reference to any specific context, the results may also contribute to our understanding of basic human decision making. Despite that there are predictions from economic theory of how rational agents would and should behave, as well as a variety of possible psychological mechanisms that may influence behavior in competitive situations, there is a lack of empirical investigations of how people (decision makers) actually behave when certainty is offered, not instead of an uncertain payoffstructure, but as a part of it, such as a system of subsidies in the form of reimbursement for not used production quotas.

Decision making tasks are commonly used as tools to understand basic principles underlying human behavior (Payne, Bettman, & Johnson, 1992). The Nobel laureate Vernon Smith, a pioneer in experimental economics, has developed ways to subject models of economic problems to laboratory simulations informally known as "wind tunnels" (The Royal Swedish Academy

of Science, 2002). These wind tunnel experiments do not usually produce a final product; it is rather a first step to see if basic principles hold. The results may then lay the ground for further investigations, before the new principle is applied in a real market. The experiments in this thesis should be viewed in a similar way. It is a first step to investigate the behavior and reactions of decision makers confronting a subsidy system, both in an interdependent context and in an individual context.

This thesis summary starts with a brief exposition of the environmental consequences of current behavior. A second section describes agreements and policies developed to reverse these trends. A third section focuses on research on decision making, both from an individual perspective and an interdependent perspective. After this follows a section devoted to describing the subsidy system, also containing a description of the experimental paradigm as well as the expected effects. Finally, a summary of three experimental studies investigating the subsidy system are presented followed by a discussion of the results.

Environmental Consequences of Current Behavior

All around the world governments and other leaders are recognizing that if current behavior continues, the resulting environmental problems will lead to an unsustainable future. In the proceedings to the 2005 World Conference on Disaster Reduction, it was stated that since the Yokohama Strategy was adopted over a decade ago, there have been about 7,100 disasters resulting from natural hazards around the world. These have killed more than 300,000 people and caused huge monetary losses. Some estimates suggest that well over 200 million people have been affected each year by "natural" disasters since 1991. Two-thirds of the recorded disasters since 1994 were floods and storms. These included record rainfall episodes, extraordinary floods, and unprecedented storms distributed across each of the five continents (Proceedings to The World Conference on Disaster Reduction, 2005).

The Intergovernmental Panel for Climate Change compiled a report in 2001 where they stated that the worst-case scenario would include an average temperature rise by 5.8 degrees Celsius in 100 years as CO_2 emissions quadruple from levels measured in 1990 (IPCC, 2001). The changes in weather patterns, which most probably are caused by global warming, have resulted in social and economic risks to small island countries and low-lying coastal areas due to that the rise in temperature will lead to increased sea levels. Over the past 50 years the size of several glaciers have been substantially reduced, and ice that has been frozen for tenths of thousands of years are now melting. This change in climate can be expected to continue, and, if measures are not taken in a nearby future to reduce the part caused by human activity, it will have

devastating consequences. It might in fact be sufficient with a temperature rise of 1.0 degree Celsius to force about 400 million people away from their current homes.

Industrial emissions accounted for 43 % of carbon released in 1995, with a growth of 1.5 % annually between 1971 and 1995. Energy generation accounted for 37.5 % of the global carbon emissions, where fossil fuels continued to dominate the heat and electric power production. If no carbon emission policies are implemented in a nearby future, the anticipated emissions will almost be doubled in 20 years. The rise in temperature could still be lessened and slowed down if the cuts in emission levels were greater and carried out earlier than current measures accomplishes. Emission cuts should therefore be carried out as soon as possible and to a significant degree (IPCC, 2001). A report from the United Nations Framework Convention on Climate Change (UNFCCC, 2003) states however that it is likely that emissions will continue to increase. According to projections made by the governments themselves (governments acceded to the Kyoto Protocol, 1997), emissions are expected to increase by 11 % from 2000 to 2010 (UNFCCC, 2003).

Besides the industrial and energy sectors, motorized traffic is one important source of the increasing emissions. A lot of attention has been focused on reducing its impact with a variety of different policies. Despite these efforts, the transport sector increased its greenhouse gas emissions by 20 % between 1990 and 2000, and has the highest projected increase in the current decade. In 1999 about 22 % of the total CO_2 emissions and 20 % to 25 % of the total energy consumption in the world emanated from the transport sector (IPCC, 2001; United Nations Environment Program [UNEP], 2001). In other words, the transport sector is one of the most significant contributors to environmental unsustainability. At present about 50 % of the demand for oil is accounted for by the transport sector (UNEP, 2001), and projections have been made stating that oil (as the main cause of CO_2 emissions in the transport sector) will continue to be the prime component in fuel-production for an additional 50 years (Azar, Lindgren, & Andersson, 2003) if not drastic measures are taken into force. The consequences from the increasing transports are however not only an environmental concern, although this might be the most important aspect for the future, it is also a question of financial cost for the community. According to May, Jopson, and Matthews (2003), in European cities alone traffic congestion costs in excess of €100B each year, and at the same time the impact of local pollution on health imposes additional costs of similar magnitude. Despite the positive relationship over the past 50 years between increased

mobility and economic growth[1] (Koppen, 1995), many countries are now acknowledging the negative consequences of the increasing trends of traffic, both from an economic and an environmental perspective. It leads to global and local air pollution, congestion, noise, and health problems, but is also expected to lead to excessive land use and unsustainable transport systems (Greene & Wegener, 1997). Since many metropolitan areas already are experiencing these problems, different regulations and policies are being considered (Littman, 2003). Whether or not these measures are sufficient is questioned (Babiker, Metcalf, & Reilly, 2003; Carraro & Galeotti, 1997; Hensher, 1998; Sterner & van den Bergh, 1998).

Agreements and Policies

Human behavior clearly needs to change to at least halt the increasing trends of emission levels, and hopefully reduce them over time. To accomplish this, environmental policies entailing cooperation between states are needed (IPCC, 1995a, 1995b, 2001). In order to develop and sustain such international cooperation, parties must reach some form of agreements. Such international agreements are variously referred to as treaties, conventions, protocols, or acts. These agreements are analogous to contracts in domestic law: they stipulate what the parties must and must not do. However, one big difference is that international agreements cannot be enforced by a third party; they must be self-enforcing (Barrett, 1998). Therefore, governments in each country have a responsibility to comply with the agreements to cherish cooperation between the parties in order to not erode possibilities of future collaboration by acquiring a bad reputation as a non-cooperator (Goats, Barry, & Friedman, 2003). Reputation is however only one of many factors that may influence the process and the outcome in negotiations. Other factors that may influence both first-time encounters as well as repeated encounters are, for instance, how the negotiation is framed and perceived by the negotiators, cultural differences, financial status, social comparisons, fairness considerations, and domestic law (Bazerman, Curhan, Moore, & Valley, 2000; Raiffa, 1982; Thompson, 1990). All these factors may influence the outcome at different stages of the negotiation process (Barrett, 1998). If we add uncertainty of other parties' behavior during the negotiation, uncertainty whether other parties will comply with the final agreement and sustain cooperation, and uncertainty regarding the consequences of the agreement, it seems to be an almost impossible task to reach agreements at all.

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[1] It is generally accepted that there is a positive relationship between transport and economic activity (Koppen, 1995). However, it is debated whether increasing mobility increases economic activity, or vice versa (Meersman & van de Voorde, 2002).

Reaching agreements is even further complicated because the process can involve well over 150 states. However, despite this complexity, negotiations have successfully led to environmental treaties. In 1992 the international community negotiated the United Nation Framework Convention on Climate Change in Rio, which five years later resulted in binding obligations in the Kyoto Protocol (Kyoto Protocol, 1997). This was the first step towards a worldwide agreement to reduce emissions. In line with the Kyoto Protocol, the European Union decided to reduce carbon emissions by 8 % between 2008 and 2012 (IPCC, 2001). The progress in countries acceded to the protocol are monitored by the countries themselves by a yearly report to UNFCCC regarding what kind of policies they implement, their current levels of emissions, and their projected levels of emissions in the near future.

Policies have been implemented both within and between countries all over the world to meet the goals of the Protocol. Some of them target production, whereas others target consumption.

Targeting Production

One step toward sustainable production levels has been taken with the introduction of the European Union Emission Trading Scheme (EU ETS) at the beginning of 2005 (EU, 2005). The trading scheme's first phase runs from 2005 to 2007 and a second phase will run between 2007 and 2012 to coincide with the first Kyoto Commitment Period. Further five-year periods are expected to follow. The EU ETS is a cap-and-trade system where governments of EU member states are required to set an emission cap for all installations covered by the scheme. Each installation is allocated allowances for the particular commitment period in question. The number of allowances allocated to each installation for any given period (the number of tradable allowances each installation receives) is defined in documents called National Allocation Plans.[2] How these allowances are allocated differs between states, using either "benchmarking" or "grandfathering".[3] The allowances could either be allocated without charge or be auctioned by the governments (5 % of the total allowances for the first period 2005-2007, and 10 % for the second period 2007-2012 may be sold by the government using auctions). The companies involved in the scheme

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[2] These allowances are allocated to installations exceeding a pre-specified size.

