Self-inflicted injury as a rational decision process: The case of Citrus harvesters in Argentina

Enrique Martin Luccioni

Instituto de Economía - INTA

Currently in the Argentine province of Tucuman there are approximately 45.000 citrus harvesters. In the year 2010, insurance companies began to notice an increase in the amount of suspicious injuries which presented features typical of self-inflicted injuries. What first seemed like isolated cases later became widespread throughout the province to the point that it caught the media's attention. The medical literature considers self-inflicted injuries as intentional destruction of one's body tissue without suicidal intent, for purposes not socially sanctioned. This work analyzes the said behavior from the rational agent view, for that, the self-inflicted injury is used as a deceit tool that diminishes the probability of being discovered. Additionally Argentinean workers compensation law it's examined to detect perverse incentives.

Introduction

Fraud to insurers produces millions of dollars loss every year. This case is particularly important in the worker compensation insurance market, since the fraud strategies imply, many times, to threaten the own body to obtain financial compensation. Following the psychological literature, Klonsky et al. (2011) defines self-inflicted injury as intentional destruction of one's body tissue without suicidal intent, for purposes not socially sanctioned. The psychological literature, furthermore, is focused on intrapersonal functions (i.e. Favazza 2011), and it is seen as a strategy to deal with emotional problems. This behavior seems to be caused by mental disorders, although the self-inflicted injury may be used for different purposes. The biological and sociological literature takes a different approach using signaling theory, for example Hagen et al. (2008) analyzes it as a costly signal in an environment where words do not imply a credible commitment. Nevertheless, this work will analyze the self-inflicted injury from a different view; we will turn to the economic fraud literature to study it as a tool to conceal an accidental state of nature, particularly a work-related injury.[1]

In the province of Tucumán, there are about 45.000 citrus harvesters, known as "swallows", since they go across the country throughout the year performing their duties. Even though they work legally, and therefore they have retirement payments and medical insurance, the work conditions are not optimal (Bendini et. Al 2011). What's more, there are complaints of the "Unión Argentina de Trabajadores Rurales y Estibadores" (UATRE) due to the overcrowding conditions where harvesters are during their stay in other provinces. A basic characteristic of this work, in addition to its migratory aspect, is the temporal nature, since the contracts last less than 6 months, and the payment varies according to the harvested amount by worker.

As of 2010, the insurers started to notice an increase of hand injuries (including fingers) with self-inflicted injury components. What at first seemed to be isolated accidents became later into an endemic issue, calling the attention of the media. The victims usually allege they fell from the stairs, which causes internal trauma or even fissures in the fingers. Then they magnify the real injury, even though self-inflicted, which allows them to receive huge amounts of money.

---

[1] For a detailed analysis of insurance fraud literature, you may consult Picard (2013)

This work proposes a rational agents framework to model the behavior of a dishonest worker that simulates an accident to receive a monetary compensation. The dishonest worker has the option of inflicting injuries on him/herself to diminish the possibility of being discovered. The insurer will have to take into account these behavior when preparing the optimal audit policy. But if the self-inflicted injury deceit function is efficient, a complete audit won't be enough to stop fraud. It may also happen that, if the worker is overcompensated, which means he/she is paid more for the injury than the private loss this represents to the policyholder, even a total injury will be profitable. There are also results related to the audit process, especially if the audit is too severe, this incentives the self-inflicted injury, which diminishes the effective possibility of discovering fraud.

The model presented here is not limited only to the case of hazardous work insurance, there is another possible use, that is to explain the behavior of deserters in the battle field with self-inflicted injuries or any behavior where an audit may be avoided destroying the own resources. This work is organized in the following way. Part I introduces the self-inflicted injury issue from a rational agent viewpoint. Part II and III develop a formal model of fraud with self-inflicted injury. Part IV uses the obtained results to perform an analytic narrative of collected empirical data.

1. The Rational Agents approach

Rational choice theory is widely used in social sciences to predict and explain human behavior in widely diverse situations, from understanding the behavior of an individual who is seeking employment to the final decision made by a suicide victim[2]. If harvesters desire to maximize his utility, then how is it possible that they decide to harm themselves? To answer this question we must understand the context in which the self-harm occurs. In the insurance market there may be a possibility that the policyholders commit fraud. This completely rational decision's aim could be to obtain a sum of money by fraudulently simulating an accident, the cost of the aforementioned action is to be found committing a crime, therefore the stricter the medic-legal examination, the lesser the profit will be from committing fraud.

---

[2] This possibility is studied by Becker and Posner (2004). It is interesting that medical literature makes a clear difference between self-injury and suicide. Even Favazza (2011) presents a complex relation where self-harm acts as means of self-help in order to avoid suicide

The dishonest policyholder has two tools to avoid being uncovered during an inspection, self-inflicted injury and simulation. The first of these diminishes the probabilities of being exposed as the damage inflicted is real and tangible. Simulation, on the other hand, is pretending to have an inexistent injury. The present paper will concentrate on both aspects, the main point is that in a fraud both techniques can co-occur. A person who decides to simulate an injury can self-inflict a real damage but not necessarily as severe as the damage he is simulating which gives him/her a potential benefit.

It is inevitable to make cold conceptualizations and disregard certain aspects in order to understand the rational behavior of self-harmers. Body parts could be understood as capital; however, there is a fundamental difference between conventional capital and human limbs. While in the first case it is possible to access a conventional market where money is willingly exchanged for capital (for example when buying a car), in the second case there does not exist a market for them, mainly because current technology does not allow it. And even if it did, individuals would refuse to participate for several reasons which will be analyzed later. Nevertheless, it is necessary to point out that, although it may be disgusting, certain body parts can be willingly swapped, for example, it is known of the existence of a black market involving the trade of kidneys from living donors, Becker and Elias (2007) analyze the economic effects of said possibility.

Nevertheless, fraud is not a voluntary exchange as only one of the parts is benefited in it, i.e. that the policyholder is benefited at the expense of the insurance company. Summing up, a dishonest policyholder will simulate and self-inflict injuries if the profit is greater than the estimated costs, i.e. If the expected monetary (and non-monetary) income outweighs both the cost of being uncovered and the loss of capital because of self-harm.

1.1 Self-Injury in the Psychological and Sociological literature.

Nock & Prinstein (2004) present a functional self-harm model where they define two dichotomous categories, in first place the reason to self-harm can be intra personal or social, in second place the reinforcement can be positive (if followed by a favorable stimulus) or negative (if followed by the suppression of an unfavorable stimulus). Nock (2008) presents an additional

subdivision in the social category by considering self-harm as a call for help, and as a signal of strength or physical fitness.

With the rational agents approach, Kaminski (2004) studied self-harm based on his personal experience as a political prisoner. He considers two strategic uses of self-harm, on one hand, self-harm as a signal and on the other, as the simulation of an accident. However, he only models the first of these. Gambetta (2009) rationalizes the behavior of prisoners who use self-harm as a strategic signal and also presents the necessary conditions for there to exist self-harm as a costly signal of bravery. Griller (2013) introduces a formalization of the previously mentioned games and a refinement of the requirements for their existence. Following the approach of evolutionary biology, Haget et Al (2008) presents a sophistication of the classic signaling model by considering a multiple period negotiation model, by this hypothesis, if the costs of choosing and exchanging couple are too high, then self-harm can be an efficient mechanism to pressure the partner and that way obtain compromises.

Heide and Kleiber's (2006) forensic medicine study organizes self-harm in three groups, psychological, judicial and material. These last two can be easily modeled with the fraud approach presented in this paper. For example, within the judicial motivations there is the simulation of a penal crime and the defense against recriminations (justify an absence). The motivations are for example, insurance fraud, military draft evasion or improving life conditions in prison by being transferred to a hospital.

