



LUND UNIVERSITY
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Economic Consequences of Firewood Machinery Accidents

– A Cost of Illness Study in the Southern
Health Care Region of Sweden

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Abstract

The purpose of this thesis is to estimate the costs associated with hand injuries inflicted by log splitters and circular saws, and by doing this also estimate a value of prevention. This is carried out in the form of a cost of illness study with an incidence approach.

A consecutive data material comprising 57 patients was obtained from the Department of Hand Surgery at Malmö University Hospital (UMAS). The observed period of time ranged from 1999 to 2003. Most injuries affected the hand or the forearm.

Total cost to society in the southern health care region is estimated to approximately € 14.5 million per year. Total cost is the sum of direct costs, productivity loss and life quality loss, where life quality loss stands for the largest part.

Key words: hand injury, cost of illness, firewood, log splitter, circular saw

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Introduction

Man has throughout history burned wood to keep warm and to prepare food. Still today wood is a commonly used fuel. Thanks to rising energy prices and an increasing awareness of the climate change, the use of firewood as a source of energy is experiencing a renaissance. Sweden is a country endowed with large forest resources, making firewood production relatively cheap and uncomplicated. Hence, many Swedes prepare their own firewood and use it to heaten their homes. Traditional tools, like saw and axe, have widely been replaced by an increasing number and variety of powered firewood machinery. Since 1986 an eightfold increase in the number of log splitters sold has taken place (Lindroos, 2005). Firewood machines are very powerful, and a large number of accidents occur every year, typically resulting in hand injuries. This imposes human suffering and costs to society.

Purpose

Our primary goal is to estimate the costs to society that arise from hand injuries caused by the utilization of firewood machinery, or more specifically, log splitters and circular saws. This is carried out in the form of a cost of illness study with an incidence approach, applied on a material accounting for the south health care region of Sweden. By hand injuries we mean injuries relating to the function of the hand, that is injuries to the hand, wrist, forearm, and also injuries to the upper arm affecting blood vessels and nerves, since the function of the hand is not isolated to itself.

Our second objective is to estimate the cost imposed per machine and in this way discuss whether it is possible to prevent some of the harm caused by firewood activity by some kind of preventative measure amounting to the same cost. An efficient solution would provide a potential saving of costs to society. To come up with an appropriate conclusion, it is important that the injury costs have been calculated adequately.

The costs considered here, are the costs affecting the whole of society (to be distinguished from the state). This is due to the fact that the view of this study is societal, trying to improve the welfare of the society as a whole by investigating inefficiencies in how resources are spent. There are different costs to society associated with the hand injuries and we separate

them into three categories; direct costs, productivity loss, and life quality loss. The direct costs are health care costs, such as the costs for personnel, equipment and location to perform hand surgery and rehabilitation of the injured. The productivity loss is the loss of productivity to society that occurs when the patient due to his injury is hindered to pursue his work. To different degrees the injuries cause lasting pain and disability which in turn also can lead to psychological distress. These things account for the life quality loss.

The Nature of This Study

It is important for the reader to understand that this paper is not an evaluation, but a paper providing data that could be used in an evaluation. An evaluation of cost-benefit type would also consider the time consumption of using these firewood machines, the energy produced with firewood, environmental sustainability associated to the use of bio-fuel, the positive utility arising from working with firewood, price elasticity and consumer preferences to the machines, etc. To simply stop using log splitters and circular saws would bring about other costs to society, not estimated here.

This study is intended not only to be read by economists or students of economy, but also by people of other professions. This is the reason why we will explain the economic methods in terms of the rationale behind them, and how they are performed, more thoroughly than what is common practice for a thesis at the bachelor level.

Outline of the Thesis

In the background section, apart from a detailed presentation of the studied material, the hand injuries inflicted by firewood machinery will be described, as well as earlier studies made in the same line of research. Then follows an explanation and discussion of our choice and practice of methods used for the estimation of the costs. The results section will present the direct costs, productivity loss and life quality loss associated with the hand injuries. These will be further analysed and compared with other figures available in the section of discussion. What is causing the accidents, what has been done to prevent them and what further can be done is examined in the section called Prevention. The costs involved with the implantation of a preventative measure will also be described and discussed there.

All costs are reported in euro of the currency value of 2007, if not else is stated. All calculations have been done using real discount rates. It is assumed that any future inflation

will affect the different cost items at the same rate. There is also an appendix containing the results tables with the numbers expressed in SEK.

Background

Description of the Hand Injuries

The different injuries to the hand due to log splitting activities can consist of amputations, nerve injuries, injuries to the flexor tendon and extensor tendon, fractures and vascular injury resulting in impaired circulation or ischemia. The index fingers are the most commonly injured parts of the hand. Distinct types of injuries caused by screw splitters are thumb avulsion and palmar penetration. (Lindqvist et al.)

Previous Studies

There is a large amount of papers and articles present that are discussing the medical viewpoints on accidents involving firewood machinery. Justis et al. (1987) express the view that hand surgeons need to enhance their knowledge of wood working tools to better treat injuries caused by such, and that consumers need to be better informed about the risks associated with them. Similar opinions are revealed by Kristiansen and Seligson in a 1981 study of log splitter hand injuries in the Vermont area in USA. Also in 1981, an article in *Plastic and Reconstructive Surgery* finds that the – at the time relatively new – hydraulic log splitters presents a “new spectrum of hand injury”, and observes that the central digits are more exposed to danger when using these machines. Human carelessness and faulty design are observed as important factors leading to injury (Jaxheimer et al., 1981). Hellstrand (1988) concentrates on screw splitter injuries and states that use of this type of firewood machines often leads to injured fingertips and penetrated palms. A study from Denmark underlines the risks of dual working, but admits that accidents occur also when working alone. Emphasis is laid upon saying that the log must not be adjusted or moved while the pushing rod is moving. A proposition to mark every log splitter with an instruction that decrees single-person work is made (Trier and Hovgaard, 1989). Holm (1998) concludes, after a retrospective study of hand injuries caused by hydraulic log splitters in Odense, Denmark, that the severity of such hand injuries call for immediate action in prevention (such as developed common European safety standards) and information, and proposes risk illumination to all households owning a wood-fuelled furnace or fireplace. All injuries caused by powered wood splitters and seen at the Department of Hand Surgery at Uppsala University Hospital during 1995-2001 were

reviewed in a study by Lindqvist et al. The conclusion is that “[p]owered wood splitters cause severe hand injuries and further research to facilitate prevention is warranted” (ibid.).

Nonetheless, the number of studies of costs related to these injuries is limited. There are however some reports and papers that touches this issue more or less deeply. Accidents among self-employed forest owners have been analysed by Lindroos and Burström (2007), but their paper does not make any attempt to compute the total costs inflicted to society. There are nevertheless interesting data on the effects on working ability presented and the days of sick leave, collected from the main insurance companies in forestry. Direct health care costs were calculated to ranging from 0.4 to 0.8 million SEK per year (ibid.). In 1993, the costs for material damage (i.e. health care, property damage, administration and productivity loss) in self-employed forestry work, was estimated to 230 million SEK (approximately € 25 million). These figures were based on the accident prevention value that is calculated by the Swedish Road Administration, Vägverket (Engsås 1993 in Lindroos and Burström 2007).

Nilsson and Runemo (2007) presents data that shows that forestry was found to have the largest share of accidents resulting in sick leave longer than fourteen days, in a 2005 study of work related accidents. Total costs due to accidents in the agricultural sector was estimated to 2-3 billion SEK (€ ~ 200-300 million) a year (ibid.).

Assumptions and Background to Wood Cutting and Splitting Activities

There are indications that the number of injuries caused by firewood cutting and splitting have risen during the last decade. No major investigation has been made of the possible connections between the large health care costs and the presence of firewood processing machinery, such as circular saws and log splitters. It is likely that the more machinery of this kind there are in a society, the more, and perhaps graver, are the injuries. On the other hand one can make the argument that since new machines are being sold, older and less safe pieces of equipment are discarded, thus reducing the risk of injury. If the fact of the matter is that new equipment is remarkably safer and reduces risk of injury, then focus should be on a renewal of the stock of firewood machines, rather than some kind of new safety regulation and/or physical protection that includes all machines regardless of their age. In an article by Lindroos (2006) it is stated that the medium age of wood-splitting equipment in Sweden is about eleven years, which means that a great deal of the machines are even older. Log

splitters sold today in Sweden have some kind of safety feature, normally meaning that one-handed handling is not possible due to that both hands have to be used simultaneously to get the machine going. The CE marking requires two-handed handling and that there is only one person working with the machine at the same time (Lindroos 2006). It seems however, that this safety function is rather simple to override, considering the large number of hand accidents (ibid.). Older equipment often lacks these safety details, thus increasing the risk of injury when using old machines. To some extent, homemade machines are also present. It would not be too far-fetched to assume that those are even worse from a working security point of view.

Estimating the Stock of Firewood Machines

To be able to make adequate calculations of the relation between the stock of firewood machinery and the number and severity of injuries, figures of the total number of machines sold and in use are needed. A rough assessment of the Swedish log splitter stock can be achieved by multiplying the amount sold in 2002, which according to Lindroos (2005) is 10 944 (assumed to be a representative figure) by the average age of the equipment, that is, eleven years as mentioned earlier (Lindroos 2006), thus giving a result of about 120 000 log splitters in total. With the same method and Lindroos' data, the number of circular saws can be estimated to approximately 15 000.

There are however other ways to estimate the presence of firewood machinery in Sweden. All households that own some kind of heating equipment of combustion type, such as oil- and wood furnaces, open fireplaces and tiled stoves, are registered in the local chimney sweeping directory. In the Umeå region in northern Sweden, 74 % of those in the directory used some kind of wood splitting device, that is, hydraulic splitter, combined cutting/splitting machine or a screw type splitter. Assuming that the population in the Umeå region is representative for the rest of the country, there should be a total amount of 540 000 log splitters of different types in Sweden. This figure varies quite dramatically from the first example, where only Lindroos' data were used; hence there is need for a more thorough investigation.

From the Swedish trade association for suppliers of mobile machines (Maskinleverantörerna), we have been able to access information about the number of log splitters and circular saws sold each year between 2000 and 2007. Some problems remain though. First and foremost, not all retailers and producers of firewood machines are members of Maskinleverantörerna.

Secondly; many of the Swedish producers are small family businesses, making it difficult to achieve a comprehensive view of the market. What can be seen from the Maskinleverantörerna data is that the number of new firewood machines delivered has grown rapidly until 2003, and then slightly fallen. It seems that these figures can change dramatically from one year to another. For instance, in 2000, 167 wood splitters were sold by the companies in the Maskinleverantörerna organisation, compared to 1 844 in 2003. The last record which was noted in 2007 shows a total sale of 564 machines, which must be considered to be low compared to the sales in former years, which have been approximately 1 500 every year. The vending of circular saws show the same characteristics, that is, growth from 2000, a peak in 2003, and then a slight diminution. It is possible – and rather likely – that the reduction in sales during the last couple of years is an effect of increased competition from large wholesale retailers and “Do-It-Yourself” stores.