[3] "Benchmarking" refers to setting a common standard that allows different cases to be compared. In the context of the EU ETS, it refers to the setting of a common emission factor (or related factor, such as an energy efficiency factor) to determine emission allocations. For example, one simple benchmarking formula would be to develop an emission factor (e.g., emissions per unit of output or input) for each sector and then use this set of emission factors along with information on the output/input of each facility to develop allowance allocations for all participating facilities. The benchmarking approach can be contrasted to the "grandfathering" approach that base allocations exclusively on historical emissions data.

can either use the emission allowances as "payment" for producing emissions, or sell them on a free market where other companies could buy them to increase their emissions (The Carbon Trust, 2004; van Ierland, 2004). If producers emit more than their share of allowances, large fees will be imposed as punishment. To meet the targets of the Kyoto Protocol with fewer emissions, EU will reduce the number of emission allowances in periods across time.

The EU ETS is a policy focusing on regulating production and could therefore also be categorized as a supply policy. Restriction on supply has also been used as a method to prevent the depletion of scarce resources. As an example, an individual transferable quota (ITQ) market was designed to regulate fishing to avoid devastating collapses of fish populations in New Zealand (Newell, Sanchirico, & Kerr, 2005). The system has so far been regarded as a success. In the ITQ market, fishermen are allocated quotas of different fish species and may trade these quotas between each other or use the quotas themselves.

Within the transport sector policies have been used in a slightly different way. Since the main cause of increasing emissions from the transport sector is the increased number of vehicles and trips, especially within urban areas, a wide variety of policies have been implemented focusing on how to cope with the transportation needs in combination with how to reduce emissions (Littman, 2003). May et al. (2003) reviewed the literature identifying some 80 types of *transport demand management* (TDM) measures. Although the name TDM states that it concerns transport demand, some of the measures focus directly on supply (production). These policies are prohibitive in its nature, forcing people to not travel by car. Examples of such policies are, for instance, road closure, prohibition of cars in city centers, and car-free zones (Loukopoulos, Jacobsson, Gärling, Schneider, & Fujii, 2004, 2005), prohibition combined with time restrictions (Cambridgeshire County Council, 2005), and reduced number of parking spaces indirectly forcing people to not use their cars (K.T. Analytics, 1995).

Policies targeting supply are effective at regulating the use of roads, the use of resources, and availability of products. The negative aspect is that people do not like them, especially if the policies take away something, thereby forcing them to change their current behavior (Jacobsson, Fujii, & Gärling, 2000). This form of policies might however be necessary to fulfil the environmental targets.

Simultaneously with the implementation of these forcing measures, other policies have been developed and implemented focusing on the demand for car use, to be used as a complement. The purpose has been on one hand to force people to change their behavior (supply measure) and at the same time to reduce the demand for the service or product voluntarily.

Targeting Consumption

Policies targeting consumption (demand) can be categorized in two different groups. One group focuses on information, the other on providing attractive alternatives. Information campaigns try to convince people to change behavior or give information of alternatives. The individualized marketing in Perth, Australia, is one example where individualized information was provided on alternative transportation mode to make people change their car use (Department of Transport Western Australia, 2000). Another means has been to use commercials in television and newspapers, or pamphlets trying to influence people, for instance, to use energy more efficiently or start recycling. Though the popularity among the citizens is high for these kinds of policies, the success of changing behavior has been limited (Craig & McCann, 1978; Dwyer, 1993). The second group of demand measures involves changing infrastructure (increasing public transport and walk and bicycle lanes) and introducing subsidies for public transport (Fujii & Kitamura, 2003).

There is a third group of policies, targeting consumption and production at the same time. This group of policies involves increased monetary costs such as congestion pricing (Banister, 2003; Goodwin, 1997; Johansson-Stenman, 1999), carbon taxes on energy and fuel (Sterner, 2002), and gasoline taxes or kilometre charges (Ubbels, Rietveld, & Peeters, 2002). The price increase is viewed by some people as prohibitive, directly influencing them when they cannot afford the price. Others, that can afford the price increase in the short-run, will be influence in the long-run (Sterner, 2002).

There appears to be a consensus that a portfolio of policies should be implemented, consisting of both more coercive measures forcing braking habits, and less coercive measures encouraging alternatives (Carraro & Galeotti, 1997; Comeau & Chapman, 2002; Gärling et al., 2002; Meyer, 1999). Although several of these supply and demand measures have been implemented in various parts of the world, there are still increasing trends in consumption and in the use of resources. Therefore, developing and empirically investigating new policies are called for.

Decision making

Each day we face numerous situations in which we make decisions, such as for instance, getting out of bed or not, taking the bus or the car, buying a lottery ticket, taking a life insurance, or how to manage our savings. These questions have been studied in a variety of disciplines such as philosophy, economics, and psychology. A huge number of research papers have been published over the years dealing with various aspects of decison making. In this section I have chosen to present parts that are most relevant for the studies in this thesis. In

psychology the field is generally known as behavioral decison making, and is studied in all branches of psychology (van der Pligt, 1996). Some decisions are individual in their caracter, which I refer to as *individual decision making*, whereas other decisions are made in social interactions and may have consequences for both the decision maker and others, which I refer to as *interdependent decision making*.

Individual Decision Making

Decision making, both by lay people and experts, has attracted extensive research attention, not the least because it has been found to diverge from normative principles of rationality (Shafir & LeBoeuf, 2002). The basic assumption of rationality is that individuals form correct beliefs about events in their environment and about other people's behavior. Given these beliefs, people choose the actions that best satisfy their preferences (von Neuman & Morgenstern, 1947; Savage, 1954). Von Neuman and Morgenstern's (1947) Expected utility theory posits that if a person's choice follows certain rules or axioms, it is possible to derive utilities for each specific alternative. The expected utility of a specific alternative is the sum of numbers associated with each possible consequence of that alternative, weighted by the probability that each consequence will occur. However, an abundance of research in both economics and psychology has shown that normative models of humans as rational decision makers do not always describe behavior accurately (Allais, 1953 [cited in Baron, 2000]; Camerer & Fehr, 2006; Dawes, 1998; Kahneman, 2003; Kahneman, Slovic, & Tversky, 1982; Payne, Bettman, & Johnson, 1993; Simon, 1955). It has therefore been suggested that utility maximization should be seen as a goal rather than as a description of actual behavior (Kahneman & Thaler, 2006).

The Allais Paradox can perhaps be used to exemplify deviations from rationality (Allais, 1953 [cited in Baron, 2000]). It was shown that people given pairs of binary choices in a lottery displayed inconsistent preferences. In the lottery, the first choice was between alternative A1 (100% chance of winning 1 000) and alternative A2 (10% of winning 5 000, 89% of winning 1 000, and 1% of getting nothing), and the second choice were between alternative B1 (11% chance of winning 1 000, 89% chance to win nothing) and alternative B2 (10% chance of winning 5 000 and 90% chance of getting nothing). If people are consistent and assign a very high utility on reducing uncertainty, they will choose alternative 1 in both choice tasks, since both alternatives reduce uncertainty with 1%. If maximizing expected value has the highest utility, the second alternative will be chosen in both tasks. However, it was found that people display inconsistent preferences, preferring alternative 1 in choice A, and alternative 2 in choice B.

Kahneman and Tversky (1979) formulated Prospect theory as a response to the failures of normative utility theories to explain actual behavior. Their theory attempts to describe and explain decisions under uncertainty, rather than to postulate how people should behave. Two phenomena were important in the formulation of Prospect theory. The first was the *certainty effect*, which refers to the tendency to give excessive weight to outcomes that are certain, as compared to outcomes that are merely probable. The certainty effect explains the inconsistent choice in for instance the *Allais paradox*, where reducing uncertainty with 1 % was more important when it led to certainty compared to when it reduced uncertainty from 11 % to 10 %. The second phenomenon was the *reflection effect*, which is the tendency to reverse the preference order between two alternatives depending on whether it is framed as a loss or as a gain (Tversky & Kahneman, 1981). For instance, in the choice between (A) a sure loss of 100, and (B) a 50 per cent chance to loose nothing and a 50 per cent chance to loose 200, people generally prefer the risky alternative (B). However, when the same gamble is offered as gains with alternative (A) giving a sure gain of 100, and (B) a 50 per cent chance to win nothing and a 50 per cent chance to win 200, people generally prefer the certain alternative (A). According to the expected utility theory, the two alternatives should be equally attractive. Hence, both the certainty effect and the reflection effect violate the theory. The value function of Prospect theory is defined in terms of gains and losses relative to a psychologically neutral reference point, and has a S-shaped form; concave for gains (above the reference point) and convex for losses (below the reference point). The convex part is steeper than the concave part, which means that a loss of 100 is more unpleasant than a gain of 100 is pleasant. The S-shape implies also that the subjective difference between gaining nothing and gaining 100 is greater than the difference between gaining 900 and gaining 1000. Kahneman and Tversky's paper from 1979 on Prospect theory is one of the most cited works in social sciences, and may be argued to be one of the most influencial. However, although the patterns of behavior described by the theory have been confirmed in several studies, Tversky and Kahneman themselves states that: "Prospect theory … should be viewed as an approximation, incomplete, and simplified description of the evaluation of risky prospects" (1981, p. 454). Thus, they give room for additional mechanisms influencing decisions making under uncertainty.