The focus on self-harm from Fraud theory is mentioned peripherally by many authors but it is never modeled, for example, Kaminski (2004) explains the utility of simulation in prison and exemplifies with his personal communication with a political prisoner who used simulation and self-harm to be transferred to a different prison. Unlike the signaling approach, the object of this study is to create a model of an individual's behavior who simulates and accident so as to obtain a benefit or avoid a loss. As a tactic to diminish the probabilities of being uncovered, the individual counts with the option to injury himself. Self-harm will not be a signal to transmit an honest message but actually economic fraud theory will be applied and self-harm will be presented now as a tool to deceive an audit process.

It is self-evident that self-harm is a highly repugnant act, as Roth (2006) mentions, repugnancy represents a real constraint to the individual, nevertheless if the livings conditions are critical, taboos disappear and behaviors which in other situations would be unappealing, stop being so. A factor which a priori would seem to directly influence the decision to self-harm is educational level; however is not obvious if an educated person in situation of extreme poverty will not perform aversive acts as a non-educated one.[3]

The decision to self-harm will be functional as long as it is the best option available among other alternatives, for example if the individual has no access to a loan, then the alternatives to obtain money will be diminished. If the individual has a sense of belonging to his institution he will have fewer motivations to commit fraud. It is reasonable to think that for example a patriotic conscript would not avoid doing his military service. Similarly if the objectives of a company are in line with its worker's, then the worker's motivations to do wrong will decrease. Although some works like Miyazaki's (2009) relate the ethic perception of wronging with the perception of injustice, it is necessary to expand such analysis to self-harm, where identity probably plays a leading role.[4]

2. Model with random audit: Only simulation

The model shown below is the fraud and adverse selection model of Picard (1996) and Picard (2013). To summarize, the optimal audit strategy of insurers is modeled in a market where the policyholders have non-observable moral costs, which creates an adverse selection issue. This is due to that some dishonest policyholders with low moral costs will be encouraged to commit fraud simulating an accident. To avoid this, the insurers may commit themselves to a sanction audit policy.

It is assumed that policyholders may suffer a loss L with probability $\delta \in (0,1)$. Policyholders will have to pay a premium P for coverage t. The insurers will audit and detect successfully a fraud with probability $p \in [0,1]$ at a cost c. It is also assumed that L is determined in an exogenous way, that t remains constant whether audited or not, and dishonest policyholders

---

[3] A very aversive behavior is cannibalism, Peña (2008) mentions that in the case of flight 571, which crashed in Los Andes, survivors had to resort to cannibalism. These people are regarded as educated beings and yet they did it due to the extreme situation had to face.

[4] An analysis of the relationship between economy and identity in Akerlof and Kranton (2010)

won't fall into any transaction cost when simulating an accident. An exogenous sanction B is assumed for the policyholders to pay when they are detected committing fraud the more severe they are the lower the incentives to commit fraud will be. This must be considered in a broad sense, as the cost is not only monetary but it also social.

Policyholders will be dishonest with an exogenous determined probability $\sigma \in (0,1)$. Dishonest will simulate an accident with an endogenous determined probability $\alpha \in [0,1]$. On the other hand, honest policyholders will always say the truth since it is supposed that for them it is too expensive to lie. Additionally, it will be supposed that if a dishonest policyholder suffered an accident, he will not have to resort to fraud. The state-contingent net wealth, when fraud is not committed, is given by $W_f = W - P$, the state-contingent net wealth of dishonest policyholders who are discovered committing fraud will be $W_f = W - P - B$ while the state-contingent net wealth of those who are not discovered is given by $W_f = W - P + t$. Finally, the utility of policyholders is represented by a function Von Neumann-Morgenstern $U_{(.)}$ doubly distinguishable.

A three stage game is set out. First, nature decides if the policyholder is dishonest (σ) and if he/she suffered an accident(δ). Second, all policyholders claim the compensation if the suffer an accident. Dishonest policyholders who did not suffered an accident commit fraud with probability (α). After the accidents were reported in stage 2, the insurer audits with probability (p). It is assumed the insurer may be committed to an audit strategy, which implies it has a Stackelberg advantage in the game, and in consequence he will choose the audit probability accordingly to the reaction function of the inmates not involved in an accident.

The variable to optimize is the probability of committing fraud α, so honest policyholders and those dishonest who suffered an accident will not take any decision once they know their condition, in model terms their utility will be $u(W - P + t - L)$ if they suffered an accident and $u(W - P)$ if they are honest policyholders who did not suffer an accident. The case of those dishonest not involved in an accident is different and their utility will be the result of

$$EU = \alpha\left[pU_{(W-P-B)} + (1-p)U_{(W-P+t)}\right] + (1-\alpha)U_{(W-P)} \tag{1}$$

The dishonest policyholder that did not suffer an accident will seek to maximize (1). They will have motivations to commit fraud as long as the probability to be uncovered is minor than a limit probability which will be named $\tilde{p}$. This probability is the result of the derivation of (1) with respect to the probability to commit fraud. The said probability will be the one that guarantees $\frac{\partial EU}{\partial \alpha} = 0$ because in case of indifference, it will be assumed that dishonest policyholders will prefer not to commit fraud. Taking into account the first derivative, making it equal to zero, and clearing p the limit probability is given by

$$\tilde{p}_{(t,P)} = \frac{U_{(W-P+t)} - U_{(W-P)}}{U_{(W-P+t)} - U_{(W-P-B)}} \in (0,1) \tag{2}$$

If $p > \tilde{p}_{(t,P)}$ then $\frac{\partial EU}{\partial \alpha} < 0$ which implies a diminishment of the expected utility if fraud is committed, the opposite will happen if $p < \tilde{p}_{(t,P)}$, then $\frac{\partial EU}{\partial \alpha} > 0$, so the optimal strategy of the opportunists that didn't suffer any loss is given by

$$\alpha_{(t,P)} \begin{cases} = 0 \; if \; p > \tilde{p} \\ \in [0,1] \; if \; p = \tilde{p} \\ = 1 \; if \; p < \tilde{p} \end{cases} \tag{3}$$

On the other hand, the insurers will try to minimize their costs which are given by

$$IC = t\delta + \alpha\sigma(1 - \delta)(1 - p)t \tag{4}$$

$$AC = pc\delta + \alpha\sigma(1 - \delta)pc \tag{5}$$

Where (4) is the expected costs of insurance reimbursement, the first term corresponds to the payment to injured policyholders, while the second term indicates the payment to dishonest policyholders that committed fraud. Equation (5) is the expected cost of the audit, the first term refers to the cost of auditing policyholders, while the second term represents the cost of auditing dishonest policyholders that committed fraud. The total cost will be $C = IC + AC$. The insurer may choose an audit level p that minimizes their total costs, in order to find a equilibrium three levels will be important. Considering the jailer's costs set in (4) and (5) and the policyholders behavior in (3) it is possible to find equilibrium 1.

Equilibrium I. If there is a commitment to an audit policy, the equilibrium of an audit game is characterized by

$$p^c_{(t,P,\sigma)} = 0 \; and \; \alpha^c_{(t,P,\sigma)} = 1 \; if \; c > c_o$$

$$p^c_{(t,P,\sigma)} = \tilde{p}_{(t,P)} \; and \; \alpha^c_{(t,P,\sigma)} = 0 \; if \; c \leq c_o$$

$$C^c_{(t,P,\sigma)} = min\{t[\delta + \sigma(1-\delta)], \delta[t + \tilde{p}_{(t,P)}c]\}$$

$$c_o = \frac{(1-\delta)\sigma t}{\delta\tilde{p}_{(t,P)}}$$

The intuition behind Equilibrium I is simple. Given a premium P, a coverage t and a proportion σ of dishonest policyholders, only two strategies will be viable, auditing until the dishonest policyholders doesn't have incentives to simulate an accident or to refuse any audit allowing the simulation in equilibrium. The optimal decision will be the one that minimizes the insurer costs. Therefore there will be a limit cost c_o under which it will be optimal to audit.