Thanks to Ola Lindroos’ work, there is thorough information of the actors in the market of the year of 2002. To access information from the entire period, we have contacted those enterprises that manufacture and/or retail firewood equipment not being members of the “Maskinleverantörerna” organisation. Most of the companies in our limited survey were however reluctant to give out information on their sales figures. The large actors (Clas Ohlson, Silvan, JULA) admitted though that the number of delivered firewood machines in general and especially hydraulic log splitters had risen remarkably over the last few years. Taking these somewhat contradictory facts into account, it can be concluded that assessing the whole spectrum of the issue is problematic, but a qualified guess is that large providers of tools, machines and construction equipment, are increasing their market share relative to small manufacturers and importers.

Due to lack of reliable and comprehensive data on the yearly sales and the existing stock of machines, we have chosen to estimate the number of machines more roughly. It is stated in Lindroos et al. (2007) and Lindroos (2006) that the mean age of log splitters and circular saws is 9.5 and 11 years, respectively. From telephone interviews with representatives for the larger firms in the market, the average life of log splitters has been estimated to 10-20 years for the more expensive equipment, and 2-3 years for a cheaper machine, usually manufactured in Asia. However, many of the operative machines today are older than that. In this study, the average life of a log splitter has been assumed to be 15 years. For circular saws, it is assumed to be 30 years.

Material – Data from Malmö University Hospital

In the material that this study is focusing on, a total of 66 consecutive cases have been registered. All of them were treated at the Department of Hand Surgery at Malmö University hospital between 1999 and 2003, for rather serious injuries to the hand or arm. The catchment area population of the department is approximately 1.8 million. Nine of the patients were injured while working with axes, and for this reason they were excluded from our study. We chose not to include axe-related injuries, since we decided at an early stage that we wanted to maintain focus on power tools, and the consequences that the use of them has for society.

Expressing Severity and Disability as Values: the HISS and DASH Scores

Among surgeons and other physicians, the ability to present an injury in condensed, standardized form, is important to facilitate research, follow-ups and evaluations, as well as economic studies. Therefore, a number of methods have been invented to give numeric values to different types of injuries. The Hand Injury Severity Score (HISS) is specifically designed to measure hand injuries, but it is not very widely used in practise, as can be seen in its limited use in the literature. This might have something to do with the fact that the HISS score shows some weaknesses when it comes to classifying, among others, vascular injuries and crushed nerves (Rosberg, 2004). In addition, the HISS cannot be used to classify injuries above the wrist. A HISS below 20 points is considered as a minor injury, over 20 but below 51 as moderate, between 51 and 100 as severe and over 100 as major (Campbell et al., 2006). Both Campbell et al. and Mink van der Molen et al. (1999) have found significant correlation between HISS score and work absence. In this study, the HISS score varies from 6 to 332 with a mean of 93.

While HISS is a way to quantify injuries at the time of the first contact to a physician, the DASH (Disability of Arm, Hand and Shoulder) pointing system measures the long-term disability caused by an injury, and is assessed some time after the hospital session¹. The patient is asked to fill in a 30-item disability/symptom scale that concerns the patient's health status during the preceding week (McConnel et al. in Atroshi et al., 2000). The result shall be disqualified if more than three items are left unanswered. This is the core of the DASH data collection. The patient's responses are then transformed into a score that stretches from 0 (no disability) to 100 (severest disability) (Atroshi et al., 2000 p. 613-614). In our study material,

¹ Swedish DASH questionnaire available at http://www.dash.iwh.on.ca/assets/images/pdfs/Swedish_DASH.pdf

the DASH evaluation was carried out after 2 to 7 years, resulting in scores between 0 and 55, with a mean of 18. The Swedish translation (ibid.) of the DASH questionnaire, which originally is from the United States, was used in the survey. According to Rosberg, 54 of the DASH questionnaires (82 %) were possible to use in the analysis. One of the patients had died, one had left the country, and ten patients did not participate.

The condition of the patients was given a HISS score on arrival, indicating the severity of the injury. The length of emergency hospital stay varied substantially, from 2 to 31 days, and with an average value of seven days. 19 patients stayed at another ward for some time after the initial emergency care. Two to seven years after the hospital stay, a follow-up study was carried out by the department, resulting in a DASH score, an index that gives an indication of the more permanent level of disability due to the injury (also described in detail above). The average DASH score turned out to be 18.2 points (see table 1 for details).

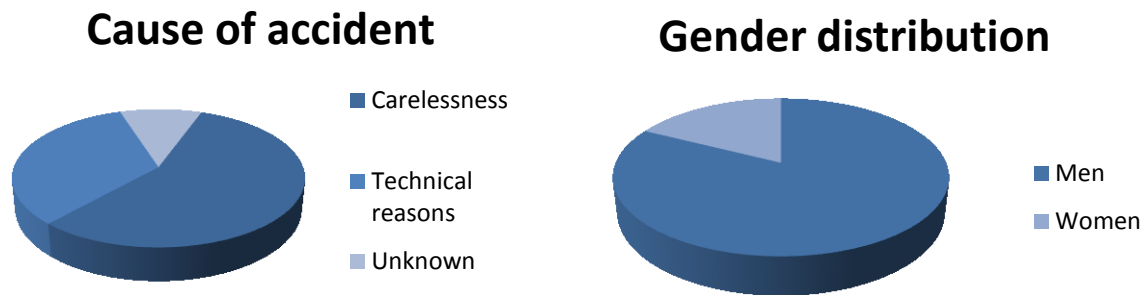
Description in Detail

Table 1: Descriptive statistics of the material

	Age	HISS	Days of hospital care	Sick days	DASH
Mean	50,4	92,9	7,32	123,6	18,2
Median	51	67	6	30	10
Min. value	8	6	2	0	0
Max. value	81	332	31	884	55
Std. Deviation	18,02	80,21	6,02	198,01	19,20
Variance	324,89	6433,63	36,19	39209,11	368,57
Mode	66	10	2	0	0
Number of obs.	57	51	55	57	47
Missing	10	6	2	10	10
Range	8-81	6-332	2-31	0-884	0-55

Ten patients were women. When asked about the cause of accident, 56 % stated carelessness as the main reason, one third claimed technical reasons, and 11 % did not give any explanation (see figures below).

Figure 1: Cause of accident and gender distribution



The direct costs were available in the material, calculated by Hans-Eric Rosberg at the department of hand surgery at the Malmö University Hospital (UMAS). Direct costs comprise surgery costs, staff costs, costs of hospitalization and rehabilitation, as well as all other costs directly associated with hospital-based health care. See table 2 for prices of the most common activities. Costs were calculated using the administrative prices paid by a referring hospital to the Department of Hand Surgery in the year 2006. Injuries were seen in all months but with a top in April. All patients were treated as inpatients and the median length of stay was six days. 61 % of the patients were gainfully employed at the time of injury.

Table 2: Costs for a few common care measures, € per unit.

Measure/ Cost	€	Per
Emergency surgery	27.4	Minute
Planned surgery	13.7	Minute
Emergency ward stay	1007	24 hours
Ward stay	480	24 hours
Policlinical care	179	Visit
Rehabilitation visit	72.1	Visit

Method

A Cost of Illness Approach

As one of our goals with this study is to estimate the costs of injuries associated with firewood machinery, it makes it in part a cost of illness study. Cost of illness (COI) studies have been criticized of not being able to provide good basis for policy decisions, thus having no other purpose than curiosity. This has been argued by Sheill et al. (1987) while recognizing COI to be a legitimate approach only if an intervention capable of totally preventing the ailment is possible. From our point of view, an intervention close to doing this should be possible in this case.

Our analysis is incidence-based, meaning that we are assigning the flow of costs associated with an injury to the year the flow starts i.e. the year the injury occurred². This means that all costs should be discounted to their present value for the year that the injury occurred. This will allow us to see what the costs have been for every year studied (Ament and Evers, 1993). Our data did not contain any detailed information on when different treatments took place, resulting in that discounting of direct costs was not possible. This has however probably not affected the results to a noteworthy extent, considering that in most cases the direct costs, constituted of health care as surgery and rehabilitation, has been carried out in close connection to the time of injury.

Discounting

The Rationale behind Discounting

It is always better to receive a benefit at an earlier time or to encounter a cost at a later time, since this gives more options. This is among economists known as the notion of time preference, which is a preference for benefits today rather than in the future. There are many reasons to why this is the case. The uncertainty about the future is one reason, and a short-term view of life is another. Individuals might also be expecting to be wealthier in the future, which is a view consistent with the trend of long-term positive economic growth since the Second World War. This means that the individual puts higher value on an amount of money

² Another approach is prevalence-based COI which is assigning costs to the year they are borne. The differences

today, since it will make a greater difference for him today than in the future when he is richer. It is also possible to obtain a positive return on a risk free investment, such as government bonds or keeping money on a bank account, even when the effect of inflation has been considered (Drummond et al., 2005).

Discounting in Practice

In the estimation of costs associated with hand injuries inflicted of log splitting or –cutting that is being done in this paper, the costs associated to an injury that are actually being borne in a later year is not valued as high as if it was carried in the same year. Thus, to reflect this difference of value the discounting procedure is carried out. The typical calculation of the present value of an investment is performed as in this example from Drummond et al. (2005, p. 73) for three years.

$$\begin{aligned}
 P &= \sum_{n=0}^2 F_n (1 + r)^{-n} = F_0 + \frac{F_1}{(1 + r)} + \frac{F_2}{(1 + r)^2} \\
 &= F_0 + \frac{F_1}{(1.05)} + \frac{F_2}{(1.05)^2}
 \end{aligned}$$

Where:

P = present value

F_n = future cost at year n

r = annual interest (discount) rate, in this example 5 %

This assumes that all the costs occur at the beginning of each year, which means that the first year is not to be discounted, but the second year should be discounted with one year and the third with two years, and so forth. This assumption has been made when discounting has taken place in the estimations presented in this thesis.

Choice of Discount Rate

There have traditionally been two competing theories regarding the proper measure for discount rates for public projects, being the social opportunity cost approach and the social rate of time preference.

The first is to be explained as the real rate of return to society forgone in the private sector. Public investments can be seen as competing with private investments, resulting in displacing or crowding them out. The discount rate is therefore constructed as a weighted average of other discount rates applicable to different sectors in the economy providing resources to the programmes under evaluation.