A somewhat different approach compared to Prospect theory (that roughly divides outcomes into those above and below a reference value, or status quo) was developed by Lopez (1987). In her SP/A theory, two emotions, fear and hope, operate on the willingness to take risks. The *S* stands for *security*, the *P* stands for *potential*, and the *A* stands for *aspiration*. Security relates to the attention people pay to the worst outcome, potential relates to the attention

people pay to the best outcome, and aspiration relates to the attention people pay to whether a certain desired level is achieved. Lopez illustrates the theory by an example of choices of crops by farmers. The substance farmers often choose between two types of crops, food crops and cash crops. The prices of food crops are stable but generally low, whereas prices of cash crops are uncertain and vary over time, but can offer a potentially higher outcome. The common strategy by these farmers is to choose crops by planting food crops until their lowest needs are met, and plant cash crops on the rest of their land to potentially increase profit. Fear of falling below subsistence motivates the level of food crops, whereas the aspiration of escaping poverty motivates the level of cash crops. Lopez argues that the emotions of fear and hope are in conflict within all individuals. This might explain why the very same people buy both insurance policies and lottery tickets; they want to be both assured to not go below a lowest level of need, while at the same time have the chance of a substantial increase of wealth.

In studies of risk taking behavior, gambles with binary choice tasks have commonly been used (as with the reflection effect or Allais paradox described above). However, in many situations in real life there are often not only two alternatives to choose between, there can be several possible alternatives, where each has several possible outcomes, with varying probabilities associated with each alternative. Thus, decision making is sometimes a more complex task. In normative (prescriptive) models it is assumed that all alternatives and all information are processed to assess utilities and weights so that the alternative with the highest expected utility may be chosen. This assumption requires extensive information-processing capabilities in human decision making. Simon (1955) argued that decision makers, rather than being perfectly rational, should be viewed as boundedly rational with restricted cognitive capacity, and do therefore not have the ability to process all possible information. Instead they behave so as to satisfice rather than to maximize possible outcomes. With this as a starting point, a research program of heuristics and biases evolved (Kahneman & Tversky, 1973; Tversky & Kahneman, 1974; Kahneman, Slovic, & Tversky, 1982). In this research it was found that people rely on a limited number of cognitive shortcuts or judgmental heuristics, referred to as "rules of thumb", due to among other things, lack of cognitive capacity, for convenience, or by habit. Heuristics are used to simplify the sometimes complex tasks of decision making in a world with uncertain outcomes, and are perhaps necessary to survive in this complex world. However, these heuristics may also create biased results leading to errors in the decision making process, and to violations of normative principles (Tversky & Kahneman, 1974). Thus, there are two sides in the program, a positive side focusing on sophisticated, fast, and reliable responses to complex tasks, and a negative side focusing on biases and

errors caused by these cognitive shortcuts. It has been argued that the heuristics and biases approach have had a big impact foremost due to the quality of the research, but also due to the adequate presentation at an appropriate time, and of its good articulation (Gilovich, Griffin, & Kahneman, 2002). There have however been differences of opinions about this research, both with regard to ecological validity, and whether or not the use of heuristics makes us (un)smart (Gigerenser, Todd, and The ABC Research Group, 1999). Arguments have in fact been raised that the heuristics and biases approach deals with artificial problems and that the results is a product of experimental manipulations (Gigerenser, 2004). Still, quite a number of heuristic choice rules have been documented over the years, such as, availability, representativeness, recognition, anchoring and adjustment, and diversification (see, e.g., Gigerenzer, Todd, & The ABC Research Group, 1999; Kahneman, Slovic & Tversky, 1982; Read & Lowenstein, 1995).

To give a better understanding of the way in which heuristics may cause errors, or biases, I will give some examples. *Anchoring and adjustment* is a heuristic influencing the way people assess probabilities intuitively. According to this heuristic, people start with an implicitly suggested reference point, an "anchor", and make adjustments from this anchor to reach their estimate. The anchor could be based on earlier experiences, or on information taken from the situation. People have been shown to anchor too heavily on this one piece of information by making final estimates too close to the original anchor. An example is given by Tversky and Kahneman (1974) who asked participants to first make a comparative assessment such as ''Are the pecentage of African nations in the UN more or less than the number that comes up on this wheel of fortune?'', and then to provide an absolute estimate of the number of nations. The results showed that when the wheel stopped at a low number, the estimates of the number of nations were lower compared to when the wheel stopped at a high number, despite that the number on the wheel of fortune obviously were irrelevant information to base their decison on. Another example is the *representativeness heuristic* which is the tendency to judge probabilities according to representativeness or similarity (Baron, 2000). A simple demonstration of how this may lead to a biased result was presented by Agnoli (1991) who asked children questions like "In summer at the beach are there more women or tanned women?" or "Does the mailman put more letters or more pieces of mail in your mailbox?". Using the representativeness heuristic, children responded by saying that there are more tanned women and letters, which is wrong since tanned women are included in the group of women on the beach and could therefore not be a larger group. Similarly, letters are included in pieces of mail, which makes it impossible for letters to outnumber the total pieces of mail. This bias is not excusively used by children,

it has also been found to be used by adults (Kahneman, Slovic & Tversky, 1982). A *diversification heuristic* may be used in choices between different prospects. To not putting all eggs in the same basket may sometimes prove to be a good thing, but may at other times be the opposite. For instance, Simonson (1990) conducted experiments where participants chose snacks. The results showed that when purchasing snacks on one occasion that should last for several days, participants diversified and chose different sorts of snacks, whereas when the purchase was made on separate days (one snack each day), they preferred to not diversify and chose their favourite snack each time. The same pattern was found in real-life choices by families purchasing yogurt (Simonson & Winer, 1992). Thus, consumers tend to choose more diversity than they will subsequently want, which has been referred to as the *diversification bias* (Read & Loewenstein, 1995). Diversification as a default choice has also been found in other areas, such as managerial decision making (Fox, Bardolet, & Lieb, 2005) and investments in premium pension schemes (Hedesström, Svedsäter, & Gärling, 2004, 2006, in press), where people tend to diversify between prospects in ways that do not maximize utility. To explain this behavior, it has been suggested that people are risk aversive and therefore prefer prospects that most likely will avoid the worst outcome (Kahn & Lehmann, 1991). This is the same principle entailed by Prospect theory, assuming that people are generally risk averse when outcomes are positive (Kahneman and Tversky, 1979), and corresponds to the aspect of security in the SP/A theory (Lopez, 1987).

Interdependent Decision Making

In order to study interdependent decision making in controlled environments, experimental games have been developed. Pruitt and Kimmel (1977) define an experimental game as "a laboratory task used to study how people behave in an interdependent situation, where (*a*) each individual must make one or more decisions that affect his own and the other's welfare; (*b*) the outcomes of these decisions are expressed in numerical form, and; (*c*) the numbers that express these outcomes are chosen beforehand by the experimenter" (pp. 363-364). In 1960, Schelling introduced the idea of *mixed-motives* (see Komorita & Parks, 1995). This refers to a situation where for two or more individuals there is a conflict between the motives to cooperate (and maximise joint outcome) or compete with each other (to maximize individual outcome). A large body of research has been devoted to understanding how people behave, and should behave, when faced with this kind of conflict (see reviews by Komorita & Parks, 1995; Pruitt & Kimmel, 1977).

For the purpose of testing whether or not people act rational, different experimental games have been designed that are analogues to real life "resource dilemmas" (see Komorita & Parks, 1994; Hargreaves-Heap &

Varoufakis, 1995). If people harvest too much from a common resource, it will lead to depletion of the resource, if people harvest too little, they may not take a large enough share to make a living. Thus, the resource dilemma arises from the conflict of using the resource efficiently in the long run (collective interest), and harvesting as much as possible in order to maximize short-term gains (individualistic interest). This kind of "common pool" resource dilemma (Gardner, Ostrom, & Walker, 1990) has been experimentally investigated in many studies. A similar conflict of interest arises in a price competition between firms or agents. In this situation consumer demand is equivalent to the resource in the common pool resource dilemma, where it is in the interest of the individual decision maker to take as large share of the market as possible. However, to do that, it may be required that prices are cut which may lead to low profits. If you do not cut price, but your opponent does, you may end up without any sales at all, which in the long run may take you out of business.