2.1 Characterization of the worker compensation market

There are unique characteristics in the worker compensation market that compel to perform modifications to the shown model. Until now, it has been assumed that there aren't any costs for simulating an accident; this makes sense when the insured object can be easily manipulated, for example Dionne & Gagné (2002) adapt Picard's (1996) model to contemplate a car insurance where the policyholder may hide his vehicle or even sell it in the black market. Nevertheless, it is more difficult to simulate a work accident since the policyholder cannot hide (nor sell) the insured good, in this case the policyholder's own body.

As an example, a typical case of fraud due to self-inflicted injury is described. The policyholder decides to declare an inexistent accident that produces a disability to him/her in his/her hand forefinger. This disability produces a mobility loss reflected in a future wealth loss (L) that has the corresponding compensation (t). To diminish the probability of being discovered, a big damage is done with a blunt tool so the individual has to be nursed immediately to treat the injury. Then he/she has incentives to enlarge the recovery time to keep cashing the salary, for

9

that the policyholder numbs the hand tightening it strong with a kerchief, which diminishes the mobility. Once obtained the certificate of discharge, the policyholder is seen by the occupational health doctor, who will state the disability percentage that will determine the compensation. Again, the policyholder may use different tools to magnify the appearance of the permanent damage, this way the policyholder may deceive the auditing doctor with less damage (that's shortly will be defined as D) that the declared injury (L). In the extreme case the damage is total; the doctor won't be able to detect fraud since complex medical and legal tools will be need.

The market may be characterized by four agents, on one side by the policyholder and his/her medical advisor that has the aim to defend the injured interest, and on the other side the insurer and the medical examiner. The latter has a fundamental role since he/she is not only the one who will state the disability percentage that will determine the compensation, but also the auditor who will make sure that the injury was caused by a work accident and not an intentional action. From here, we will suppose the auditing doctor has a natural skill to discover if the patient really got hurt in accordance with the simulation model, but once he sees a real injury is too difficult to find out if it was self-inflected or as a consequence of a work accident, and even if the doctor has a strong suspect that this is a case of self-inflicted injury it will be supposed he does not count with the necessary tools to classify it as a fraud case. In model terms, this implies that even if the auditing cost (c) is low, as long as there is harm, the skill to discover a fraud will be threatened so it won't be true that the probability of auditing is equal to the effective probability of discovering fraud given a deceit function that's shortly will be defined as $\omega_{(D)}$. Besides, it will be supposed that the aims of the occupational health doctor are lined to the one of the insurer, and for simplicity, medical advisor modelling will be omitted.

In this way the work leaves aside the cost manipulation models of Bond and Crocker (1997) where manipulation affects directly the costs and falsification models of Crocker and Morgan (1997) where the policyholder raises the received compensation over sizing the injury. It won't be a necessary condition to guess that dishonest policyholders appraise their body less than the rest of the policyholders. For example Bouergeon and Picard (2000) suppose an arson model where the policyholder has private information about the real value of the property, and this is

the characteristic that incentives them to destroy their own assets, however, the self-inflicted damage does not affect the probability of being uncovered.

3. Model with auditing manipulation: Simulation and self-inflicted injury.

Now there is a change to the original model to include the possibility for dishonest policyholders to inflict injuries on themselves to diminish the probability of being detected by deceit function. Dishonest policyholders inflict a damage $D \in [0, \infty)$ that will cause an effective wealth loss. At the same time, $\omega_{(D,L)} \in [0,1]$it is a technology that allows diminishing the probability of being detected[5]. This way the auditing probability p will differ from the effective probability of discovering s dishonest policyholder given by $p\omega_{(D)}$. It is supposed that $\omega_{(D=0)} = 1$, $\omega_{(D \geq L)} = 0$ and that $\frac{\partial \omega}{\partial D} < 0$. This implies that if the damage is total, then the effective probability of being discovered is non-existent, so the doctor is not able to differentiate a real accident from a fraud when the harm is total.

A new game of three stages is set out. First, nature decides if the policyholder is dishonest $(\sigma)$and if he/she suffered an accident (δ). Then all policyholders claim the compensation if they suffer an accident. Dishonest policyholders decide to commit fraud with probability(α) and inflict injuries on themselves to a damage level (D). After the accidents were reported in stage 2, the insurer audits with probability (p) y and discover fraud with probability $p\omega_{(D)}$

The inclusion of the self-inflicted injury will produce significantly different results in the optimal auditing policy. The deceit function can be understood as one which allows to diminish the probabilities of being uncovered with the minimal possible damage, and also as one which allows to minimize the risk of a "mala praxis" when self-injuring. It condenses the policyholder ability to diminish the probabilities of being uncovered after self-harming. For example, those that are more talented at lying will be able to diminish the probability more easily; on the other hand, incompetent auditors may be deceived with low damage wounds. It must be noticed that as long as new and better examinational tools are used then the more effective the audit will be. It is

---

[5] *L* Represents the loss for disability once the injury healed. Dishonest policyholders have incentives to feign an injury worst than the real damage, for that *D* is not necessarily equal to the simulated total loss *L.* In practice, an injury that produces a wealth loss of *L* may be reached in different ways, from sprains to burns.

important to notice that as long as this technology improves, the motivation to self-harm will increase independently of what happens with the other examined variables.

Intuitively, a decreasing and convex deceit technology implies that with relatively low damage the effective probability of being uncovered may rapidly diminish. More convex functions guarantee the same level of deceit with a minor level of self-harm. It is possible to think an extreme case where a tiny amount of damage guarantees not being detected which could occur if the policyholder is extremely skilled at deception, or if the auditor is completely incompetent at detecting frauds. Graph I shows three convex functions, $\omega_{(D)}^3$ can be considered as the most efficient one, as it can produce the same level of deceit with a minor amount of damage.

Graph I – Deceit functions technologies

The expected utility of the dishonest policyholder that did not suffer any loss (6) will be similar to equation (1) with the deceiving function added, self-harm will generate a loss of utility, but it will also generate an increment of the expected utility by diminishing the effective probability of being uncovered.

$$EU = \alpha\big[p\omega_{(D)}U_{(W-P-B-D)} + (1 - p\omega_{(D)})U_{(W-P+t-D)}\big] + (1 - \alpha)U_{(W-P)} \qquad (6)$$

It is then evident that a the expected utility may increase if it is guaranteed that for relatively low levels of damage, a more than proportional diminishment in the effective probability of being uncovered (and punished) takes place. This result is the main reason to add self-harm as an additional tool to conceal a fraud. Taking the first derivative with respect to $\boldsymbol{\alpha}$ found the expected utility of committing a fraud for a given audit level.

$$\frac{\partial EU}{\partial \alpha} = p\omega_{(D,L)}U_{(W-P-B-D)} + \big(1 - p\omega_{(D,L)}\big)U_{(W-P+t-D)} - U_{(W-P)} \qquad (7)$$

Once again the optimal strategy of the policyholder will be committing fraud while the condition $\frac{\partial EU}{\partial \alpha}$ is positive. Moreover the policyholder may inflict an injury on his/her self to increase the expected utility. The said condition implies to find an optimal harm level when deriving the condition $\frac{\partial EU}{\partial \alpha}$ with respect to D, i.e.

$$\frac{\partial EU}{\partial \alpha \partial D} = p\left\{\frac{\partial \omega_{(D)}}{\partial D}\left[U_{(W-P-B-D)} - U_{(W-P+t-D)}\right] + \omega_{(D)}\left[U'_{(W-P+t-D)} - U'_{(W-P-B-D)}\right]\right\} - U'_{(W-P+t-D)}(8)$$

From equation (8) and the second order condition presented in the annex, a level of self-harm which maximizes the expected benefit can be found. The optimal damage is the result of an interaction between the real cost of self-harming and the profit expected by the diminishment of the effective probability of being uncovered.