The other theory, social rate of time preference, is to be seen as a measure of the collective willingness of the society to not consume today in order to consume more tomorrow. It could be argued that the interest rate on a risk-free investment, such as long-term government bonds, represents the individual's rate of time preference, which could be aggregated for all individuals to be the social rate of time preference. This would result in a discount rate being the same as the real interest rate of long-term government bonds (Drummond et al., 2005).

When it comes to actual discount rates being used, there is a high prevalence of a 5 % rate in literature. Using this has of course the advantage that a study will be easily comparable to other studies using the same rate. A 3 % rate was suggested by the US Public Health Service Panel on Cost-Effectiveness in Health and Medicine, since they estimated this to be the most appropriate real discount rate for economic evaluations. They also recognized the usefulness of using 5 % for some time ahead, in order to compare with earlier studies. This has led to the recommendation by Drummond et al. (2005) to undertake a base case analysis using a rate announced in the jurisdiction concerned (or the rates mentioned above), and to undertake a sensitivity analysis with the discount rates of 0%, 3%, and 5%, when performing economic evaluations (p. 77). This is also the recommendation of the Pharmaceutical Benefits Board of Sweden (LFN).

Discounting of Health Effects

When it comes to discounting of health effects, and whether it should be discounted at the same or different rate as monetary costs or even at all, is a matter of controversy even though the current practice and most recommendations suggest that they should be discounted at the same rate, irrespective of if the effects are expressed in terms of money or some health measure (Cairns, 2001). This is important to discuss as this study has measured the health effects over a long time span in QALYs and also valued the effect in monetary terms.

It is of course appealing to have the same rate for all discounting, thereby having consistency in the calculations. There are however reasons not to. Cairns (2001) concludes that the question that needs to be asked is what the present value of future life years is. Is the marginal value of an additional life year constant? He argues that if life years are discounted at the same rate as monetary costs, then this is equal to a constant valuation of an additional life year over time. If the life years were left undiscounted, and simply summed, this would according to Cairns be equivalent to assuming that the fall in discount factor as the life years gained recede into the future, is exactly balanced by a rise in the marginal valuation of life years gained. This would mean that the value of health would increase over time which could be explained by that the society would be increasingly rich. It is difficult to say that any of these practices provides a good solution, and Cairns concludes that both of these practices will involve an element of approximation. Brouwer et al. (2007) have recently recommended the British National Institute for Health and Clinical Excellence (NICE) to go back to their previous recommendation, discounting health effects at a lower rate than monetary costs, in order to reflect the growing value of health over time.

There has also been some concern regarding double discounting when imposing a conventional discount rate to QALYs calculated with the time trade-off based preference, since they already have a time preference component built in (MacKeigan et al., 2003).

In this study, we adopt the recommendations given by LFN. For the discounting of the health effects this means that they too will be discounted at a 3 % discount rate, but that the sensitivity analysis will also have a section where the health effects are left undiscounted when other costs will be discounted at 3 %.

Estimating Productivity Loss

There are mainly two different approaches to estimate the productivity changes. The human capital approach and the friction cost method. Each of these methods has been widely used in health economics research, and both of them have characteristic advantages and drawbacks. In the following sections, a deeper description and discussion of these different approaches will be provided.

Human Capital Approach

This approach is estimating productivity benefits on the basis of the present value of the additional streams of income for people as a result of a given health care programme (Sculpher, 2001). One can interpret this as an implicit assumption that the objective of health care was to maximize national productivity, and it has met criticism due to this.

The approach has its foundation in neoclassical labour theory and theory of the firm. A profit-maximizing firm would employ labour until the marginal revenue product of the last unit of employment equals the employment cost of the firm. The employment cost consists of the gross wage including additional costs of employment, such as social fees and taxes. Following neoclassical theory stating that individuals have diminishing marginal utility from leisure, an individual will devote time to paid work until the opportunity cost of that time equals the marginal benefit which is the wage-rate, net of taxes, coming from employment. When sick, leisure time is also foregone but one can also argue that the time off work is increasing the leisure time. Following neoclassical theory, one should expect the value of this time to counterbalance the productivity loss from the time off work, but since the individual is sick, it can be assumed that the value of the extra leisure time is negligible. This becomes even more apparent when considering that the individual, as mentioned, has a diminishing marginal utility from leisure, and that the individual from the usual part of his leisure time as sick receives less utility than when healthy (Sculpher, 2001). Our estimation of the values of changes in leisure time is thus zero, meaning that leisure time will not be considered.

A problem with this approach is that it is excluding or discriminating against non-market activities such as household work or voluntary work. The productivity loss arising from these will not be captured by the method, as understood by Ament and Evers (1993) among others. This will be a source of underestimation of the true costs of productivity lost. Another problem with the human capital approach arises when trying to measure the welfare loss from deaths³.

³ An individual's loss from dying is assumed to be equal to its productivity loss, which is an assumption without solid ground. This is however not a problem here, since there are no deaths related to the injuries studied in this material.

Friction Cost Method

It has been argued that the human capital approach overestimate the true cost to society for people with sick leave. In the case of short-term absence, a loss in production could be compensated for by the worker when he returns, or his colleagues could help filling in for him. All jobs contain some tasks that are less important than others, and when there is a lack of labour, these tasks are the first to be foregone during a short period of absence. This makes it possible to argue that value of the productivity lost at the margin is likely to be lower than the average wage. During a long term of absence, the employer is likely to hire a replacement worker, which would compensate for lost productivity. There will however be some productivity lost, which depends on the time and cost of organizing the replacement, the quality of the replacement, and the following adjustments in the economy resulting in that a previously unemployed person will be employed. (Drummond et al., 2005)

The idea of the friction cost method is that the amount of production lost due to disease is depending on the so called friction period, that is, the time-span organizations need to restore the initial production level. Industry, location and category of worker are different aspects that will affect the friction period, and thus the challenge will lie within estimating the relevant friction periods. When such estimations have been made, they have given estimates of lost production that are much lower than from those obtained from the human capital approach. (ibid.)

The Case against Friction Cost Method

The friction cost method is however not as commonly used as the human capital approach. Pritchard and Sculpher (2000) found in a sample of 40 studies that only seven had used friction cost method, compared to 26 that used human capital approach.

It has been argued that the friction cost approach is based on implausible assumptions not coherent with neoclassical economic theory. Johanneson and Karlsson (1997) argue that in the case of short-term absence, even if the employer has got diminishing returns to labour, it does not mean that the human capital approach would overestimate the value of the loss in production. The neo-classical theory predicts that an employer will hire labour up to the point where his marginal utility of the last person employed will be equal to zero. The absence of a worker would correspond to a marginal loss of labour, which for the employer is equal to the

total cost of having the person employed. According to this, the human capital approach could provide a correct estimation of the loss of productivity. One can also imagine that an underestimation of the value also could occur if the person absent occupies a key function, thus being difficult to replace.

Johannesson and Karlsson also reject the argument of those arguing for friction cost method, of the notion that sick persons would make up for the time lost when this person returns, because this implies that leisure time would be reduced, and the opportunity cost of this leisure time would then be the indirect cost. The human capital approach would give an estimate of this cost. When it comes to long-term absence, Johannesson and Karlsson conclude that after the friction period, the price of labour will be set close to zero using the friction cost method, and that this is supported by neither neo-classical economic theory nor empirical observations. The notion that a formerly unemployed person would fill the vacancy of the absent worker, or that it would lead to a chain of replacements ending with a formerly unemployed being employed, seems unlikely. The previously unemployed must then also be assumed to not have obtained a job elsewhere during the absence of the employed, would he never been sick. Alternatively, if he would have obtained a job it would have led to someone else becoming unemployed.

Johannesson and Karlsson also assert that if the friction cost method was to be used to estimate indirect costs, in order to be consistent it should also be used to estimate direct costs, since they in large part consist of labour costs. As the costs for additional labour are set close to zero, the same would apply to these labour costs.

As the friction cost method is not consistent with neo-classical theory, and not as widely used as the human capital approach, we choose not to use this method. The human capital approach on the other hand is consistent with micro economic theory, widely used both historically and contemporary, and more accepted for estimating productivity losses. It is also recommended by LFN. This makes it a strong case for the human capital approach which is why we choose to use it.

Considerations of Equity

Productivity cost has by the United States panel on Cost-Effectiveness in Health and Medicine been referred to as “the costs associated with lost or impaired ability to work or to engage in leisure activities due to morbidity and lost economic productivity due to death” (Sculpher, 2001). When the perspective of a study is societal, it is a study that tries to improve the welfare of the society by investigating if a given policy includes inefficiencies for the society as a whole. If the amount of money spent in one sector of the economy has an effect of the amount of money spent in another sector, the connection should be investigated so that resources will be used in best possible way (ibid.).

When considering productivity costs as motivated by efficiency arguments, there might be some concern regarding equity implications of considering these costs. This is due to the fact that the value of an individual’s time is based on their earnings from employment as this is reflecting their level of productivity. The logical conclusion that could be derived from this is that those interventions that may return more productive individuals to work will be favoured when compared to interventions returning less productive people to work. Some economists therefore recommend using a common wage for all individuals thereby avoiding this discrimination (Drummond et al., 2005).

Olsen and Richardson (1999) have discussed this and concluded that the solution depends on the value judgements on which the analysis is based. Our viewpoint is that if there is an inefficiency in resources spent, and that this can be solved in order to free resources to society or to go even, with the result that people would not be injured, then this is something good, and it is up to the society how to handle and distribute the potential resources freed.

The discussion and controversy surrounding inclusion of lost productivity makes it important to follow some guidelines given by Drummond et al. (2005). We therefore report productivity changes separately in order for the reader to choose whether he would like to include it or not, and we also report it in days of sick-leave, as this is a non-controversial way of presenting productivity loss. In addition we make an estimation of productivity loss by using a common wage for all individuals, for those preferring this approach and to see if it produces considerably different outcomes.

Evaluation of Life Quality: QALY

When performing any type of health care action, be it a nationwide reconstruction of the entire health care system or a single choice between two different treatments to a specific patient, some kind of utility analysis has to be carried out. Whether something should be done, and if this is the case, how it should be done, is a question that can vary a lot in terms of complexity and difficulty. Common sense can go a long way, but sooner or later it will be hard to analyze the whole spectrum of different alternatives and their associated costs, benefits and drawbacks without a thorough quantitative evaluation.