The Prisoner's dilemma game (PDG) is a simple version of a price competition involving only two agents. The structure of the payoffs in the PDG became the conceptual foundation from which the resource dilemma research expanded. The PDG is most easily explained by a parable: "You and Bob rob a bank. The next day the police round up the usual suspects, including you and Bob. Isolating you in separate rooms, they want to strike a deal. The police promise that you can go free plus get a monetary reward if you snitch (defect). However, you know they are trying to strike the same deal with Bob. If you keep your mouth shut (cooperate) and Bob snitches, then you will spend the next 20 years behind bars. Lurking in the background is the possibility that you both snitch. If this happens then you both go to jail, but with reduced sentences to 10 years since you both defected (made a deal with the police). On the other hand, if you both cooperate with each other and keep your mouths shut, you will both be convicted for some other minor crime and sentenced to 2 years."

In the PDG the outcome is unfavourable if both act individualistically. But if both cooperate, they are jointly better off than if one cooperates and another one defects. Similar dilemmas are common in business. For example, a price competition between two nearby gas stations has the same features as the PDG, but with an extended payoff matrix with multiple choices. The price levels they choose, and whether their opponent cooperates or defects, control the size of the individual gains. If one gas station acts individualistically by lowering its price, it will increase its business at the competitor's expense. But if both slash prices, both reduce profits.

Thousands of studies on iterated PDG's have been performed (Axelrod, 1984; Pruitt & Kimmel, 1977; Rappaport & Chammah, 1965). Going back in time, The Bible, Confucius, and many philosophers have all developed different sets of principles for how one should deal with resource dilemmas. However, leaving

the moral and ethical aspects unchallenged, it has been suggested that no strategy is evolutionary stable since the strategy adopted by the opponent will alter the optimal strategy (Boyd & Lorberbaum, 1987). In addition to individual differences in cooperation (Messick & McClintock, 1968), the following factors have been shown to affect coopeation: the number of encounters (Rappaport & Chammah, 1965), strategies (Axelrod, 1984), punishments and rewards (McCusker & Carnevale, 1985; Yamagishi, 1988), and communication (Dawes, McTavish, & Shaklee, 1977). The results are however not unequivocal, and different theories have been proposed to explain the results (Ostrom, 1998; Pruitt & Kimmel, 1977).

Methods have been found to solve or at least reduce the dilemma in price competitions. Messick (1999) describes one possible solution through an example of a price competition between the Coca-Cola and Pepsi companies. In 1997 the two companies had been in a price-war for a while, reaching price levels that cut deeply into their profit margins. The solution of their problem came when the Wall Street Journal[4] reported that the chief executive and the president of Coca-Cola had sent out a memo to their executives saying that in one month's time Coca-Cola would attempt to increase prices. The memo also stated that Coca-Cola had no motivation to reduce prices, except in response to a competitive initiative from Pepsi. This strategy is similar to the effective tit-for-tat[5] strategy investigated in experimental studies (Axelrod, 1984), in that Coca-Cola would not be the first to defect and reduce the price, but if Pepsi did, Coca-Cola would.

Another strategy that has shown to inhibit price-wars and lead to higher prices over time is the introduction of low-price guarantees and price-matching guarantees where competing firms promise the consumers to match their opponents' prices. If the competitors start to cut prices in this situation, it would lead to a sure loss for everyone; hence they don't cut prices and the price war resolves (Fatás & Mañez, 2001). This is somewhat surprising since consumers interpret price-matching guarantees as favourable (Jain & Srivastava, 2000).

These examples seem to be good solutions. However, it is argued that price-matching guarantees are collusive, resulting in reduced competition (Mao, 2005). Furthermore, Coca-Cola's attempt at stopping the price war involved communication with the opponent in order to make an agreement regarding price. Since price cooperation and coalitions are prohibited by law in many countries, it is important to consider whether there are other means to solve a "price competition dilemma" without forcing parties to create coalitions and start collusive and cooperative behavior.

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[4] Deogun, N. (1997). Wall Street Journal, Thursday, June 12, p. A3.
[5] In tit-for-tat the decision maker always repeats the opponent's decision in the next round.

One way to inhibit a possible price war without creating coalitions or signing binding agreements may be to introduce structural solutions that change the payoff structure. Research has shown that structural solutions in the form of both punishment and reward influence interdependent decision making (Komorita & Parks, 1994; McCusker & Carnevale, 1985; Yamagishi, 1988). In 1994, Basu discussed the paradoxes of rationality in game theory when creating the "Traveler's dilemma," a kind of PDG with an extended payoff matrix. In the Traveler's dilemma two persons have each to decide a value (between 2 and 100) for identical antiques that got smashed during their flight back from a remote island. The person demanding the lower price receives the demanded price and an additional two dollars from the person with higher demand. The person demanding the higher price receives the lowest demanded price minus two dollars. If both demand the same price, they both receive the price they demanded. The rational behavior would be for both players to demand 2. The rational behind this assumption is that if you demand 99 and your opponent 100, you will get 101 and your opponent 97. However, since you expect your opponent to adhere to the same plan, which means that both will demand 99 and end up with 99, you would do better by demanding 98 and thereby receive 100, and so it goes on. This *backward induction* will continue to the demand of 2 where it stops (which is the unique Nash equilibrium). Basu (1994) argues that people would not act rational when facing the Traveler's dilemma; they would rather choose a higher demand than 2 that leads to a higher payoff for both opponents. Becker, Carter, and Naeve (2005) confirmed this line of reasoning when they performed a one-shot experiment on the Traveler's dilemma in which experts in the form of members of the Game Theory Society were asked to submit both a strategy and their belief concerning the average strategy of their opponents. The results showed that very few entrants expected and played the unique Nash equilibrium, while they observed a fifth of the participants playing the cooperative solution of the game. Thus, experts of rationality and Game theory do not even themselves behave rationally according to normative theroy. Capra, Goeree, Gomez, and Holt (1999, 2002) conducted experiments with imperfect price competition,[6] testing the Traveler's dilemma with different levels of punishment for setting the higher price. The results showed that when participants knew they would receive a high percentage (low punishment) of the earnings of a lower bidder, they set higher prices compared to when they knew they would receive a low percentage (high punishment). When the possible loss resulting from not setting the lowest price

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[6] Imperfect price competition refers to a situation where the actor setting the lowest price does not capture the entire market.

was reduced, participants' increased their prices. A structural solution thus changed the decision makers' behavior.

The Subsidy System

The report from UNFCCC (2003) clearly shows that policies currently in use have not led to the reduction targets set up by the agreements. Therefore, the need to develop and implement a portfolio of additional policies focusing on reducing emissions and changing the behavior of producers and consumers are urgent (Carraro & Galeotti, 1997; Comeau & Chapman, 2002; EEA, 2004). This thesis investigates effects of introducing certainty on decision making in the form of a subsidy system. In the subsidy system the government decides a maximum quota of production, emission, or use of a scarce resource, and allocates this amount among the competitors on the market (equally or according to some given standard, e.g., grandfathering or benchmarketing).[7] It may for instance be the quota allowed for fishermen to fish cod, the total amount of carbon emissions allowed in the energy industry, or the amount of sales of gasoline. If a competitor does not use the entire allocated share of quotas, the government will reimburse these quotas with a subsidy for each unit of the quota not used.

The subsidy system shows similarities with the Emission Trading Scheme of the EU, but with the important difference that the number of allocated quotas/allowances not utilized are reimbursed (subsidized) by the government, and not sold to other actors on the market. The reason for this is threefold: (1) In a market with fixed maximum quotas of production or emission, a regulated subsidy system will provide the government with a mechanism to stimulate a reduction of total production of environmentally harmful products below the allowed levels. Systems implemented at present (i.e., individual transferable quota [ITQ] markets or emission trading schemes) do not provide actors with incentives to reduce the total use of allocated quotas. These systems do only redistribute the quotas or allowances between the actors within the system. (2) Instead of selling unused allowances or quotas to an open competitive market where prices will vary from time to time depending on supply and demand, a guaranteed price will reduce the uncertainty regarding the income for the producer. (3) Not all markets are big enough to make only allowances work efficiently. Therefore, smaller markets subsidized by the government might be complements to systems already implemented, such as the EU ETS.

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[7] A part of the total number of quotas may be kept by the government to be distributed at a later stage, making it possible for new agents (replacing "old" agents leaving the market) to enter the market.

The Subsidy Game

In order to empirically study the effects of subsidies, a Subsidy game was developed to experimentally examine the subsidy system. The Subsidy game is devised as an imperfect price competition where two firms sell a product that is assumed to be identical. The competition is imperfect in the sense that the low price firm does not sell everything. This could be the case when the product is identical in all aspects but differing, for example, in the location of the sale, and where consumers have diverse preferences regarding this location. Hence, although the product is physically identical at the two firms, one of them does not capture the entire market by slightly undercutting the other. An example of such a product is gasoline, where a slight increase or decrease in price would not make all buyers change supplier. In the subsidy game, participants (the decision makers) have knowledge of this imperfect distribution as well as the total payoff structure[8].