Result 1. Given an auditing level $p > 0$ there will be a deceit technology $\omega_{(D,L)}$ convex enough to guarantee a harm level $D^*_{(p)} \in (0, L]$ that maximizes the expected utility to commit fraud.

Result 1 suggests that if the simulation technology is effective enough to quickly diminish the probability of being detected, there will be auditing levels for which the optimal strategy of policyholders will be to inflict injuries on themselves. It is clear by observing equation (8) that while there is no audit, there is no sense to inflict an injury. Nevertheless, as long as the auditing probability increases, self-inflicted injuries may increase the expected utility. This level will never be higher than the damage that is intended to simulate, as it was assumed that $\omega_{(D \geq L)} = 0$

The maximization process is the following, for a certain audit level the dishonest will determine a self-injury level which will maximize his expected utility (7). Once the optimal damage for a given level of audit is known, the policyholder must consider if self-harming is worth it, in relation to the models, this implies knowing the maximization condition's (7) behavior, if it is fulfilled that $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} > 0$ then the policyholder will decide to commit fraud, if $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} \leq 0$ then he will not. Similarly to (3), the optimal strategy will be given by (9), with the difference that now, committing fraud depends on the optimal damage D^* and the new indifference audit will be named $p^*_{(t,P,D^*)}$.

$$\alpha_{(D^*)}\begin{cases} = 0 \; if \; \frac{\partial EU_{(t,p,D^*)}}{\partial \alpha} < 0 \; with \; p > p^*_{(t,P,D^*)} \\ \in [0,1] \; if \; \frac{\partial EU_{(t,p,D^*)}}{\partial \alpha} = 0 \; with \; p = p^*_{(t,P,D^*)} \\ = 1 \; if \; \frac{\partial EU_{(t,p,D^*)}}{\partial \alpha} > 0 \; with \; p < p^*_{(t,P,D^*)} \end{cases} \qquad (9)$$

Graph II summarizes said analysis for different audit levels $p_0 < \cdots < p_4$ under the assumption that $t < L$ (sub coverage). If $p_0 = 0$ then the damage will be null as there will not be any benefits

in self-harming. If the audit level is p_1 then there will be a damage level that maximizes the expected utility, notice that $\alpha_{(D^*)}$ will be one. If the audit level is p_4 there will be a maximum in $D^*_{(p_4)} = L$, but for that damage $\alpha_{(D^*)}$ will be zero. For higher damage values (7) will diminish because $\omega_{(D \geq L)} = 0$ which implies that the effective probability of discovering fraud is zero, so no additionally benefits will be obtained after $D^* > L$.

Graph II –Fraud incentives with self-injury

Result 2. If $t = L$, $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} = 0$ if there is an audit level $p \geq p^*_{(t,P,D^*)} \in [0,1]$ that guaranty $D^* = t$ so that $\omega_{(D^*)} = 0$

Result 3. If $t < L$, $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} = 0$ if there is an audit level $p = p^*_{(t,P,D^*)} \in [0,1]$ that guaranty $D^* < t$ so that $\omega_{(D^*)} > 0$.

In case of sub coverage ($t < L$) the dishonest policyholder will never completely self-damage. In Graph II, the audit level p_4 implies maximization with total damage ($D^* = t$), but (7) will be negative so for p_4 the dishonest policyholder will not deceive. Notice that p_3 guaranties indifference to fraud with less than total damage. When coverage equals the value of the loss ($t = L$) the audit probability that fully disincentives fraud will have an associate damage equal the coverage. This is not graphed but imagine that the curve for p_4 touch the axis when $D^* = L$.

Result 4. If $t > L$ so still with total damage, i.e. $D^*_{(p)} = L$, $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} > 0$ for any auditing level.

In case of overcompensation even if every case was audited, the auditor will never be able to effectively demonstrate that the injury is a fraud if the damage is total. It is important to note that the result does not depend on the deceit technology's convexity but on the assumption $\omega_{(D \geq L)} = 0$, this means that if $D^* = L$ the auditor does not have the necessary tools to pronounce the case as a fraudulent one. There are different ways where the payment can outweigh the loss. A possible case is that the policyholder may give less value to his extremities that the insurance payment. Another case is where the state regulates the value of compensations and a higher payment is assigned.

Graph III shows what happens if it is supposed that $t > L$, every curve converges at the same point in the positive zone when the damage is total as (7) will not depend on the audit level, due to the assumption $\omega_{(D \geq A)} = 0$. For values $D > L$ the expected utility derivative is always diminishing and therefore any additional damage will only cause losses.

Graph III –Fraud incentives whit overcompensation

Result 5. Even if $t < L$ there won't necessary be an auditing level $\boldsymbol{p}^*_{(t,P,D^*)} \in [0,1]$ guaranteeing

$$\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} = 0$$

If $p^*_{(t,P,D^*)}$ is defined as the probability which guarantees that prisoner is indifferent to commit fraud, this will not necessarily be found in interval [0,1]. Equation (10) represents the effective probability of fraud discouragement $p\omega_{(D)} \in (0,1)$ with $\omega_{(D^*)} \neq 0$.

$$p^*_{(t,P,D^*)}\omega_{(D^*)} = \frac{U_{(W-D^*)} - U_{(W-l_i)}}{U_{(W-D^*)} - U_{(W-B-l_i-D^*)}} \in (0,1) \tag{10}$$

But there are no reasons that guarantee $p^*_{(t,P,D^*)} \in (0,1)$ because $\omega_{(D^*)} \in [0,1]$. In graph II a particular case can be observed, where $p_3 = p^*_{(t,P,D^*)}$ guarantees $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} = 0$, nonetheless, nothing ensures "a priori" that the audit probability exists in the interval.

Result 6. If $t \leq L$ and there is an auditing level $p^*_{(t,P,D^*)} \in [0,1]$ guaranteeing that $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} = 0$ so $p^*_{(t,P,D^*)} \geq \tilde{p}_{(t,P)}$

If policyholders inflict injuries on themselves, the limit auditing level guaranteeing that they don't commit fraud is always higher or equal to the case of just simulation. When $p = \tilde{p}_{(t,P)}$ the expected utility from committing fraud without self-harms is zero, which is coherent with the simulation-only model. However, it is possible to obtain a higher expected utility by self-harming a level D^*. This result can be observed in graphs II and in III for $p = \tilde{p}_{(t,P)}$ where the absence of any damage implies $\frac{\partial EU_{(t,P,D=0)}}{\partial \alpha} = 0$ while $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} > 0$

Result 7. If $t = L$ The effective probability of detecting a fraud given by $p\omega_{(D)}$reaches a maximum with respect to the auditing level p.[6]

Result 7 presents a strong implication, as high audit levels may imply a minor effective probability of uncovering a simulator. Graph IV summarizes this information: as the audit reaches the probability $p^*_{(t,P,D^*)}$, the effective probability $p^*_{(t,P,D^*)}\omega_{(D^*)}$ diminishes toward cero, however, for $p < p^*_{(t,P,D^*)}$it will be fulfilled that $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} > 0$ which implies that $\alpha = 1$, and in consequence, a progressive path towards $p^*_{(t,P,D^*)}$will mean an initial growth of the effective probability until a maximum is reached at $\bar{p}$ and then a diminishment until they are indifferent between committing fraud or not, i.e. where $\frac{\partial EU_{(t,P,D^*)}}{\partial \alpha} = 0$ and therefore $\alpha = 0$.