In cost-utility analysis, a number of different indices and grading systems are used to establish good grounds for decision making. Among these, the Quality Adjusted Life Years (QALY) evaluation is among the most important (Folland et al., 2007 p. 81). One of the large advantages of using QALY in health care evaluations is that it combines measures of both quantity and quality of life years gained (Torrance, 1997). The QALY uses a scale to assign a value of life quality ranging from zero to one to each year. A value of zero is a state equal to being dead, and the value one indicates perfect health. In general you can say that the QALY weights are derived from individuals' preferences regarding their health status, i.e. how important they consider good health to be. The normal procedure to compute weights of QALY is to sum up the results from a large number of people (Folland et al., 2007). The gathering of QALY data will be discussed further down. Once the appropriate weights are set, the number of Quality Adjusted Life Years gained can be calculated like this:

$$QALY = \sum_{i=1}^{\text{maximum duration}} F_i q_i / (1 + d)^i$$

Where:

F_i = the probability that the person is still alive at age i

d = the time discount factor

q = the quality weight, thus ranging from 0 to 1 for the individual's remaining life (ibid.).

How to Calculate QALYs: EQ-5D

In analyses of medical conditions, it is important to know how much a certain condition of diagnosis affects the overall quality of life. Therefore, a questionnaire has been constructed in

order to assess a large number of people's views on the life quality effect from various forms of health conditions. In Europe, the EQ-5D is the most widely used. It is a preference based measurement tool developed by the EuroQol organisation which is a network of international multidisciplinary researchers, with the objective to do research on the measurement of health-related quality of life. The group is today an international organisation, but consisted initially only of European researchers, hence the name (Szende et al., 2007 p. 7).

An EQ-5D questionnaire⁴ consists of five rather simple questions, with three response alternatives each, and one thermometer-like grading scale, also known as VAS (Visual Analogue Scale), where the respondent is asked to estimate his or her overall experienced quality of life (Oppe et al., 2007). Each of the five questions asks the patient to grade his ability to live a normal life from five different aspects such as mobility and pain, usually from no problems at all to very large problems, and the answers are then translated to a five-digit code, for example 11231, where the first digit corresponds to the response of the first question and so forth. The value on the VAS in turn, corresponds to a quality index, ranging from 0 (dead) to 1 (perfect health). Hence, using the results from several people, a quality value can be given to many of the 243 combinations of answers on the questionnaire, making it possible to estimate the population's general discomfort from different health states. The transcription is usually presented as a table of tariffs, or a statistical presentation, giving each variable a parameter, calculated by linear regression (Szende, 2007). The digit-codes that cannot be given a qualitative value empirically can thus be assigned a calculated value, using linear regression.

Sets of EQ-5D tariffs have been calculated for the population of several countries, such as Denmark, USA and a group of some European countries together, but not for Sweden alone. An adequate set of tariffs must thus be chosen to translate our DASH-scores to QALYs. We chose to use Danish tariffs, for a number of reasons. Firstly, the Danish population is in matters of age distribution, income level and traditions similar to the Swedish. Secondly, the European tariffs, though containing a large number of observations, showed some weaknesses⁵, and only contained a very small Swedish sample. Thirdly, some of the values

⁴ Available from www.euroqol.org, however not for free.

⁵ "It should be noted however, that data from certain European studies that did not follow a full VAS valuation approach, such as Sweden, Germany, and the Netherlands, were still included in the European Value Set." (Szende et al., 2007)

were calculated at an early stage in the work using Danish tariffs, and they simply did not differ very much from the other tariffs.

It is important to discuss how society should value one QALY if harm is caused by unwillingness to comply with safety instructions. It is not unlikely that a person willingly taking the risk to severely injure him or her by violating the safety instructions of a log splitter, values one life year with perfect health less than other people. It is however likely that a healthy person have difficulties assessing the risk of injury, as well as imagining what effect an injury will have, thus making him or her more careless. A person already injured, on the other hand, is probably willing to give up quite a large amount of money to be able to use – for instance – a damaged hand as he/she used to do before the accident. One can conclude that it is easy to make rational choices – when it is too late.

The monetary value of one QALY that is used in this thesis is approximately € 64 000. Discussing human pain and suffering in monetary terms is necessarily a problematic issue. However, this can be very important, in order to assess the cost-effectiveness of for example a new drug, and is becoming even more so, as new and usually more expensive treatments are invented. LFN has estimated that the value of a QALY is approximately 600 000 SEK, which corresponds to about € 64 400. It must be kept in mind, that this value is not absolute or always true. Other values can be assigned, depending on who is doing it. The Swedish National Board of Health and Welfare (Socialstyrelsen) refuses to set an absolute value of a QALY, but concludes that a treatment is to be considered expensive if the cost of one QALY gained exceeds 500 000 SEK \approx € 54 000 (Stenberg, 2007). Since there is no market for pain or suffering, these prices are not prices in the true meaning of the word, but rather assessments of the general public's willingness to pay for one year experiencing perfect health. The increasing number of very costly treatments has made the issue of assigning monetary values to QALYs crucial. In earlier days, this problem was ignored by letting the health care budgets run a deficit, allowing for expensive treatments without a further assessment of the relative utility to the patient (ibid.).

The idea of QALYs might seem somewhat harsh at first glance, valuing economical effectiveness instead of giving each patient best possible care. However, resources are scarce, and using QALYs in modern health care does facilitate maximizing the utility of a given amount of money in terms of improved health and less somatical and mental suffering. For the

decision makers at multiple levels in the health care organisation, better and more efficient outcomes within the budget constraint is easier to obtain using QALYs. Also, it must not be forgotten that the egalitarian view imposing the principles of equal value and fair treatment, are by law coherent within the health sector. The option, that is not to use QALYs, would be far from ethical, since it paves the way for useless and expensive treatments, media power and poorly underpinned treatments based on temporary trends.

Putting Theory into Practice

Estimating Productivity loss

To estimate the loss of productivity according to the Human Capital Approach, we used equations from Posnett and Jan (1996). We made some modifications in order for it to fit Swedish conditions and to offer a good explanation of how the estimation was achieved.

As discussed earlier, the productivity loss is estimated as the employment cost of the firm. The employment cost consists of the gross wage including additional costs of employment, such as social fees and taxes. Posnett and Jan (1996) express this as:

$$\text{Full wage rate} = w' = w(1 + r) + wb$$

Where:

w = gross wage rate

r = the rate of employer payroll (or national insurance) tax.

b = employer superannuation (pension) rate.

Our modification:

$$\text{Full wage rate} = w' = w(1 + h)(1 + s)$$

Where:

h = holiday pay rate.

s = social fees rate, among other fees including rate of employer payroll tax and employer superannuation rate.

Data on average monthly gross wage was collected from the database of Statistics Sweden (SCB) and matched to the occupation of each individual. There were 28 employed individuals with sick-leave of which 23 were men and five were women. We made however no difference in wages due to gender, assuming that the true productivity loss would not differ between genders. Studies have been made that are supporting the fact that the wage gap between men and women within the same company and occupation only to a small extent can be explained by productivity differences (Petersen et al., 2007). Therefore, we chose the wage rate for each occupation that was higher, which most of the times were those of men.

Since the data on the gross wage was for 2006 and the direct costs for 2007, the wages were adjusted to 2007 price level. This was done by using consumer price index from Statistics Sweden. In this way all costs will be presented in the currency value of year 2007. The social fees rate used is also the rate for the year 2007, collected from ekonomifakta.se, being 38.97 % for blue collar workers and 48.33 % for white collar workers. The holiday pay rate was set to 13 %, where 12 % is the legal obligation, but 13 % is a more likely figure, reflecting the different agreements in the labour market.

This full wage rate was then multiplied with the time in sick leave, where one month was considered to be 30 days long. The productivity losses were discounted to the year of the time of injury by using a discount rate of 3 %, following the standard of LFN. It could be argued that since these years of sick leave has already taken place the actual interest rate for those years could be used. In that way the actual cost for those years could be estimated. This is however not common practice, and by using the discount rate of LFN, we will see the cost as it would have been estimated at the same time as the injury, as if faced with the estimated costs at that time. A sensitivity analysis was carried out by using different discount rates in order to estimate the size of impact different rates would have on the costs.

Some early retirements occurred due to the injuries. The resulting productivity losses from these were calculated in a similar way, for the time left to the regular retirement age of 65. Since we did not have the exact age of the individual, but only the age in whole years at the time of injury, an additional six months was put to the age in order to better estimate their actual age. Five weeks of time was subtracted from each year of early retirement and also for those cases when sick-leave lasted a full year, assuming that the individual would have spent

this time on holiday, had he been in the labour force. The length of holiday can be quite different depending on occupation, union agreements, sector of employment etc. The legal obligation is five weeks, which is why we use this length. If the reason for early retirement was a combination of the hand injury and some other illness, the productivity loss due to the hand injury was assumed to consist of 50 % of the total productivity loss.

The productivity loss due to early retirement was subsequently discounted to the year of the injury, in the same manner as for the days of sick leave, following the incidence approach of cost of illness studies.

Implementation of QALYs in the Study

One must realize that putting a numeric value on life quality by necessity is a complicated issue when it comes to both ethical and economical considerations. In health economics, methods have been developed to estimate a price even for things that are not traded at any market. These intangible costs of which loss of life quality is one, must however be dealt with, and in some way measured.

In this study, the two hand surgeons Hans-Eric Rosberg and Lars Dahlin at UMAS assessed, for each of the patients, a EQ-5D score code, based on the existing DASH data, that was collected earlier. These five-digit codes were then translated to quality scores, using Danish TTO-tariffs. Why these tariffs were chosen is discussed above. The quality scores indicate the quality of life one year, ranging from 0 to 1. When multiplying the resulting values (e.g. 0.87), with the patient's remaining years of life, an estimation of the total number of QALYs lost can be made. For obvious reasons, the time of death of an individual is normally impossible to tell. Therefore, the remaining life years' assumption, calculated for each specific age cohort by Statistics Sweden, was used. It is thus an average, so this estimation should not differ very much from the true outcome.

The number of life years lost was then multiplied with € 64 400, thus giving the total cost of lost quality of life (see above for discussion about this amount). However, one must also pay attention to that some kind of discounting has to be carried out, as has to be done for any cost taking place in the future. A more thorough examination of the different viewpoints on this issue can be found in the "Discounting" section. As is recommended by LFN, we chose to use 3 % as the discounting rate.

Results

Costs

In the table below, the costs associated with injuries due to both types of the machines is to be found. All costs are reported in euro of the average currency value of 2007 as reported by the Swedish Central Bank, where € 1 = 9.2481 SEK or 1 SEK = € 0.1081. The productivity loss consists of the costs for sick leave and early retirements, and the separated costs for these can be read out.