The Subsidy game is design in form of an iterated competition (repeated encounters). The participants' task is to play the role of a producer, setting prices and selling products on a market. Each participant is given a maximum number of units that they can produce to sell on a market. All participants have the same prerequisites in each encounter with an opponent. To make the demand function and the payoff structure in the experimental game easy to understand for the participants, it is assumed that the total demand is linearly related to the lowest decided price, that is, one unit increase in price will result in one unit reduction in demand. To exemplify: if the lowest of the set prices is 40, then 100 units will be sold in total. If the lowest of the set prices in the next encounter is 39, then 101 units will be sold in total, and so forth. The game uses an imperfect distribution of sold units between the participants, similar to the structure of the Traveler's dilemma (Basu, 1994). One important difference is though that the imperfect distribution is not fixed. Instead it is determined by the size of the difference between the participants' prices. The larger the price difference, the larger the difference in number of sold units will be. The participant setting the lowest price sells the largest proportion of the units on the market and receives the highest payoff. As an example: if one participant sets the price of 40 and the opponent sets the price of 75, then 90 units will be sold in total (determined by the lowest set price). The participant setting the price of 40 will sell 76 units and thereby earn 3040 (40 x 76), the opponent setting the price of 75 will sell 14 units and earn 1050 (75 x 14). In the next encounter, if the lowest set price is still 40 and the opponent this time sets the price of 45, they will still sell 90 units in total, but these will be divided

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[8] The derivations of the demand and payoff structures are given in Appendix A.

differently; the price of 40 will sell 60 units and earn 2400, and the price of 45 will sell 30 units and earn 1350 (see Appendix A for derivations of payoffs).

A subsidy is introduced that reimburses both participants with a specified price for each of the units they do not sell. This means that if a participant can produce (maximum allowed production) for instance 100 units but only sells 60 units, s/he will be subsidized for the 40 units s/he did not sell. A higher set price will, as described above, result in fewer sold units, and consequently more units will be reimbursed by a subsidy. Still, the participant with the lowest set price (above the price of the subsidy) will make a larger profit and sell more than the participant setting the highest price. This is an important feature of the game, since preserving competition is required in real markets.

After each decision participants receive complete feedback, where information is provided of the opponent's price decision, the number of units they and their opponent each sold, as well as the income for themselves and their opponent. This information is available throughout the experimental session, making it possible to see all preceding encounters. To further increase external validity, the point payoffs are exchanged to real cash money at the end of the game. By using different levels of the subsidy, sometimes known and sometimes uncertain, the effects of subsidies under different circumstances can be studied.

Behavioral Theory and Expected Effects

The subsidy is expected to lead to decisions to set higher prices, leading to reduced sales, at the same time as competition is preserved. This is furthermore assumed to reduce production of environmentally harmful products, or to reduce the use of scarce resources over time. Bazerman et al. (2000) pointed out the need to investigate the psychological mechanisms that guide behavior and compare the outcome with prescriptively rational decisions in order to understand how and why people decide as they do. An abundance of previous research (Dawes, 1998; Hastie & Dawes, 2001; Kahneman & Tversky, 2000) has shown that a variety of possible psychological mechanisms may influence behavior in competitive situations, causing both lay people and experts to frequently deviate from rational principles of decision making. Therefore, even if the devised subsidy system creates incentives that ought to make producers set higher prices and reduce production, this cannot simply be assumed to be the case. Thus, in order to find out how individuals actually make decisions when facing a subsidy system, empirical tests are needed.

In empirical studies on decision making, it has been found that anchors and reference values influence choices (Kahneman, Slovic, & Tversky, 1982; Raiffa, 1982; Tversky & Kahneman, 1974). In the subsidy game the decision maker may be influenced by reference values in a conceptually similar way as has been

found in dyadic price negotiations[9] (Bazerman et al., 2000; Kristensen & Gärling, 1997a, 1997b; Thompson, 1990). In price negotiations it is assumed that the opponents' reservation prices define the higher and lower bounds of a bargaining zone (Neale & Northcraft, 1991; Thompson, 1990). The subsidy may provide knowledge of the lowest price an actor would set. Since there are incentives to set a price below the opponent's price, information of the opponent's previously set price provides knowledge of a highest price an actor would set. Thus, the opponent's previous price and the subsidy level constitute the boundaries of a price setting zone, similar to the bargaining zone in price negotiations. These boundaries may be used by sellers trying to reduce or avoid uncertainty regarding their competitor's price decision and thereby the outcomes of their own decision.

Summary of Empirical Studies

The aim of three empirical studies was to investigate the effects of certainty on decision making under uncertainty. The point of departure was a practical environmental problem of production of environmentally harmful products. More specifically, the three studies examined effects of subsidies on price settings and production decisions, using the "Subsidy game". The studies tested (1) whether the subsidy system influences decision makers to set higher prices (compared to without a subsidy) leading to fewer sales and thus less production, (2) whether it affects competitiveness, and (3) in what way production decisions are influenced by the opportunity to diversify between getting profits from a subsidy and getting profits from producing to an uncertain market. In the first two studies the subsidy system was investigated in an interdependent decision making context, whereas an individual decision making context was used in the third study.

Study I

The aim of Study I was to examine and describe in what way a subsidy influence price decisions, and also how uncertainty of the level of the subsidy affect these decisions. Two experiments were performed. A version of the subsidy game, devised as an individual non-competitive price setting game, was conducted to assess participants' understanding of the instructions and payoffs. Two levels of the subsidy for unsold units were compared with a control condition without the subsidy. Thirty-six undergraduates were recruited, with equal numbers of participants randomly assigned to a condition

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[9] Some argue that the comparison between matrix games and negotiator behavior should be made with caution (Walters, Stuhlmacher, & Meyer, 1998) since in many negotiation studies the negotiators are given information only about their own payoffs (Thompson, 1990).

without a subsidy, to a condition with a low subsidy, and to a condition with a high subsidy. The results showed that participants set optimal prices, that is, prices that maximized their outcome, after minimal experience with the game. Although a difference was observed in the beginning between the subsidy conditions and the condition without a subsidy, this difference was reduced. This indicates that the instructions and payoffs were properly understood.

In the main experiment another 120 undergraduates volunteered to participate. A competitive subsidy game was employed to asses the effects of the subsidy in a competitive setting. Equal numbers participants were randomly assigned to five conditions: no subsidy, low subsidy, high subsidy, low-uncertainty subsidy, and high-uncertainty subsidy. Within each condition they were randomly assigned to one of twelve dyads.

The results showed that subsidies led to higher prices and counteracted price decreases, thereby inhibiting increases in sales, despite the competitive nature of the game. This contrasted with the control condition without a subsidy where prices decreased and sales increased. Furthermore, a high subsidy had a stronger effect than a low subsidy. At the same time, the average income or profit from sales (with income from the subsidy not included) did not decrease in any of the subsidy conditions, as was the case in the condition without a subsidy. It was furthermore found that uncertainty regarding the level of the subsidy did not change the results.

Analyses were also performed of the direction of change of the price decisions, that is, whether participants increased or decreased their price in response to the opponent's previous decision. The results demonstrated that when participants set a lower price than their competitor (and earned more), they tended to increase their price next time, and when they set a higher price than their competitor (and earned less) they decreased the price. Thus, since participants had an incentive to earn a profit from sales, they stayed competitive and did not exploit the subsidy.

Two possible explanations are offered for the results. The first is that the subsidy reduced the uncertainty associated with the competitor's prices because participants believed that their competitor is unwilling to set prices below the level of the subsidy. This parallels the effect of knowledge of an opponent's reservation price in dyadic price negotiations. When uncertainty of the level of the subsidy is introduced, it is suggested that previously encountered subsidy levels are used to form an expectation of the subsidy level in the next trial. Since the average of the uncertain subsidy levels did not differ from the high subsidy level, and the price decisions did not differ between the high subsidy condition and the two uncertainty conditions, it may be assumed that participants inferred a moving average subsidy level, thereby reducing the uncertainty

regarding the level of the subsidy. Thus they may have used this average as the lower bound of the reservation price.

A second explanation is that since the probability of selling did not differ between conditions, participants' higher set prices may have reflected increased risk taking. Since not choosing the lowest price still guaranteed some income, they could afford to take the risk of setting higher prices for the chance to increase their outcome.

Study II

Study II aimed at testing whether competitive behavior among participants was affected by the subsidy. This is an important aspect of any environmental regulation to be introduced on a market, since EU prohibits coalitions or cartels. To address this issue, in addition to competitive conditions where payoffs were paid individually (as in the main experiment in Study I), conditions were introduced where competition was removed by splitting the payoff equally among participants in dyads. It was also tested that the participants' understood the demand and payoff structure by displaying the payoffs matrix alongside the written instructions, followed by a quiz prior to the actual experiment. It was expected that removal of competition would provide incentives to start collusive and cooperative price decisions, thus leading to higher prices and a higher income than if competition was maintained in the subsidy condition. It was also hypothesized that if a subsidy does not influence competition, the previously observed higher prices in subsidy conditions than in a condition without a subsidy would remain.

The results demonstrated differences between the subsidy conditions with and without competition. When the payoffs in the latter conditions were split equally to motivate cooperation, participants coordinated their decisions and set higher prices leading to a higher total income compared to those in the competitive conditions. If the subsidy had resulted in cooperative or collusive behavior, participants in the competitive subsidy condition would have been able to coordinate their prices better to increase their total income by setting prices similar to those in the condition without competition with a subsidy. Participants' answers in the pre-test quiz showed that they understood the instructions payoffs correctly. Therefore, conclusions can be drawn that the results were not due to a lack of understanding of the payoffs.