Graph IV- Effective probability

As in the simulation-only case, auditors seek to minimize their costs, but now the effective probability of uncovering a dishonest inmate affects the expected effort cost.

$$IC = t\delta + \alpha\sigma(1 - \delta)(1 - p\omega_{(D)})t \tag{11}$$

$$AC = \delta pc + \alpha\sigma(1 - \delta)pc \tag{12}$$

Where IC is the expected costs of insurance reimbursement made in transferring the injured inmate and AC is the audit's expected cost. The new total cost is very similar to the simulation-only case, with the aggregate of the deceit function in the effort's expected cost. To obtain the equilibrium the total costs will be defined, C_n in the case that there is no audit, C_m if the effective probability is maximized, and lastly C_a if fraud is completely refrained. The new equilibrium of the auditing game is given by equilibrium 2.

Equilibrium 2. If there is a commitment to an auditing policy and it is accomplished that $t \leq L$ and $p^*_{(t,P,D^*)} \in [0,1]$, the equilibrium of an auditing game is characterized by

$$p^c_{(t,P,\sigma)} = 0 \ and \ \alpha^c_{(t,P,\sigma)} = 1 \ if \ c > c_o$$

---

6 For simplicity this result will be derived for $t = L$ but I can be extended to sub coverage levels.

$$p^c_{(t,P,\sigma)} = p^*_{(t,P,D^*)} \; and \; \alpha^c_{(t,P,\sigma)} = 0 \; if \; c \leq c_o$$

$$c_o = \frac{(1-\delta)\sigma t}{\delta p^*_{(t,P,D^*)}}$$

$$C^c_{(t,P,\sigma)} = min\{t[\delta + \sigma(1-\delta)], \delta[t + p^*_{(t,P,D^*)}c]\}$$

If $t > L$ or if $p^*_{(t,P,D^*)} \notin [0,1]$, then the audit game's equilibrium is characterized by

$$p^c_{(t,P,\sigma)} = 0 \; and \; \alpha^c_{(t,P,\sigma)} = 1$$

The new equilibrium differs from Equilibrium I in various aspects. First, per result 4 the compensation for injury should be necessary lower than the policyholders private injury valuation, if it is not like that the damage will be total and it won't be discovered. Second, per result 5, it is inferred that the auditing probability should fall into the feasible range, if not; even a total audit won't be able to stop dishonest policyholders. Third, per result 6, it is inferred that auditing a self-inflicted injury implies a higher auditing level that just auditing simulation, so it is more expensive.

Finally, per result 7 a new potential equilibrium might arise when the effective probability of detecting fraud is maximized, but it will be shown that is not an optimal strategy. Additionally the limit audit cost c_o that will make audition preferable needs to be lower in Self-injury case because of result 6. It can also be mentioned that no damage exist in the equilibrium if the insurance company commits to an audit policy.

By supposing lineal utility functions and $\omega_{(D,A)} = 1 - \left(\frac{D}{A}\right)^\varphi$ it is simple to find the optimal damage level for a given audit level using equation (7) and (8). The φ parameter determines the function's convexity, if $\varphi \in (0,1)$ then the $\omega_{(D)}$ function will be decreasing and convex, the lower the parameter is, the higher the prisoners' ability to diminish the audit probability will be.

$$D^* = \left(\frac{p(t+B)\varphi}{L^\varphi}\right)^{\frac{1}{1-\varphi}} \tag{13}$$

Equation (13) shows that the optimal damage will be higher as the punishment for being uncovered, the audit probability and the coverage increase. The behavior $\frac{\partial D^*}{\partial L} < 0$ deserves attention, the deceit function indicates that the more serious the accident simulated is, the higher the damage needed will be so as to achieve the same level of deception. i.e. if $L_1 > L_2$ then $\omega_{(D,L_1)} > \omega_{(D,L_2)}$, however, the actual loss by self-harm will have an impact independently of the accident simulated, this implies simulating more serious injuries, which refrains the inmates from self harming, as the benefits diminish.

A general result of $\frac{\partial D^*}{\partial \varphi}$ cannot be obtained, if the denominator in equation (13) is greater than the numerator then there will be a value of φ which maximizes the damage. If $t = L$, using (13) and knowing that $D^* = t$ (by result 2) then using the first order condition (7) the optimal audit level can be derived as (14) which clearly shows that the audit level could be greater than the unity (result 5) if the deceive function is efficient enough and that greater levels of punishment guaranties a lower audit probability.

$$p^*_{(t,P,D^*)} = \frac{t}{(t+B)\varphi} \tag{14}$$

4. The case of the citrus harvesters in Tucuman

Currently, in the Argentine province of Tucuman there are approximately 45.000 citrus harvesters (UATRE reports). In the year 2010, insurance companies began to notice an increase in the amount of suspicious injuries in hands and fingers which presented typical features of self-inflicted injuries. What at first seemed like isolated cases, later became widespread throughout the province to the point that it caught the media's attention. It cannot be denied that there are factors which affect the decision of self-harm which go beyond the relation between the value the individual gives to the self-inflicted injury and the compensation he or she expects in return; it is known that even with proper documentation, retirement contribution and medical insurance, the living conditions of the harvesters are not optimal (Bendini et. al). The *Argentine union of rural workers* (UATRE by its initials in Spanish) has reported many cases of overcrowding in the workplace suffered by migrant workers. It is highly likely that these conditions affect the

decision to self-harm; however, this section will only analyze the motivation strictly related to the compensation payment.

Following Neiman (2010) the harvest is the most labor intensive of all the labor activities on citrus industry; most of the time this work is made by external specialized contractors. Harvesters are usually young men from the suburbs of Tucumán. Harvest occurs three times a year. The first "winter cut" is made between April and July, when the best fruit is picked, and it covers 60% of the production. The second "winter cut" is made between July and September with only 20% of the production. The 20% left is picked in the summer and it is sold in the domestic market.

4.1 First case of Analysis

The first case of study corresponds to a database provided by an insurance company which includes data of injuries in a specialized harvest firm. It presents 451 accidents from 2010, in which 83 accidents were hand injuries (including fingers), being the second more frequent injury (10,9%) after knees (11,3%), and followed by eye injuries (10,4%). 24 cases of self-injury in hands (including fingers) were recognized by a medical auditor; although these cases were noticed as fraud, the auditor lacked the legal tools to sanction them.

Table I presents a comparison of days on leave by the three most common types of hand injuries between the harvesters that committed fraud (22 cases) and those who did not committed fraud or were not discovered (39 cases). It can be seen that in the case of contusions and internal trauma, days lost are bigger in average for self-injurers; in the case of fractures the opposite happens. However, it must be said that there are only 8 cases of hand fractures registered so the results might be biased. As a means to achieve an objective level of injury, harvesters take two distinctive fraudulent actions. Firstly, they self-harm and avoid treating the injury correctly in order to extend the time on disability leave; and secondly, the exaggeration of the injury by means of simulation. These behaviors show that dishonest harvesters might have incentives to extend healing times.