Table 3 – The costs associated with both types of machines

Sum	1999	2000	2001	2002	2003	Average	Total
Direct costs	325 600	274 100	140 800	171 900	295 800	241 640	1 208 200
Productivity loss	437 300	366 700	85 600	133 700	679 200	340 500	1 702 500
<i>Sick leave</i>	312 800	170 000	51 800	133 700	266 000	186 860	934 300
<i>Early retirement</i>	124 500	196 800	33 800	0	413 200	153 660	768 300
Life quality loss	3 325 000	1 843 600	305 700	3 172 300	2 906 700	2 310 660	11 553 300
Total cost	4 087 900	2 484 400	532 100	3 477 900	3 881 700	2 892 800	14 464 000

It can be concluded that the costs varies from year to year, 2001 being the year with exceptionally low costs, and 1999 the year with the highest costs. The highest cost is due to lost life quality, standing for 80 % of the total cost. Productivity loss amounts to 12 % and direct costs to 8 % of the total costs. On average, the costs per year are € 2.9 million. If one prefers to leave out the life quality loss, the average cost per year amounts to about € 580 000.

When it comes to the productivity loss, the sick leave and the early retirements make up for about half the part each.

Table 4 – The costs associated with log splitters only

Log splitter	1999	2000	2001	2002	2003	Average	Total
Direct costs	215 900	146 400	118 200	106 900	275 900	172 700	1 035 900
Productivity loss	235 200	54 800	14 200	67 000	679 200	210 100	1 260 500
<i>Sick leave</i>	235 200	54 800	14 200	67 000	266 000	127 400	764 600
<i>Early retirement</i>	0	0	0	0	413 200	82 600	495 800
Life quality loss	1 354 900	641 100	305 700	1 730 800	2 906 700	1 387 800	8 327 000
Total cost	1 806 000	842 300	438 000	1 904 800	3 861 900	1 770 600	10 623 400

2001 was the year with the lowest costs associated with the log splitter, as it was for the sum of both machines. Another year with quite low costs was 2000. The year of 2003 was an exceptionally expensive year.

Table 5– The costs associated with circular saws only

Circular saw	1999	2000	2001	2002	2003	Average	Total
Direct costs	109 700	127 700	22 600	65 000	19 900	69 000	345 000
Productivity loss	202 100	311 900	71 400	66 700	0	130 400	652 100
<i>Sick leave</i>	77 600	115 200	37 600	66 700	0	59 400	297 100
<i>Early retirement</i>	124 500	196 800	33 800	0	0	71 000	355 000
Life quality loss	1 970 100	1 202 500	0	1 441 500	0	922 800	4 614 000
Total cost	2 281 900	1 642 100	94 000	1 573 200	19 900	1 122 200	5 611 100

For the Circular saw, the costs are very unequally distributed between the years. 2001 and 2003 are years with very low costs, and 1999, 2000 and 2002 are years with very high costs, 1999 being the most costly.

When comparing the costs for the two types of machines, it can be seen that the log splitter is rendering higher costs to society than the circular saw. The distribution on the different posts of direct costs, productivity loss, and life quality loss is very similar between the machines, and of course even more to the sum of them.

Productivity loss measured in days

As there is some controversy surrounding the valuation of sickness in money, the days of sick leave and early retirement are presented below.

Table 6 – Days of sick leave and early retirement

Log splitter	1999	2000	2001	2002	2003	Average	Total
Days of sick leave	1 316	437	93	554	2 198	920	5 518
Days of early retirement	0	0	0	0	4 253	851	5 104
Total cost	1 316	437	93	554	6 451	1 770	10 621

Circular saw	1999	2000	2001	2002	2003	Average	Total
Days of sick leave	929	909	303	305	0	489	2 935
Days of early retirement	1 301	2 040	445	0	0	757	4 544
Total cost	2 230	2 949	748	305	0	1 246	7 479

Sum	1999	2000	2001	2002	2003	Average	Total
Days of sick leave	2 245	1 346	396	859	2 198	1 409	8 453
Days of early retirement	1 301	2 040	445	0	4 253	1 608	9 647
Total cost	3 546	3 386	841	859	6 451	3 017	18 100

QALYs lost

Below, the life quality loss is summarized in QALYs instead of in monetary terms. The result is discounted at a 3 % discount rate.

Table 7 – The life quality loss measured in QALYs

QALYs lost	1999	2000	2001	2002	2003	Average	Total
Log splitter	21	10	5	27	45	21	107
Circular saw	30	19	0	22	0	14	71
Total	51	28	5	49	45	36	178

Statistical Differences

The two populations of injuries caused by log splitters and circular saws were tested for statistical differences of the means of the different costs, days of sick leave, HISS- and DASH scores, gender, and number of early retirements. It could be concluded that direct costs arising from log splitters are higher than for circular saws. A two-tailed t-test for equality of means, not assuming equal variance, returned a p-value of 0.026. The statistical difference of the variances could not be assumed due to a p-value of 0.031 for Levene's test for equality of variances.

Costs Adjusted to Country Level

The costs were adjusted to apply for the whole of Sweden using the population data of 2007 as provided by Statistics Sweden. This gives an idea of what the cost could be per year in the country. The result can be viewed in the table below.

Table 8 - Costs per year, adjusted to country level, rounded values.

Sweden, average cost	Log splitter	Circular saw	Sum
Direct costs	880 000	350 000	1 230 000
Productivity loss	1 070 000	670 000	1 740 000
<i>Sick leave</i>	650 000	300 000	950 000
<i>Early retirement</i>	420 000	360 000	780 000
Life quality loss	7 090 000	4 710 000	11 810 000
Total cost	9 050 000	5 730 000	14 780 000

Cost distributed on sold machines

By dividing the annual cost with the number of items sold in the year of 2002; 10 944 and 1 116, respectively (Lindroos, 2006) we calculate the average cost to society associated with each machine sold (see table 3). Thus, it is assumed that the costs and sales figures are stable over a long period of time. It is important to note that these figures are subject of considerable uncertainty since the sales volume only was estimated for a single year, and nothing is known about whether this number is representative for an average year or not.

Table 9 – Cost per machine

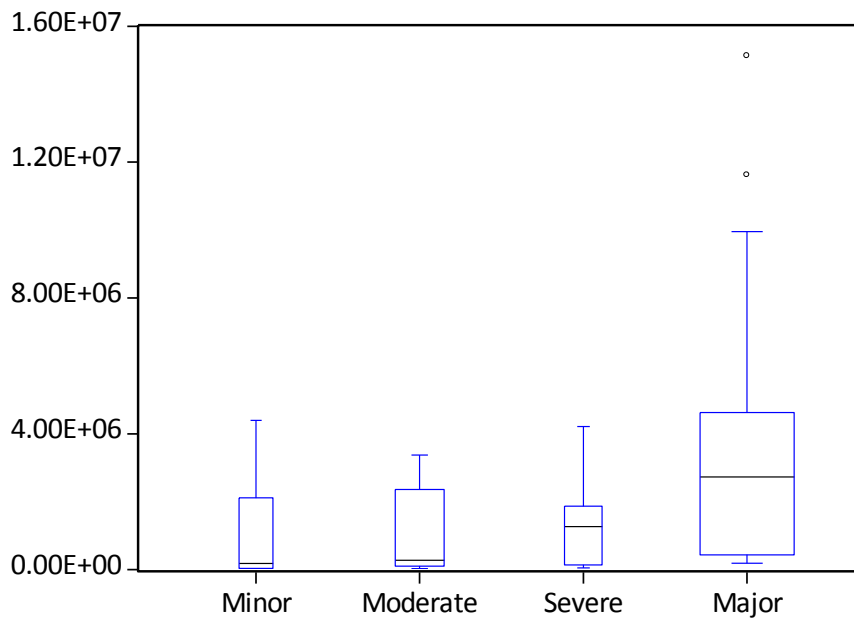
Country level	Log splitter	Circular saw
Machines sold per year	10 944	1 116
Total cost per year	9 050 000	5 730 000
Cost per machine	830	5140

It is worth noting, that, in relation to sales volume, circular saws cause costs about six times larger than log splitters and when comparing with the retail price of a machine the cost is higher. The average price in 2002 was approximately € 730 for both machine types but today, much cheaper machines are available, starting at about € 130 according to pricerunner.com.

Costs Associated to Different HISS Category

The boxplot below illustrates the distribution of the total cost for each of the four HISS categories. The width of the boxes are proportional to the number of observations.

Figure 2 – Distribution of total costs within the HISS categories



The difference in distribution between the categories was tested for statistical significance. Levene's test was carried out to check if equal variances could be assumed in the different HISS categories. If this was the case, a usual t-test to test for equality of means was performed. If not, the Games-Howell-test was used. These tests were performed for each of the cost groups direct cost, productivity loss, life quality loss and total cost.

The direct cost was significantly larger for major injuries than all other injuries ($p=0.0000$). In terms of total cost, a difference could be observed between major and moderate injuries, but this difference was not significant at the 95 %-level ($p=0.063$).

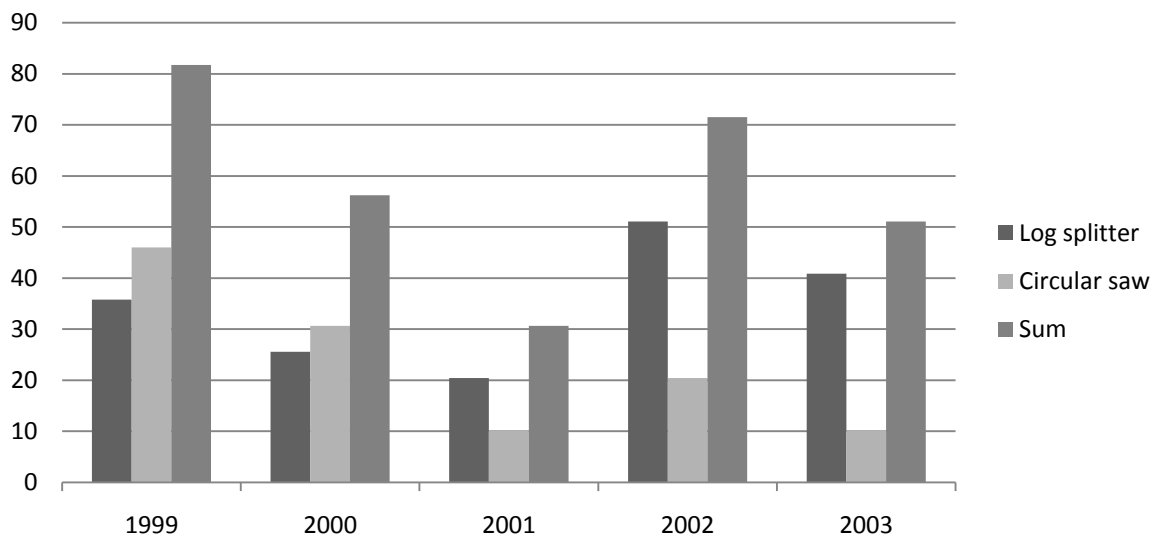
No significant differences between any of the injury categories could be found in productivity loss or life quality loss. Thus, small injuries can also be disabling.