In addition, analyses of how participants changed their prices in response to the outcome, increasing if their price was the lowest and decreasing if it was the highest, also indicated that in the competitive conditions they changed their prices in a competitive way trying to make a larger income than their competitor. This was not the case in the subsidy condition without competition.

Thus, it is concluded that the subsidy system does not eliminate competition and should therefore not violate the EU regulations.

It was found that the most effective way of increasing prices and reducing sales would be to allow cooperation. Since EU prohibit coalitions or cartels, this is however not a feasible approach. Still, the subsidy system also reduced prices and sales while preserving competitiveness, thus it may be regarded as a second best alternative.

The results, replicating the major findings of Study I, suggest that a subsidy system like that tested may be considered as one measure in a portfolio of environmental policies to achieve a sustainable future. Although no conclusive answer were found as to why participants set prices the way they did when facing the subsidy, the results show that the proposed subsidy system influences price settings in a desirable direction, potentially leading to reduced sales and thereby reduced production of environmentally harmful products. It is suggested that the subsidy system may complement or refine the EU ETS to reduce emissions from transports. The subsidy system may also be used in markets without connection to the EU ETS. One example would be to use the subsidy system as a method to prevent the depletion of finite resources, for instance, to curtail the overharvesting of endangered species such as the cod (Mason, 2002). The fishing industry could thus be compensated for the part of their quota they voluntarily not utilize, thereby motivating them to reduce their catch, preserving the cod stocks for future generations. At the same time the subsidy will provide incentives for the fishermen to stay in business during the time it takes for the resource to replenish, thus preserving their profession for future generations. It is also stressed that additional research is needed to test whether the results of the laboratory experiments apply in settings more closely mimicking actual markets.

Study III

Study III differed somewhat from Study I and II. Compared to the two previous studies, production decisions were in focus rather than selling prices (where production is influenced indirectly). In Study I it was suggested that a possible explanation of the results is that a subsidy made participants become more risk taking. A lowest profit that was certain made them afford to take the risk of setting higher prices for the chance of getting a higher outcome. Study III examined this explanation by designing new experiments where a subsidy reimbursed reduced production as in previous studies, but assessed in an individual context. Three experiments were conducted in Study III to investigate in what ways production decisions under uncertainty are influenced by certainty in the form of subsidies.

The tasks in the experiments were devised as gambles between prospects. This was accomplished by letting participants themselves decide how much they want to produce of a maximum allowed production volume, without confronting any opponents. Possible outcomes from their decisions were instead based on probability distributions determined by assumptions of how other producers behave. They were given the possibility to choose between a prospect with a certain outcome (subsidy) and a prospect with an uncertain outcome (producing to an uncertain market). In some conditions they had the opportunity to diversify between prospects, in other conditions they had not. The uncertain prospect had always the highest possible outcome, but the size of the certain prospect was varied across scenarios. Sometimes the subsidy had a higher value than the expected value (referred to as EV) of the uncertain prospect, sometimes the same value, and sometimes a lower value. The choice to diversify was thus sometimes in conflict with the goal of maximizing EV. In previous research it has been suggested that people are generally risk aversive in situations with positive outcomes (Kahneman & Tvesry, 1979) and that this is the reason why people diversify between prospects (Kahn & Lehmann, 1991; Read & Loewenstein, 1995). However, if participants diversify across the different scenarios in these experiments, it will lead to inconsistent risk taking, sometimes reduced risk taking and sometimes increased risk taking (compared to maximizing EV).

The results in the first experiment showed that when making binary choices (either produce their entire production capacity [uncertain prospect], or not produce at all and take the subsidy, [certain prospect]), about 90% of the decisions maximized EV. In a scenario where the level of the subsidy was the same as the EV of the uncertain prospect, about 55% of the choices were of the certain prospect. This is in line with previous findings that people are generally more often risk aversive when choosing between gains (Kahneman & Tversky, 1979). However, when participants in a second task were offered the possibility to diversify between producing and receiving a subsidy (that is, they could choose to produce any proportion of their production capacity and the rest would be subsidized), they chose to diversify between the two prospects. By doing this they did not maximize EV. Their choice to diversify when the subsidy was lower than the EV of producing resulted in reduced risk taking compared to the binary choice, whereas their choice to diversify when the subsidy was higher than the EV of producing resulted in increased risk taking compared to the binary choice. Thus, a consequence of participants' tendency to diversify across all scenarios was inconsistent risk taking; sometimes taking higher risks and sometimes lower risks. In the conditions where the uncertain and the certain prospect had the same EV, significantly more choices to produce

were found in the second task. It is therefore argued that preferences for diversification may lead to both increased and reduced risk taking.

A second experiment was performed to examine if participants in the first experiment chose to diversify due to *the certainty effect* (Tversky and Kahneman, 1981). Uncertainty regarding the size of the subsidy was therefore introduced in Experiment 2. It was hypothesized that if the results from Experiment 1 were due to a "certain-prospect effect", introducing uncertainty of the subsidy would make participants diversify less.

The results revealed that uncertainty of the level of the subsidy did not make participants diversify less. More than 75 % of the participants chose to diversify, and as a consequence choices in the low subsidy and high subsidy conditions did not maximize EV. Thus, the "certain-prospect effect" could not be confirmed. One explanation of diversification is the judgmental regression effect or contraction bias (Jou et al., 2004). That is, people tend to avoid extreme responses and therefore let their choices and judgments regress toward the mean. It has been suggested that the size of the judgmental regression effect increases with uncertainty (e.g., Gärling, Gamble, & Juliusson, in press). Considering the scenarios in the previous experiments, it would imply that people should have diversified and produced approximately half of their production capacity, and that uncertainty would have made participants do this to a higher extent. The results partially confirm this. In Experiment 1, participants chose to produce approximately half of their capacity, and uncertainty in Experiment 2 led to a higher frequency of diversifying choices. However, Experiment 2 also showed that uncertainty made participants produce approximately half of their production capacity only in the condition where the subsidy was lower than the EV of producing, whereas significantly less when the subsidy was higher.

In Experiment 3, the contraction bias as an explanation of diversification between the certain and the uncertain prospect was tested. A web-based experiment was designed to investigate participants' preferences for and attractiveness of different pre-specified prospects, some diversified and some non-diversified. One of the alternatives was a 50/50 diversification (i.e., producing half of their production capacity and get subsidized for the other half), among four other diversifying and non-diversifying alternatives. It was hypothesized that the judgmental regression effect would make participants prefer the 50/50 alternative to a greater extent than other alternatives, and also that they would rate attractiveness accordingly.

The results showed that that in all conditions a diversifying alternative was the most preferred. However, the most preferred alternative differed between conditions. The 75 % production and 25 % subsidy alternative was rated as the most preferred in the low subsidy condition, the alternative diversifying

equally between the certain and the risky prospect were preferred in the medium subsidy conditions, and the 25 % production and 75 % subsidy alternative were preferred in the high subsidy condition. If a judgmental regression effect had influenced the choices, participants would have preferred the alternative diversifying equally between the certain and the risky prospect across all conditions. Hence, a judgmental regression effect cannot account for the results. It was furthermore revealed, consistent with the results of Experiments 1 and 2, that participants rated diversifying alternatives as both more preferable and more attractive than non-diversifying alternatives, despite that a non-diversifying alternative maximized EV. Also, on average, alternatives with higher risks were rated as more attractive.

An explanation for the results may be that participants make trade-offs between certainty - a guaranteed outcome, and potential - the highest possible outcome. They first make sure that they are guaranteed something, which yield risk aversion, however, once this guarantee is provided they try to maximize EV, yielding risk taking. It is therefore suggested that risk aversion cannot be the only explanation for a bias toward diversification in the domain of positive outcomes.

Conclusions and Discussion

The environment on earth is degenerating due to human behavior, and is moving humankind toward an unsustainable future with increasing trends in consumption and production cause the highest emission levels ever. That it is of great importance to reduce emissions considerably in a near by future is not only recognized by political leaders, but also by industrial leaders. For instance, during the 2007 Detroit car exhibition, General Motors vice president emphasized the need to reduce the use of oil-based fuels while presenting their new generation of non-carbon driven vehicles. Although it is necessary with technological development, there is also a need to change human behavior, and to find ways to accomplish this. This thesis work took its departure in the practical problems of finding ways to reduce production of products harming the environment, and how to manage the overuse of scarce resources. It aimed at empirically investigating a policy providing producers with an incentive, in the form of a subsidy, to motivate them to reduce production or to reduce their use of scarce resources. By designing a subsidy game, wind-tunnel experiments could be performed to examine the basic functioning of the subsidy system. The experiments gave also an opportunity to study basic human functioning when certainty was offered in decision making under uncertainty, both in an individual decision making context as well as in an interdependent context. Previous studies on interdependent decision making have primarily focused on cooperative solutions to different resource dilemmas, using for instance

communication as one means. This is however not a possible solution in a market, since making agreements and creating coalitions with opponents are prohibited by law. By designing a competitive decision task simulating a market in the form of a subsidy game, the present thesis experimentally investigated how certainty, in the form of a subsidy, influence decision making under uncertainty when market regulations are not violated. Using imperfect price competition in the interdependent subsidy game mirrored the features of a real market where producers setting the lowest price do not always capture the entire market.