Table I – Days on leave by type of hand injury

Another interesting pattern found in the data is the declared day of occurrence, Graph V shows that almost 50% of the fraudulent claims where declared as if they happened on Saturdays, in clear opposition with the rest of hand injuries that seems to be evenly distributed between weekdays. This behavior can be explained by the deceit function that has been just modeled. It might be the case that they effectively self-injured on Saturdays or it might be part of an elaborated plan, either way this anomalous behavior shows that dishonest harvesters need to tale a history about how they accidentally get injured. It can also be said that only 1 out of 24 self-injured cases was a female, while 15 out of 59 cases in the control group where females.

Graph V - Declared day of occurrence

4.2 Second case of analysis

Another insurance company provided a database which includes data about two different harvester companies. The database presents 1972 accidents from 2005 to 2014. 203 of the aforementioned accidents were finger injuries, being the third more frequent injury in 2014 (13,8%), after knee (29,8%) and eye injuries (7,4%). Among finger injuries, the most common type of trauma are incised wounds with 48 cases, followed by internal trauma (44 cases) and closed fractures (42 cases). As it is very difficult to find accurate data about the number of frauds in worker's compensation insurance, aggregated statistical data will be used, which does not contain specific information about the cases of frauds. However, certain patterns can be detected, which could indicate the existence of fraudulent insurance claims.

Graph VI shows the number of accidents during the year, which displays the first abnormal patterns. While all accidents have a symmetrical distribution centered in July (21,8%) when accidents are more frequent as it is the most intensive working period (Neiman 2010), closed fractures of fingers reach their peak in August (43,6%). Additionally, the average time on leave in august for fingers closed fractures is almost 90 days while the rest of the year the average time is 74 days so not only frequency clearly rise during august but also the average time-on-leave.

Graph VI– Accidents by month

Data also shows that out of 1972 accidents between 2005 and 2014, only 243 of them took place in 2013 (12,3%), while 20 out of 39 closed fractures of fingers took place in 2013 (51,3%), highlighting that in 2013 finger fractures were disproportionately higher, probably due to fraud. In fact after consulting with auditors of the insurance company they complained about the high proportion of fingers fractures on these two firms with high fraud suspicions. As a way of illustration, the number of hand and eye injuries over the total accidents between 2005 and 2014 will be compared. There can be seen that finger injuries reach their peak in 2013 (17,3%), from which it begins to fall, probably due to the intensification of controls and audits. Meanwhile, eye injuries fall steadily over the years, from 28,3% en 2005 to 7,4% in 2014.

4.3. Law Analysis

In Argentina, law 24.557 rules workers compensation, the law aims to prevent risks during work and repair damage from accidents in the workplace. Workers have a right to receive monthly payment from their ART (Spanish acronym for occupational insurance firm) during the time in which they cannot return to their activities (with a maximum period of a year or until medical clearance) and an adequate amount of money (according to the formula which determines the base income), plus a compensation (in cases where there are permanent consequences). The formula used to calculate the compensation is the result of

$$t = 53 * Monthly\ base\ imcome * \%disability * \frac{65}{age} \tag{15}$$

Where 53 is and arbitrarily number, the monthly base income is the sum of daily wages and year-end bonuses minus retirement contributions and medical insurance payments during the last year and then calculate an average of the time worked. The disability percentage is set, in the particular case of finger injuries, accordingly to the functional limitation produced by the accident. Lastly, the term $\frac{65}{age}$ represents an age weight which will be higher the younger the individual is, so younger individuals who had a higher income in the last year and a more serious disability will receive a bigger compensation.

This formula has a couple of general problems which will be described next. Firstly, the payment does not necessarily represent what would be paid in an unregulated market, this could lead to

over compensating an injury, which consequently raises the motivations to self-harm. As it was previously mentioned, if the individual considers that to self-harm will outweigh the future loss of earnings then he will have motivations to incur serious self-injury as the audit process will be more complex. Secondly, the monthly base income is calculated according to daily wages and year-end bonuses obtained during the 12 months prior to the accident. However, people's productivity has cycle along their lives, according to this formula income will be constant throughout life and equal to those of the last 12 months. Thirdly, disability percentage can lead to inconsistent results. Decree number 659/96 contains disability charts, in which it can be observed that the amputation of a little finger causes a disability of 5%, whereas functional limitations in a little finger can be of 14%, this means that the loss of a finger generates less disability than a fracture in the same body part, also, while amputation values are different depending on the affected finger, functional limitation values only differentiate between thumbs and the remaining fingers. Therefore, motivations to self-injure less functional fingers will rise.

In the particular case of harvesters, the compensation formula used creates two other motivations to commit fraud. Firstly, the harvesting labors are seasonal, citrus harvesting season normally extends from April to August, workers receive a government subsidy called "Inter zafra" by which they receive a payment during the months in which they do not work. Still, the income from the subsidy is not as high as the payment received during the harvest. The point is that, income from harvesting is temporal and law 24.557 accounts those values yearly, therefore its payment will be an overestimation of the value for future loss of earnings. Also, we cannot forget that by law the ART must pay for the months on disability leave, in the particular case of the harvesters this is important as if the injury is coincident with the last month of the contract, then the insurance company will have to continue paying the worker during the time he is on leave. This may explains why the average time on disability leave is higher in the months nearing the end of the harvest.

Secondly, a harvester's job involves moving away from home. According to the migration model developed by Harris and Todaro (1970) it is evident that those who decide to migrate in order to work expect to earn an income which compensates the fact of being away from their homes and

which also covers the additional travel and living expenses. If a harvest worker is injured, he can return home and still get paid.

Conclusions

It is clear that self-harm can be inflicted with different goals in mind, Hagen et al. (2008) and Gambetta (2009) use economics to explain deliberate self-harm as a sign which transmits credible information. The present paper seeks to explain self-harm through the use of the rational agents model and define it as a tool to mask an accidental state of nature. It can be concluded that there are different motivations which can explain how a behavior, which may normally be deemed aberrant, can be seen as perfectly rational.

The formal model shows that if self-harm exist then the audit process must be much stricter in order to prevent that behavior. And even if every case was audited, motivations to self-harm would still exist, whether because the deceive technology is good enough to cover up the fraud, or because the compensation payment is higher than the personal assessment the policyholder makes of his injury. Therefore, in a market where self-harm exists, the audit process will be much more expensive.

A descriptive analysis of collected data is presented; the analysis shows that the average days on leave of dishonest policyholders tend to be greater than the rest of the harvesters, additionally aggregate data shows that while all accidents have a symmetrical distribution centered in July when accidents are more frequent as it is the most intensive working period, closed fractures of fingers reach their peak in August.

Finally, an analysis is made on the reasons why insurance fraud via self-harm seems to be an attractive decision for Tucuman's harvesters. Although is limited to the analysis of the motivations product of the compensation formula used in law 24.557. There are strong reasons to believe that compensation payment overestimates the real value of the loss and therefore workers would be benefited as committing fraud maximizes the expected benefits.

References

Akerlof, G. A., & Kranton, R. (2010). Identity Economics: How Our Identities Shape Our Work, Wages, and Well-Being. Princeton Press.

Becker, G. S., & Elias, J. J. (2007). Introducing incentives in the market for live and cadaveric organ donations. *The Journal of Economic Perspectives*, 3-24.

Becker, G. S., & Posner, R. A. (2004). Suicide: An economic approach. *University of Chicago*.

Bendini Isabel, Steimbreger Graciela, Trpin Verónica 2011. Trabajadores agrarios estacionales migrantes. Características y funciones de la intermediación laboral en los mercados de trabajo agrario temporario. Serie estudios e investigación n 31. Minagri

Bond, E. W., & Crocker, K. J. (1997). Hardball and the soft touch: the economics of optimal insurance contracts with costly state verification and endogenous monitoring costs. *Journal of Public Economics*, *63*(2), 239-264.