Discussion

Number of Accidents in Sweden

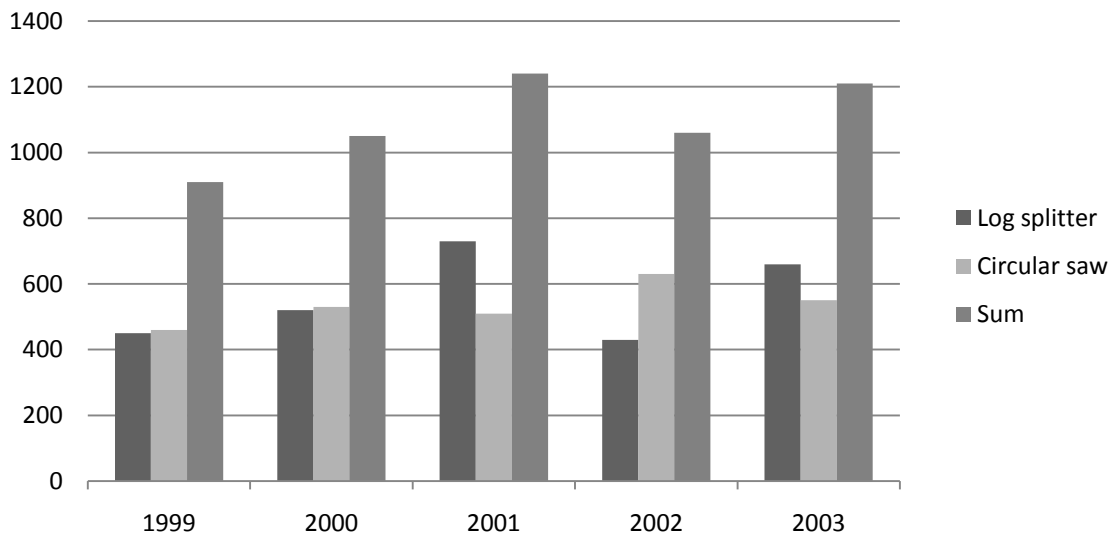
In total, there are 57 accidents recorded in the material that are caused either by circular saws (40 %) or log splitters (60 %), in the southern health care region (defined in the “Prevention costs” section). The numbers were adjusted to country level. As can be seen in figure 5, the total number of accidents varies between 30.5 in 2001 and 82 in 1999.

Figure 3 – Adjusted number of accidents in Sweden, 1999-2003



These results differ substantially from the ones calculated by The Swedish National Board of Health and Welfare, for the same period of time. Their figures are several times larger than ours, which can be seen in figure 4 below. Furthermore, the proportion between accidents caused by log splitters and circular saws differ, even though it seems to be rather random in both sets of data. Two main reasons for this can be seen. Firstly, the four counties in the southern health care region may not be representative in terms of firewood producing for Sweden as a whole. Especially in the south part of the region (Skåne) the presence of forest suitable for firewood production is very limited. In northern Sweden, which is the region of study in Lindroos et al. (2007), forest activities in general are much more common. Statistics Sweden (2005) state that the percentage of houses heated with wood and other bio fuels, is larger in the northern parts of Sweden, which also underpins the theory that the relatively small number of accidents in the southern health care region is due to less use of firewood. What slightly contradicts this theory is the fact that the highest percentage of houses

Figure 4 : Data from the National Board of Health and Welfare; number of accidents



heated with only wood and other bio fuels is found in the heavily forested region of Småland with the islands Öland and Gotland. This region comprises, among others, the county of Kronoberg, which is a part of the southern health care region, thus included in the data material from the University Hospital of Malmö that was used in our study.

Another explanation to the differences in results is the characteristics of the studied population. In the material produced by the National Board of Health and Welfare, the number of accidents caused by different pieces of equipment was assessed from questionnaire surveys at hospitals and care centrals, whose catchment area population amounts to approximately 6 % of the Swedish population (Wänskä, 2008). All information of this kind is stored in an injury database called IDB Sweden. Data from the IDB contains a wide range of injuries, from small shallow wounds to grave life-threatening conditions (IDB Sverige), thus comprising a very large number of patients and injuries. The figures from The National Board of Health and Welfare are simply not limited to grave injuries, requiring specialist attention, as is the material from the department of hand surgery at the University hospital of Malmö. Minor injuries are only to a limited extent treated at the department of hand surgery, since the competence of treating those injuries can be found at local hospitals.

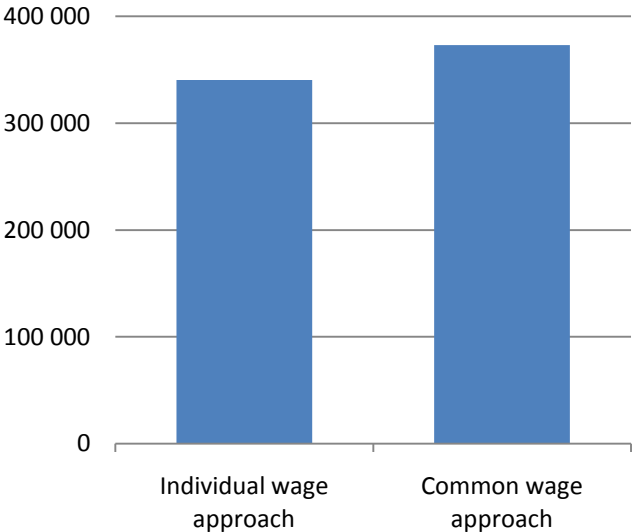
The Effect a Common Wage Would Have

An estimation of the productivity loss with a common wage was carried out in order to grasp what kind of effect this approach would have on the results if it was to be used instead of

individual wages. The common wage used was € 2763 per month. This number was reached by taking the average wage of the year 2006 from Statistics Sweden when counting both men and women, and adjusting this to the year 2007. We did not choose the male wage here since there is a difference in distribution of profession between men and women. The social fee used was the same as for blue collar workers, namely 38.97 %. This approach included two additional individuals with sick leave, specifically one unemployed and one student. Since they did not have any income in the form of wages, they were left out when using individual wages to estimate the productivity loss.

The difference per year with a common wage for all individuals would result in a variation for different years from 17 percent lower values than that of individual wages to seven percent higher. The total and average productivity loss for the years would be estimated as ten percent higher, which is shown in the figure below.

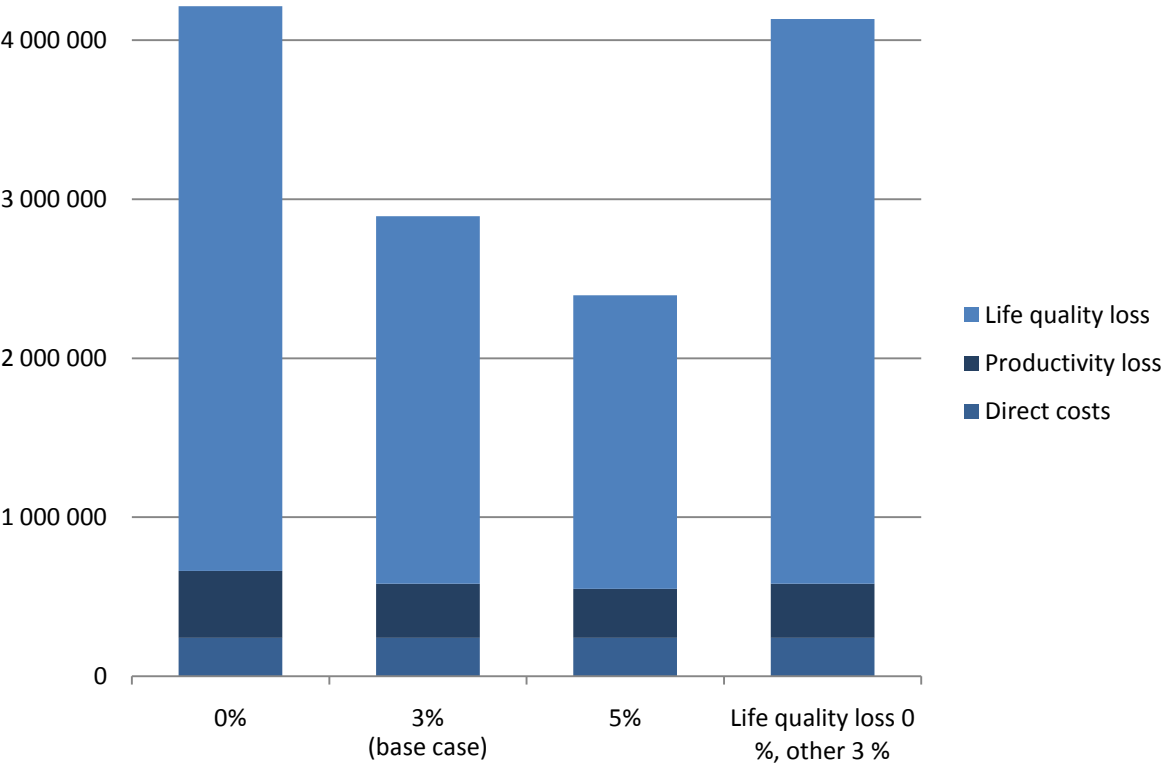
Figure 5 – Estimation of average productivity loss for both machine types; Individual and common wages



Sensitivity Analysis

A sensitivity analysis for different discount rates was carried out to see what kind of impact the discounting has on the costs. It also reveals how sensitive the different costs are to the different discount rates. As recommended by LFN, the rates are 0 %, 3% and 5 %, and also the case where health effects are left undiscounted but the other discounted at the base case level of 3 %. The result is visible in the figure below.

Figure 3 – Total average cost per year using different discount rates



The direct costs are not affected, since they are not discounted, for which reasons have been discussed above. The productivity loss is 24 % higher without discounting (i.e. 0 % discount rate) than with the 3 % discount rate used, and with a 5 % discount rate it is 10 % lower. The life quality loss is estimated to be 54 % higher without discounting, while being 20 % lower at a 5 % discount rate. Looking at the total cost, no discounting would estimate a 46 % higher number, and a 5 % rate a number 17 % lower. The special case where life quality loss is left undiscounted yields a value 43 % higher than the base case scenario.

It is apparent that the total cost is very sensitive to the choice of discount rate. The difference in sensitivity between the costs arising from productivity loss and life quality loss is explained by the fact that the life quality loss is carried under a longer time span than that of productivity loss. While the life quality loss reaches from the time of injury to the expected time of death of the individual, the productivity loss ends at the time of retirement that is at the age of 65 years.