A Theoretical View

It was suggested that the opponents use their opponent's previous price as a reference level (an upper bound), and that the information of the size of the subsidy is used as a second reference level (a lower bound). These two reference levels created a "price-setting zone" to guide decisions, similar to the decision process in price negotiations (Neale & Northcraft, 1991; Thompson, 1990). The results of the studies in this thesis indicate that this framework may not be sufficient to describe participants' decision making when certainty in the form a subsidy was offered.

Studies I and II examined the subsidy system in an interdependent competitive setting. The results showed that the subsidy led to higher prices, resulting in fewer sales. Sequential analyses of decisions revealed that participants acted competitively, indicating that the results were not due to cooperation. When uncertainty of the subsidy level was introduced (uncertainty of the lower bound of the "price setting zone"), similar results were observed. An explanation might be that since participants received information of the level of the subsidy after each trial, and the average level (across the ten decisions) was the same as for a known fixed level, perhaps participants managed to infer the subsidy level using a moving average, thereby reducing any effects of uncertainty.

The incentive in the form of a subsidy (certainty) restrained participants from starting a price war, which also led to decisions with higher individual outcome (more optimal price decisions). If the use of reference levels in a price setting zone was the only principle guiding participants' behavior, the price setting zone should have become narrower as the number of encounters increased. That is, if opponent A responded to opponent B's price (which is the upper bound of the zone) by undercutting it in the next decision to increase profits, the price opponent B would set would also be determined in the same way. If the same strategy is assumes to be used for all decisions it would imply that, since the opponents' try to undercut each other, with repeated encounters the upper bound of the price setting zone should be reduced toward the level of the

lower bound of the zone. The results of Studies I and II only partially support this line of reasoning. In contrast to what might have been expected, prices in conditions with subsidies were not moving toward the lower bound of the zone. As expected, participants did seem to take the information of the level of the subsidy and opponent's price into account when setting their prices. A weakness of the analysis in the competitive studies is however that it was only the direction of change that was investigated, not the magnitude of this change. Thus, there is a possibility that the magnitude of change in prices varied between conditions. If this change in price varied between conditions, occasionally going above the opponent's previous price, it may give support to the alternative explanation provided in Study I, where it was argued that, since not selling still guaranteed some income, a possibility is that the price decisions also reflected increased risk taking. That is, opponents could afford to set a higher price since if they chose the highest price that made them sell fewer units and earn less than their opponent, they were still guaranteed a lowest payoff. It has in fact been found in field studies, of for instance renewable energy, that subsidies make producers more willing to take risks, and that this may be one of the main reasons for high growth rates of wind energy in some European countries (Menanteau, Finon, & Lamy, 2003; Reiche & Bechberger, 2004; Ringel, 2006).

To test the hypothesis of increased risk taking as a result of certainty, an individual decision making context instead of an interdependent context was examined in Study III. The results of Experiments 1 and 2 revealed that when participants were given the possibility to diversify between a risky prospect (producing to a market) and a certain prospect (receiving a subsidy), they preferred to diversify. These choices led to inconsistent risk taking, sometimes increased risk taking and sometimes reduced risk taking, compared to when binary choices was made between a subsidies and producing. These findings were corroborated in Experiment 3 with hypothetical scenarios where participants both ranked diversifying alternatives as more preferred and rated them as more attractive than alternatives only producing or only taking the subsidy, despite that such a non-diversifying alternative had a higher expected value. The previously suggested explanation that people diversify between prospects because they are risk aversive (Kahn & Lehmann, 1991) may thus not be the only explanation to diversification. As hypothesized, diversification may sometimes also reflect increased risk taking.

When participants in Study III faced a binary choice between certainty and uncertainty, they chose the prospect with the highest expected value, which sometimes was the uncertain and sometimes the certain prospect. When they were offered the opportunity to diversify, they chose to diversify, despite that it did not maximize expected value. It was also found that although participants

did not prefer the alternative maximizing expected value when they could diversify, they nevertheless displayed some form of sensitivity toward that alternative. When the certain alternative had a higher value than the expected value from the uncertain alternative, participants preferred the alternative that diversified a larger proportion to the certain alternative, and when the certain alternative was lower than the expected value from the uncertain alternative, they preferred the alternative diversifying a larger proportion to the uncertain alternative. Thus, they did not ignore expected values, but rather made a trade-off between the certain prospect and the prospect for which they had the possibility to get the highest outcome.

On the basis of the results of the three studies in this thesis, I therefore suggest that the behavioral framework proposed in the introduction needs to be somewhat revised. Participants' decisions seem to be determined, not only by reference values, but also by an aspiration for a potentially higher outcome, which may become more pronounced when a subsidy guarantees a lowest outcome. It may therefore be a possibility that participants make active trade-offs between certainty and potential, and that this lead to inconsistent risk taking. Participants strive to first get an outcome for certain; thereafter they can take risks, which would explain the results of inconsistent risk taking in Study III. The idea that people constantly make trade-offs between values is not a new concept, it has been found in other research on decision making, such as for instance between accuracy and effort in research of information processing (see e.g., Payne, Bettman, & Johnson, 1992), and in social dilemma research where people among other things make trade-offs between fairness, efficiency and self-interest (see, e.g., Johansson, Gustafsson, Olsson, & Gärling, 2007; Wilke, 1991). The proposed explanation of a trade-off between certainty and potential resembles the behavior of farmers who first plant food crops until their lowest needs are met, and then plant cash crops on the rest of their land to potentially increase profit (Lopes, 1987). Additional research is needed to specifically address this line of reasoning in the context of subsidies as environmental regulation.

A Practical View

There is always a trade-off between studying phenomena in a laboratory where the environment can be controlled and where different factors can be studied separately, and performing studies in the field where it is harder to separate different factors influencing behavior, but where the ecological validity is much higher. In line with the idea of using experiments as wind-tunnels (The Royal Swedish Academy of Science, 2002), in this thesis it was necessary to conduct laboratory experiments to establish how decision making is influenced in a controlled environment before it can be used in the field. Despite these

limitations, it is nevertheless important to discuss possible implications of introducing the system in a market. The major findings of the three studies are that the proposed subsidy led to increased prices, reduced sales, and reduced production. In fact, it was shown that it was enough with very low levels of the subsidy, sometimes lower than the expected profit from producing, to reduce production. The cost of introducing a subsidy may thus be moderate, and perhaps a feasable measure to take. It was also found that the larger the level of the subsidy, the grater the impact on reducing production. Thus, using subsidies might be a useful tool as a complement to other environmental policies to achieve a better environment. Arguments may still be raised that since the experiments were conducted with no reference to any specified market, there is a lack of ecological validity and the results may have little bearing on functions of real markets. However, the very same fact, that the experiments were made without a specific context, could also be used as an argument that the observed results may reflect basic human functioning. If the results reflect basic human functioning that would be invariant across different contexts, the proposed subsidy system may be possible to implement in several different areas where the government has a goal of changing behavior.

A structural solution in the form of a subsidy, a guaranteed payoff, created the same effects as communication has been shown to influence price decisions (Messick, 1999). This is an important consequence of the subsidy system when considered to be implemented in a real market where cartels or coalitions are prohibited. However, it was also found that introducing cooperation was the most effective way to increase price and reduce sales. Thus, changing the legislation against cartels and coalitions, allowing it under some circumstances, may in fact lead to an even better result for the environment. A negative consequence of implementing environmental regulations with monetary incentives, with or without the possibility to create cartels, is however that the cost associated with the incentives will in the end be passed down to the consumers (Smale, Hartley, Hepburn, Ward, & Grubb, 2006). This will affect different groups in society to a different degree, and may therefore be regarded as unfair. It may also be found to be an unattractive regulation by consumers since it will force them to change their present behavior (Jacobsson, Fujii, & Gärling, 2000). However, I would argue that it is necessary to use this kind of regulation, as one means of many, to break habits and change behavior of both producers and consumers, to reach the environmental goals agreed upon (e.g., the Kyoto Protocol), and to achieve a sustainable future. To avoid that the least fortunate groups in society would be the ones that suffers, a government has always the possibility to introduce additional mechanisms that would favour these groups, making their change in behavior less costly.

An important advantage with the subsidy system is that it provides a guarantee for producers, creating a possibility for them to take more risks and invest in new technology. Since producers will continue to make a profit while reducing production and sales, the subsidy will also facilitate the adjustment processes toward cleaner technology by making it possible for the producers to invest part of their profit. This might also give rise to spill-over effects, which are indirect, or sometimes unexpected, benefits to others through technological development and knowledge diffusion (Griliches, 1992; Jaffe et al., 2005). That subsidies lead to knowledge diffusion has been used as a justification for the use of governmental subsidies to commercial research and development (Klette et al., 2000). When the transition is completed, and the national and/or international environmental goals have been reached, the subsidy system would no longer be needed.