Bourgeon, J. M., & Picard, P. (2000). Reinstatement or insurance payment in corporate fire insurance. *Journal of Risk and Insurance*, 507-526.

Boyer, M. M. (2000). Centralizing insurance fraud investigation. The Geneva Papers on Risk and Insurance Theory, 25(2), 159-178.

Crocker, K. J., & Morgan, J. (1998). Is honesty the best policy? Curtailing insurance fraud through optimal incentive contracts. *Journal of Political Economy*, *106*(2), 355-375.

Dionne, G., & Gagné, R. (2002). Replacement cost endorsement and opportunistic fraud in automobile insurance. *Journal of Risk and Uncertainty*,*24*(3), 213-230.

Favazza, A. R. (2011). *Bodies under siege: Self-mutilation and body modification in culture and psychiatry*. JHU Press.

Gambetta, D. (2009). *Codes of the underworld: How criminals communicate*. Princeton University Press.

Griller, J. (2013). *The Paradox of Self-harm in Prison: Psychopathy Or an Evolved Coping Strategy?*. Diplomica Verlag.

Hagen, E. H., Watson, P. J., & Hammerstein, P. (2008). Gestures of despair and hope: A view on deliberate self-harm from economics and evolutionary biology. *Biological Theory*, *3*(2), 123.

Harris, J. R., & Todaro, M. P. (1970). Migration, unemployment and development: a two-sector analysis. The American Economic Review, 126-142.

Heide, S., & Kleiber, M. (2006). Selbstbeschädigung–eine rechtsmedizinische Betrachtung. Dtsch Arztebl, 103(40), 2627-33. Klonsky, E. D., Muehlenkamp, J. J., Lewis, S. P., & Walsh, B. (2011). *Nonsuicidal self-injury*. Hogrefe Pub..

Miyazaki, A. D. (2009). Perceived ethicality of insurance claim fraud: do higher deductibles lead to lower ethical standards?. Journal of Business Ethics, 87(4), 589-598.

Neiman, G. (2010). Estudio sobre la demanda de trabajo en el agro argentino. Ediciones Ciccus.

Peña, M. M. (2008). Historia natural del canibalismo. Ediciones Nowtilus SL.

Picard, P. (1996). Auditing claims in the insurance market with fraud: The credibility issue. *Journal of Public Economics*, *63*(1), 27-56.

Picard, P. (2000). On the design of optimal insurance policies under manipulation of audit cost. *International Economic Review*, *41*(4), 1049-1071.

Picard, P. (2013). Economic analysis of insurance fraud. In *Handbook of Insurance* (pp. 349-395). Springer New York.

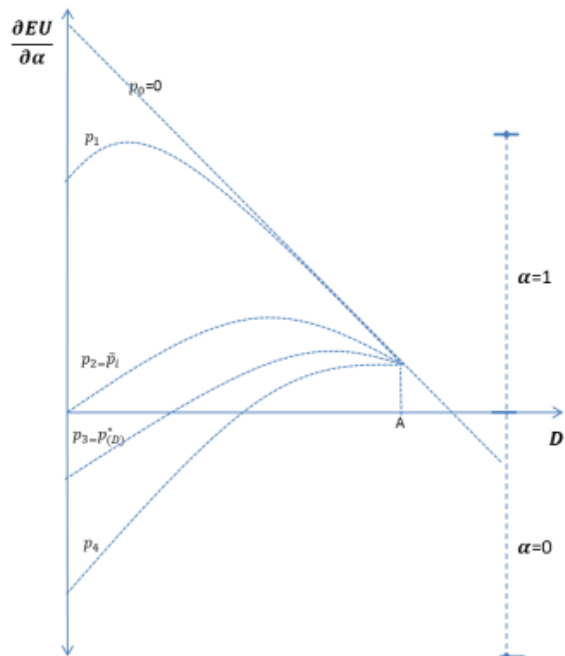Roth, A. E. (2006). *Repugnance as a Constraint on Markets* (No. w12702). National Bureau of Economic Research.
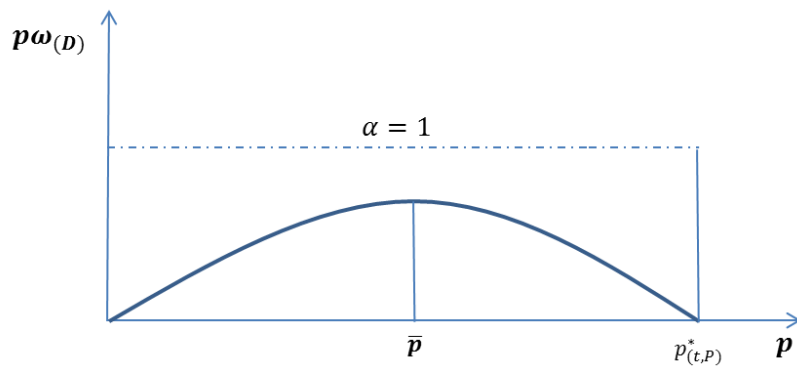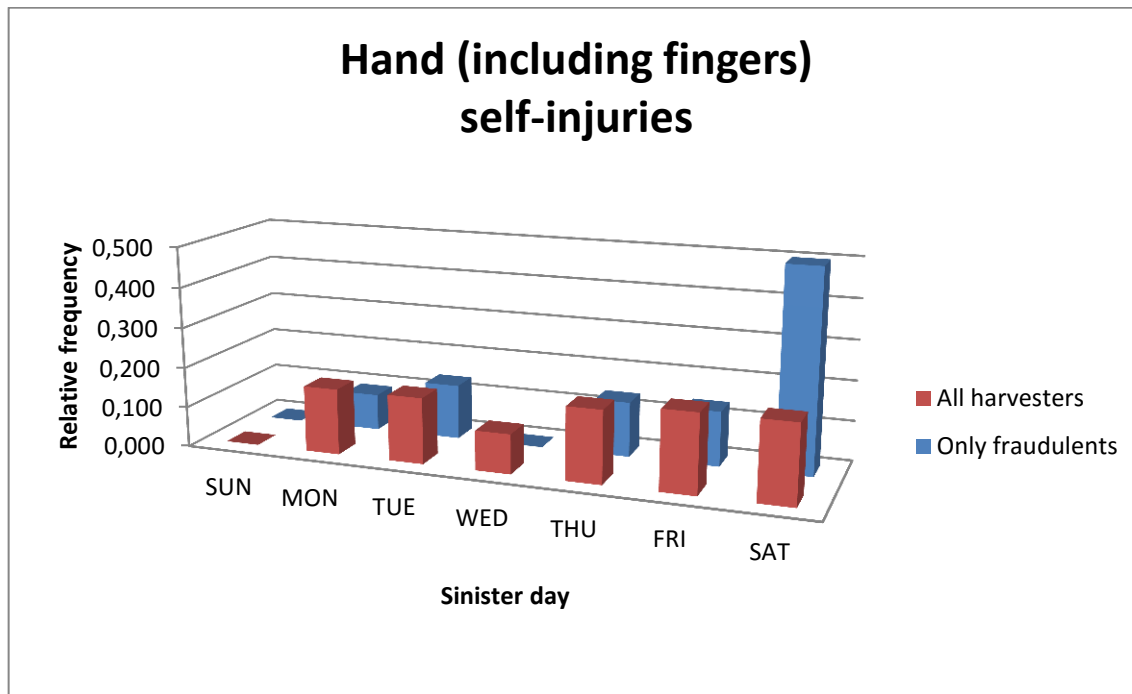
GRAPH I
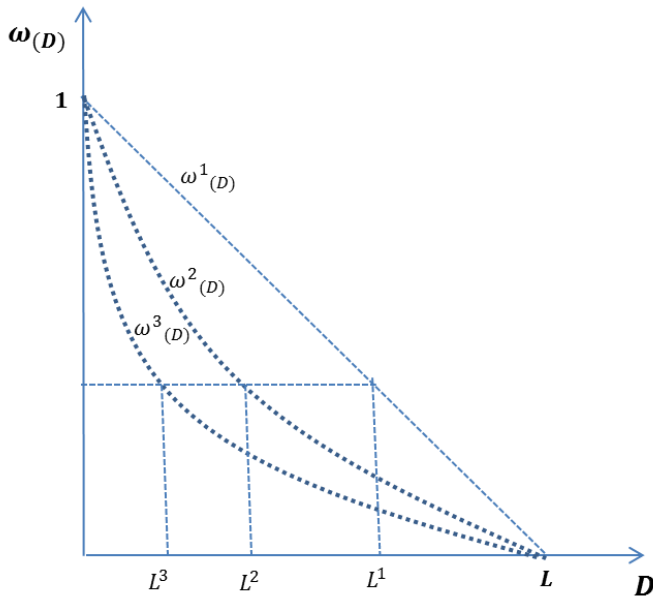
GRAPH II
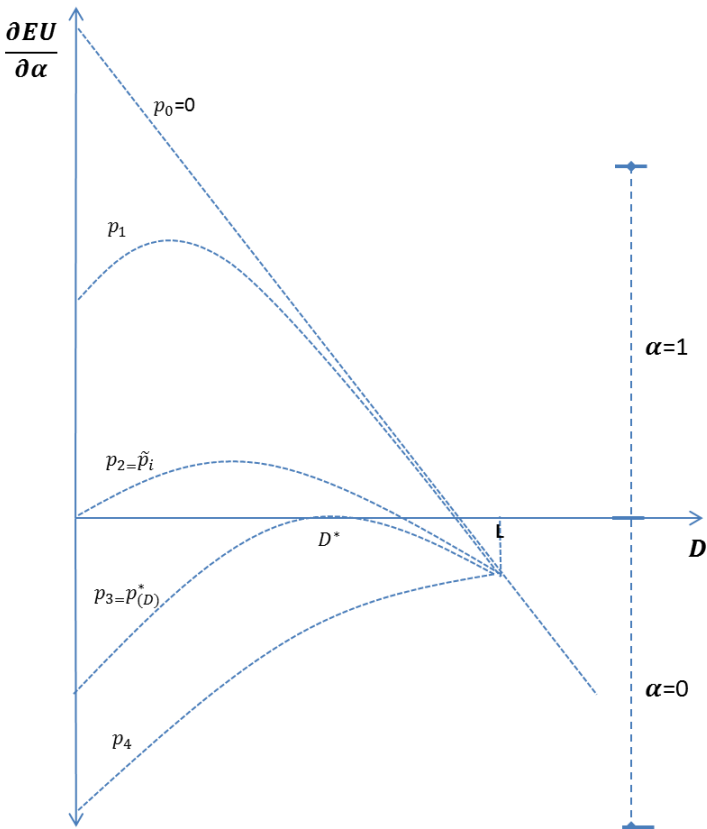
GRAPH III