Sources of Over- and Underestimation of the Costs

One source of underestimation of the costs is that expenses and disutility related to visiting the hospital are not included in the study. Such costs are, for instance, transport costs associated with getting to the hospital and back (also known as shoe leather costs) and the productivity loss arising from the time receiving care instead of working. Many people feel uneasy or experience discomfort in health care institutions, thus providing them with negative utility of receiving care from the physician (which generally causes many people to avoid seeing a physician unless it is really necessary). These costs are difficult to estimate but also relatively small, making it hard to motivate why they should be assessed.

It should also be remembered that the costs estimated in the study are those arising from injuries inflicted in the hand or arm. These are the most common limbs injured, but injuries can however also occur in other parts of the body, for which costs are not estimated. Some injuries to the hand might also be so small that there is no need to seek care at the department of hand surgery, but are rather dealt with at the local health centre, and thereby not being part of the study material.

For the productivity loss, it is assumed that if an individual would not have been injured, he would have carried out the same job until the age of retirement, without any unemployment or advancement to higher positions, thus receiving increased wage. That is, an assumption that the real wages will neither increase nor decrease, which of course is not the case in reality. To estimate productivity loss with those, though more realistic, assumptions seems however unmanageable, and would probably not yield any notably different results. As mentioned in the method section, productivity loss arising from non-market activities are not considered, thus leading to underestimation of the productivity loss.

The life quality loss estimation is the product of the expected remaining life span and the annual reduction of life quality. Expected remaining life time is assumed to be the same as for the individual's age cohort, based on the average of the whole Swedish population. That is, a population somewhat different from the one studied, meaning that the expected remaining life time may be different for the studied group before or after the time of the injury. If the individuals injured by the machines are more risk taking than in general, thus more likely to be involved in accidents and thereby having a higher probability than in general to get injured

or killed, this would overestimate the costs. If the injury shortens the length of remaining life, then this is a source of underestimation since more life years are lost. However, if the injury makes the individual more risk aware and adopts a more careful way of living, it would lead to lower life quality loss, thus being a source of overestimation.

Prevention

In this study, the costs associated with injuries that occur due to household firewood production have been estimated. It can be seen from the rather high amounts of money spent on care of these injuries, combined with estimations of the productivity loss and the willingness to pay to avoid the life quality loss associated with the injuries, that a preventative measure is strongly motivated. In this section a closer look will be taken on the existing alternatives of prevention, by looking at the causes of the accidents. How a prevention could be beneficial to society is also discussed further.

Common Causes of Accidents

This section focuses mainly on accidents with log splitters, since there is more information available about this type of machines. There are fewer reported accidents related to circular saws, and circular saws cause fewer accidents per work hour (Lindroos et al., 2007). Either this is because they are safer, or because they seem to be more dangerous, featuring a sharp blade with lots of sharp teeth, thus making the operators more cautious. A study from Massachusetts supports this theory, in observing that circular saws accounted for relatively few injuries, even though they are thought to be quite dangerous (Justis et al., 1987). When comparing the sales figures of 2002 with the number of accidents per year for the two machine types however, the amount of injuries per circular saw sold seems very high in comparison with the number of injuries.

Among the patients in our study material, a large share state that they were injured because of carelessness, 56 %. Weariness, due to monotonous work during long time, can be a factor that increases injury risk caused by carelessness. Children are often present in the situation of an accident, disturbing the working person, or getting their self injured while curiously examining the machine too closely. Accidents relating to presence of multiple adult persons are discussed further down.

Safety instruction for log splitters usually state that the splitter must be placed on a level and stable ground. Precautions to get a good grip between shoes and ground must be made. This is important since slipping, falling, and turnover of the equipment can have disastrous

consequences. When working with screw splitters (however not very common these days) the risk of injury rises if gloves, watches or long sleeves are worn, since those objects can be pulled in by the rotating cone very quickly (Hellstrand 1989).

A very common situation when the accident takes place is that the operator is trying to adjust the log while the ram is moving, thus keeping the hands in the working area of the machine (Holm, 1998). This was the case in 88 % of the accidents observed by Holm.

Thus it can be concluded that the human factor plays the biggest part in the accidents with firewood tools. It is naturally difficult to design log splitters and circular saws to be absolutely foolproof (this goes for any kind of equipment), but more should be able to be done to prevent the human factor from having such large effects.

Dual Working as a Cause of Accident

A study from Denmark shows that several injuries occur when there is more than one person working with the log splitter at the same time (Trier et al., 1989). The associated article tells about two cases where severe injuries have occurred due to that one person was placing the log on the platform while the other operated the hydraulic driving ram. In both cases, the person who was placing the logs had, respectively, one and two of the fingers squeezed between the moving log and the wedge. One of the injured men had to have both his damaged fingers partially amputated (Trier et al., 1989). It is worth noting that in both cases, the machinery was industrial made, and featured a “dead man’s grip”, i.e. that both hands are required to start the movement of the piston, which should make the handling very safe. However, this safety issue is more or less worthless if more than one person is involved in the actual handling of the log splitter.

The standards state that the machines should be used by a single operator, and that wedge type log splitters should feature two-hand controls. When following these instructions, the machines should be safe. There are however indications that the instructions regarding single-person operating often are violated (Lindroos et al., 2006). Some retailers even make it a marketing point that their log splitters can be operated with a pedal, thus leaving both hands free⁶. This is not the case in Sweden.

⁶ <http://www.daviesimplementsltd.co.uk/thor.htm>

In our material there are six injured persons – 10.5 % of all injured persons in the survey – that have declared that there were two persons working together on the machine at the time of the accident. Surprisingly, women were dramatically over-represented among these; four out of six were female (i.e. 67 % women compared to 18 % in the entire study). Not so surprising is that all of these injuries were caused by a hydraulic log splitter. In a study of the University Hospital of Norrland in Umeå, as much as 43 % of the injuries occurred when there was more than one person working with the machine at the same time (Lindroos 2006). As also can be seen from the Danish study cited above, the usual circumstance of a dual-worker accident is that one person places the logs on the platform, while the other one controls the hydraulic piston. While working in pairs, misunderstandings, weariness due to long work time and misjudgement in timing are common contributory causes of accidents (Kristiansen and Seligson 1981).

Existing Safety Measures

Much can be said about the dangers associated with preparation of firewood. Already in a 1981 article in the *Journal of Occupational Medicine*, an increase is noted in the number of hand injuries, combined with a rise in market supply of “hazardous wood harvesting and processing equipment” (Kristiansen and Seligson, 1981). The authors consider the fact that log splitters often are provided on a rental basis, increases the risks for injury, since the users lack experience from working with power tools. A few ideas are presented on the possible means to avoid severe log splitter accidents, for example longer cycle times for the driving rams and a kind of basket that maintains the log in position (which apparently was available on some models at the time). A request for rental companies to offer standardized training demonstrations is also expressed, as well as a wish that consumers should be better informed on the risks associated with these machines (ibid.). Nilsson and Runemo (2007) have similar ideas about the last remark (see next section).

Since 1995, all new machines sold in Sweden have to comply with the European Union safety standards for machine use (EN 609-1; EN 609-2; EN ISO 11681-1; prEN 1870-6) (Lindroos et al., 2007). Interviews with representatives for three of the largest providers of small wood machines, SilvanBygg, Clas Ohlson i Insjön AB and JULA, gives a hint about the safety standard of today’s machinery. All of the three companies claim that the most common type

of log splitter, a horizontal hydraulic wedge splitter, is safe when the safety instruction is followed. The vertical type of log splitter is not sold anymore by any of the above named companies, but is the most common type of log splitter sold in Germany. There should not be a big difference when it comes to safety, however, since a vertical splitter assuredly is harder to modify for single-handed use, but also implies that the hands are closer to the working area (Bortas 2008).

It is a problem that safety features can be overridden. The lever controlling the hydraulic pressure, which requires two-handed operating, can be stuck in the “on” position, for instance with tape or an adequately sized wooden stick. Another easy way to overrule safety features is to work in pairs, one pushing the buttons or levers, while the other feeds logs into the machine.

Suggested Solutions

One of the main goals with this thesis is to discuss the cost and benefits of some kind of preventive action. In our model we will assume that this hypothetical feature will be one hundred percent effective, meaning that it will deter all potential accidents. Of course, such a measure does not exist, but taking into account all different kinds of preventive matters and analysing them and their effectiveness in detail would make the required work effort go out of hand rather quickly. Therefore, we have simply assumed that a new safety attribute would make it impossible to get hurt while working with wood splitting and wood cutting equipment. This measure could be some kind of mechanical device, e.g. protective shields, a law stating that dangerous machine models were to be forbidden or some kind of education in how to handle this type of equipment. There are proposals to subsidize a so called “Chainsaw driver’s licence” education to prevent accidents with this kind of equipment, since this is considered to have a proven effect on risk reducing (Nilsson and Runemo 2007, p. 6). The idea is to give all buyers of chainsaws a voucher, giving them a discount of up to 50% of the price for a chainsaw course (ibid.). Since there already is a market for this kind of education in the handling of other small-scale forest equipment, it is likely that the introduction of a similar education in safe handling for users of firewood machines could give positive effects. An education of some kind is also in line with the observation that it is the operator himself (it is usually a man) that is the direct or indirect cause of the accident.

As mentioned earlier, a basket holding the log in place is suggested by Kristiansen and Seligson (1981). As far as we know, there is no log splitter on the market today where the safety handle (also known as hydraulic handle) is impossible to override. A button or lever that has to return to its original position after every splitting cycle would make it more difficult to overrule the idea with dual hand controls, since the machine will not work if the lever or button is in a fixed position (i.e. stuck due to human intervention).

Financing the Prevention

The construction of the Swedish health care system is indirectly subsidizing risk taking, since the cost of health care to the greatest extent is not carried by the individual but by the whole society. As people do not take costs to society in account when using firewood machinery, this renders an inefficiency which should be subject to an intervention.