One limitation of the present studies of interdependent decision making is that they only investigated dyads. This was a deliberately chosen approach in order to make basic principles as transparent as possible. Introducing more actors may however influence the results, and in future research it is important to study if the goal is to mimic real markets where it is more common with multiple actors. It is also important to recognize that the simulated market in the experiment was somewhat simplified as compared to what can be expected of a real market. For instance, actors on a market do not usually have the capacity to capture the entire demand themselves, as actors in the experiments could. Also, in the experiments, to make the competitive situation easy to understand for the participants, consumer demand was set to be linearly increasing with to price. Price elasticity may of course vary considerably as a function of product and time. An example would be the transport sector where consumers seems to be less sensitive to price increases in the short run, but more sensitive in the long run (Johansson-Stenman, 1999; Sterner, 2002).

Economists have previously noted problems with implementing subsidy systems (Sterner, 2002). One is that subsidies may create incentives for firms and people to obtain the subsidy, and that this may lead to inefficiency. The results in the present thesis to some extent support this notion. Participants traded off a higher expected value from producing to recieve parts of their outcome from a subsidy with a certain but lower outcome. It was however also found that participants stayed competitive, thereby not exploiting the subsidy in the two competitive experiments. It is important that regulators determine under which conditions a firm should obtain the subsidy. To counteract that the subsidy is exploited, new producers can be prevented from entering the market to only obtain the subsidy. There are several different ways in which this can be accomplished. For instance, as in the EU ETS, one way would be to only let actors above a pre-specified size join the system. Another way would be to use

grandfathering as an allocation principle, that is, that each actor is allocated quotas of production or sales according to previous levels. This means that if a producer only obtains the subsidy (and do not sell at all), no quotas would be allocated the next time, and thus the producer would be excluded from the system. Furthermore, when new producers want to enter the market, the government may decide how large part of the total quotas to allocate to such producers.

The subsidy system may also be used as a method to prevent depletion of finite resources, for instance, to curtail the overharvesting of endangered species such as the cod (Mason, 2002). The fishing industry could thus be compensated for the part of their quota they voluntarily not utilize, thereby motivating them to reduce their catch, preserving the cod stocks for future generations. At the same time the subsidy will provide incentives for the fishermen to stay in business during the time it takes for the resource to replenish, thus preserving their profession for future generations. When the resource size has become stable the subsidy will no longer be needed.

Concluding Remarks

Although the studies in this thesis have been performed in the form of "wind tunnel" experiments, the results nevertheless clearly show that the basic construction of the subsidy system influences behavior in a desirable direction. With further refinement, it may be a useful tool, providing incentives for producers to voluntarily reduce production below regulated maximum levels. Thus, with additional research with both a theoretical and a practical perspective, the knowledge of effects of certainty on decision making under uncertainty may become useful for policy makers in the design of new environmental regulations.

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Appendix A

Derivation of payoffs in the Subsidy game.

Suppose the demand for *D* units of a product is linearly related to its price per unit *P*, that is

$$D = D_{max} - cP \quad (D_{max}, c, P > 0)$$
      (1),

where D_{max} is the maximal demand and *c* a constant expressing price sensitivity. The profit *I* earned by a firm when there is no competition (ignoring production costs) is given by

$$I = DP$$
      (2)

or substituting equation (2)

$$I = D_{max}P - cP^2$$
      (3).

Therefore, the maximal profit, $\frac{\partial I}{\partial P} = 0$, is obtained for the price set at $D_{max}/2c$.

If a subsidy denoted P_0 for unsold units is added to the profit, the total profit *T* is given by

$$T = I + (D_{max} - D)P_0$$
      (4).

As shown in the graph below, adding the subsidy increases the price for obtaining the maximal profit, $\frac{\partial T}{\partial P} = 0$, to $(D_{max} + cP_0)/2c$. Equation 4 was used to calculate the point profits in the experiment in the pilot-study of Study I.
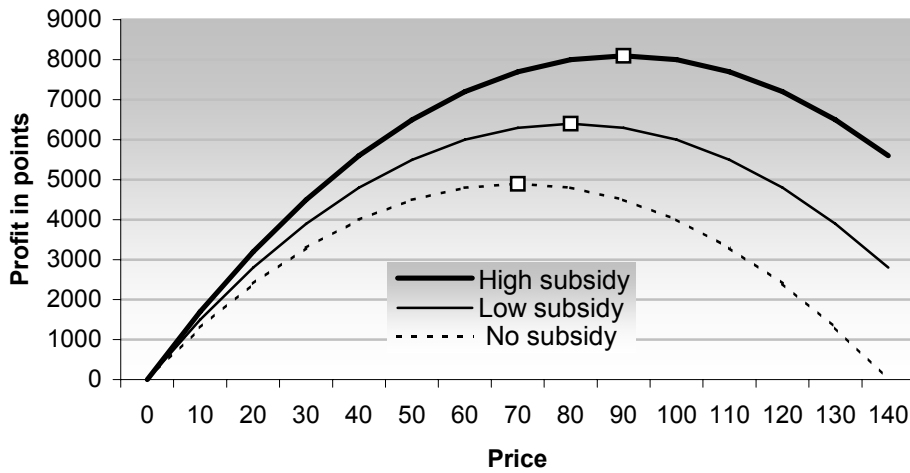
In a duopoly with price competition between two producers *i* and *j*, for simplicity it is assumed that the demand is determined by the lowest price P_i ($<P_j$), thus

$$D = D_{max} - cP_i$$

(5).

Because different factors make the price competition imperfect, the producer asking the highest price may still sell units at this price. Thus, it is assumed that

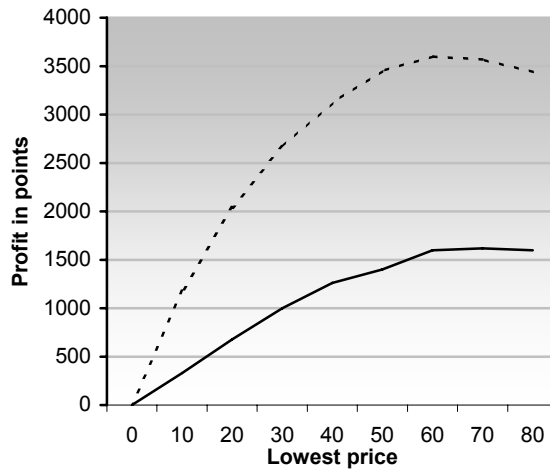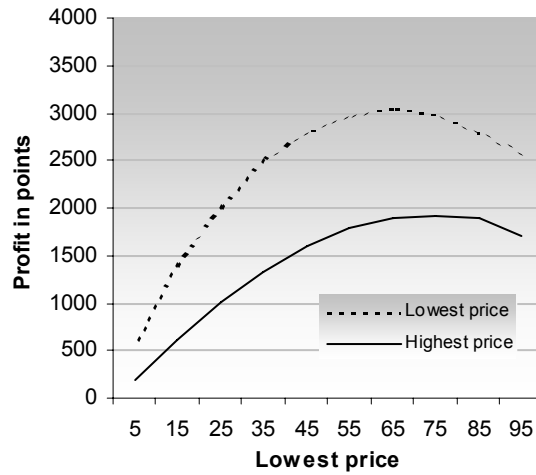$$D_i = 0.5(1 + ((P_j - P_i)/P_j)^{0.5})(D_{max} - cP_i) \qquad (6a),$$

$$D_j = D_{max} - cP_i - D_i$$

(6b).

The profit each producer earns is then given as

$$I_i = D_i P_i$$

(7a),

$$I_j = D_j P_j$$

(7b).

The way in which the profits vary with price is illustrated in the graphs below. The upper graph illustrates when the price difference Pj-Pi is low (5 points) and the lower graph when this difference is high (20 points).

When the subsidy for unsold units is added to the profit, the total profit *T* is given as

$$T_i = I_i + 0.5(D_{max} - D_i)P_0$$

(8a),

$$T_j = I_j + 0.5(D_{max} - D_j)P_0$$

(8b).

Equations (8a) and (8b) were used to calculate the point profits in the experiment in both Study I and Study II (except the pilot-study). The constant c was set to 1. Furthermore, the subsidy was not multiplied by 0.5 so as to make the total point payoff the same as in the pilot-study.

43

Appendix B

I. Olsson, L. E., Akiyama, M., Gärling, T., Gustafsson, M., & Loukopoulos, P. (2006). Examining the Use of Subsidies for the Abatement of Greenhouse Gas Emissions through Experimental Simulations. *European Environment, 16*, 184-197.

II. Olsson, L. E., & Gärling, T. (in press). Staying competitive while subsidized: A governmental policy to reduce production of environmentally harmful products. *Environment and Planning C: Government & Policy.*

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