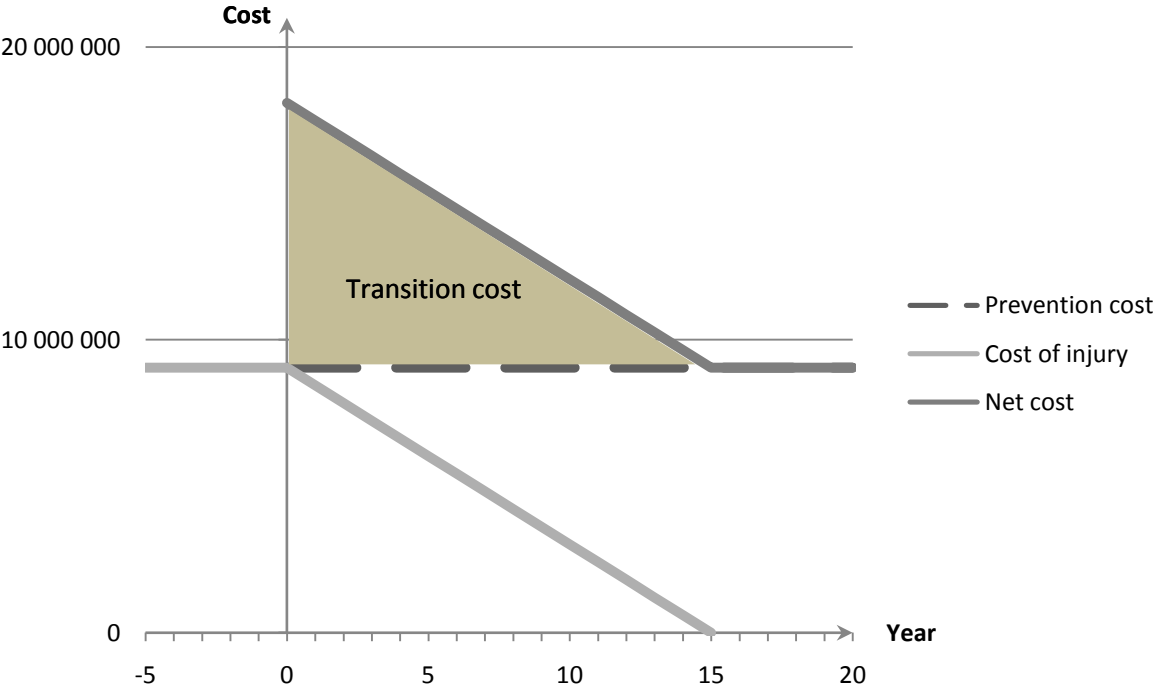
This study has valued a preventative measure to € 830 per log splitter and € 5140 per circular saw, as these are the yearly costs per unit sold. The cost of a prevention could be laid upon the consumer or the retailer, thus lowering the demand for wood splitters, alternatively, decreasing the quantity supplied by the retailer, depending on the different price elasticities at the market. Who formally has to pay is not very important according to microeconomic theory. Another possibility is that the government takes on this cost to lower the number of injuries, for instance by providing some kind of firewood working educational programme, either partly or completely subsidized. In other areas where the use of a product is imposing costs on the society, for instance smoking, taxes are laid upon those products in order for the financing to a higher extent being done by those imposing the costs. In contrast to smoking, firewood production has positive externalities associated to the activity, being for instance a bio-fuel, why such a policy is not recommended.

It is also possible for the government to subsidize safer equipment, so that the price gap between cheaper and more expensive (that is, safer) machines becomes smaller. This would give the customer incitements to invest in less risky machinery. This solution is probably best in combination with new safety standards, driving more insecure models out of the market. However, since Sweden is a member of the European common market, such rules could be hard to implement, both from a legal and practical point of view.

Transition Cost of a Prevention

The following is a hypothetical example of what would happen if a preventive measure, preventing all accidents, was introduced at year 0, amounting to the same cost as the injuries occurring from the accidents. Assumptions made are that the number of sold units per year will be constant, the assumed length of use for the devices are 15 years for log splitters and 30 years for circular saws, and that every unit sold will replace an old unit that has reached its end of use. It is also assumed that the preventative measure not will result in less effective machines, and that the demand for the machines not will be affected. Using the numbers for sales and costs presented earlier, this would lead to a transition cost amounting to € 68 million for log splitters, represented in the figure below by the triangle framed by the y-axis and the lines of net cost and prevention cost. The same cost would for circular saws be € 86 million over 30 years. After the transition period the costs of injury would be completely replaced by the prevention cost.

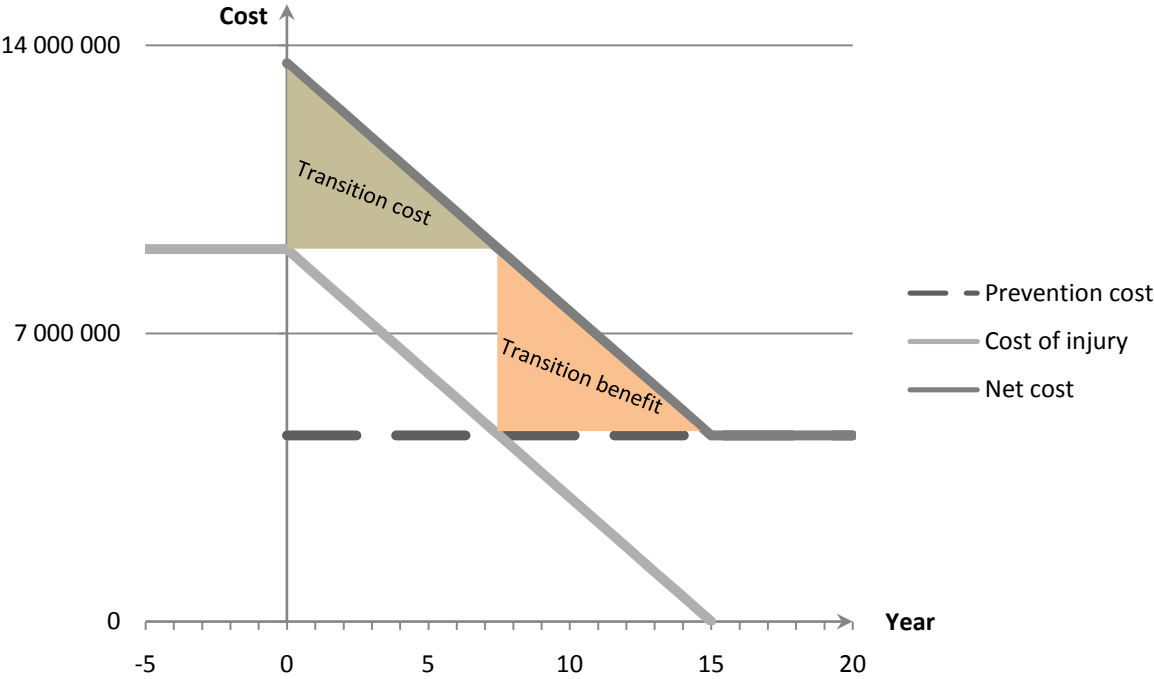
Figure 6 - Transition cost for the preventative measure of log splitter. The cost of the preventative measure is equal to that of the injuries.



If prevention was available at a lower cost per machine than the costs associated per machine, this would also lead to a transition cost, although it would be lower. Over time, this solution

would however be beneficial to society, since the costs after the transition period would be lower than before. It demands however a society able and willing to carry the transition cost. It can be shown that for prevention at the price of half of the injury costs, the net transition cost would be zero:

Figure 7 - Transition cost for the preventative measure of log splitter. The cost of the preventative measure is half of that of the injuries.



Conclusion

This study has estimated the costs to society arising from hand injuries associated with log splitters and circular saws. The result is that there are substantial costs to society from these injuries and the life quality loss stands for the highest cost. It is important though to remember that the costs are very sensitive to the choice of discount rate. There are however great benefits to society of the use of these machines, not estimated here. To simply stop using these machines is thereby not a plausible idea. As the costs are compared to the sales figures, it becomes however clear that the price of a preventative measure could be set quite high, especially in the case of circular saws. Further sales figures are however needed in order to confirm this. A measure that completely eradicates all injuries is probably close to impossible to construct, but we would like to think that some measure preventing many of the injuries, is as possible as it is motivated. If this is the case the society could reach a higher level of utility, which motivates the financing of this measure to be done at a societal level, since the individual do not take these costs into account.

The construction of a preventive measure is however not a problem for economists to solve, but we hope that this study can motivate research into that area. A complete cost benefit analysis is also desirable, in order to be able to conclude that the benefits of these machines are higher than the costs.

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Appendix

Tables in Swedish currency, SEK.

Table 10 – Costs associated with log splitters, rounded values in SEK.

Log splitter	1999	2000	2001	2002	2003	Average	Total
Direct costs	1 996 000	1 354 000	1 093 000	989 000	2 552 000	1 597 000	9 580 000
Productivity loss	2 175 000	507 000	131 000	620 000	6 281 000	1 943 000	11 657 000
<i>Sick leave</i>	2 175 000	507 000	131 000	620 000	2 460 000	1 179 000	7 071 000
<i>Early retirement</i>	0	0	0	0	3 821 000	764 000	4 586 000
Life quality loss	12 530 000	5 929 000	2 827 000	16 007 000	26 882 000	12 835 000	77 009 000
Total cost	16 702 000	7 790 000	4 050 000	17 615 000	35 715 000	16 374 000	98 246 000

Table 11 – Costs associated with circular saws, rounded values in SEK.

Circular saw	1999	2000	2001	2002	2003	Average	Total
Direct costs	1 015 000	1 181 000	209 000	601 000	184 000	638 000	3 191 000
Productivity loss	1 869 000	2 885 000	660 000	617 000	0	1 206 000	6 031 000
<i>Sick leave</i>	718 000	1 065 000	347 000	617 000	0	549 000	2 747 000
<i>Early retirement</i>	1 151 000	1 820 000	313 000	0	0	657 000	3 283 000
Life quality loss	18 220 000	11 120 000	0	13 331 000	0	8 534 000	42 671 000
Total cost	21 103 000	15 186 000	869 000	14 549 000	184 000	10 378 000	51 892 000

Table 12 – Costs associated with both types of machines, rounded values in SEK.

Sum	1999	2000	2001	2002	2003	Average	Total
Direct costs	3 011 000	2 535 000	1 302 000	1 590 000	2 736 000	2 235 000	11 174 000
Productivity loss	4 044 000	3 392 000	791 000	1 237 000	6 281 000	3 149 000	15 745 000
<i>Sick leave</i>	2 893 000	1 572 000	478 000	1 237 000	2 460 000	1 728 000	8 640 000
<i>Early retirement</i>	1 151 000	1 820 000	313 000	0	3 821 000	1 421 000	7 105 000
Life quality loss	30 750 000	17 049 000	2 827 000	29 337 000	26 882 000	21 369 000	106 845 000
Total cost	37 805 000	22 976 000	4 920 000	32 164 000	35 899 000	26 753 000	133 764 000

Table 13 – Costs per year, adjusted to country level, rounded values in SEK.

Sweden, avg cost, SEK	Log splitter	Circular saw	Sum
Direct costs	8 158 000	3 260 000	11 418 000
Productivity loss	9 926 000	6 162 000	16 088 000
<i>Sick leave</i>	6 021 000	2 807 000	8 829 000
<i>Early retirement</i>	3 905 000	3 355 000	7 260 000
Life quality loss	65 576 000	43 602 000	109 178 000
Total cost	83 660 000	53 025 000	136 685 000

Table 14 – Average cost per machine, SEK.

Country level	Log splitter	Circular saw
Machines sold/year	10 944	1 116
Total cost /year	83 660 000	53 025 000
Cost per machine	8000	48000