GRAPH IV

TABLE I - Work days lost

		n	mean	median
			Work days lost	
Contusions	**control**	19	57,42	18,00
	Fraudulent	12	74,00	68,50
Traumatism	**control**	16	72,50	25,00
	Fraudulent	6	78,33	70,00
Fractures	**control**	4	107,75	100,00
	Fraudulent	4	103,50	95,50

GRAPH V - Hand (including fingers) self-injuries

GRAPH VI - Distribution of accidents per month
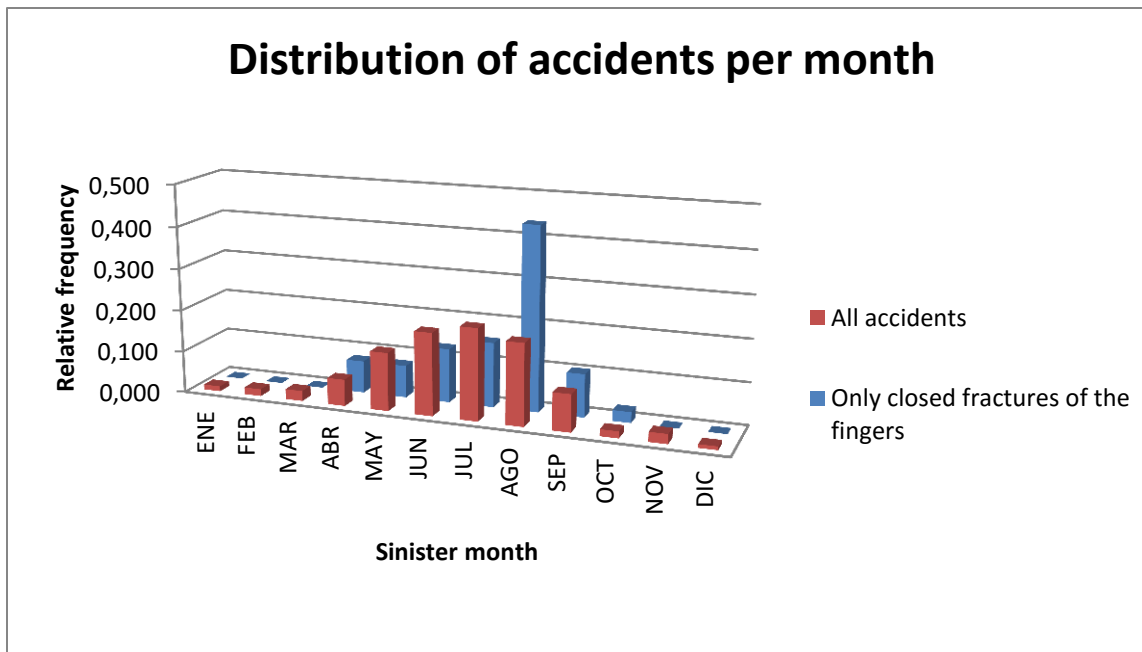
ANNEX

Proof of result 1.

For matters of simplicity the utility function will be renamed as $U_{(.)}^M = U_{(W-P-B-D)}$ and $U_{(.)}^B = U_{(W-D-P+t)}$. It is known that $0 < U_{(.)}^M < U_{(.)}^B, U_{(.)}^{'M} > U_{(.)}^{'B} > 0$ and $U_{(.)}^{''M} < U_{(.)}^{''B} < 0$, also $\frac{\partial \omega}{\partial D} < 0$ and $\frac{\partial^2 \omega}{\partial^2 D} > 0$, the second order condition is obtained from the derivation of (8).

$$\frac{\partial EU}{\partial \alpha \partial^2 D} = p \frac{\partial^2 \omega}{\partial^2 D}\left[U_{(.)}^M - U_{(.)}^B\right] + 2p \frac{\partial \omega}{\partial D}\left[U_{(.)}^{'B} - U_{(.)}^{'M}\right] + p\omega\left[U_{(.)}^{''M} - U_{(.)}^{''B}\right] + +U_{(.)}^{''B} \tag{16}$$

The first, third and fourth terms are negative, while the second term is positive, therefore it cannot be guaranteed "a priori" that the second order condition will be fulfilled. However, suppose a deceit function convex enough so that with damage close to zero it guarantee $\omega_{(L,D)} \cong 0$. Because of this, there will always exist a function convex enough to be guarantee (8) negativity. For lineal utility functions the derivative is much simpler; the first and second order conditions will be $\frac{\partial EU}{\partial \alpha \partial D} = -p \frac{\partial \omega}{\partial D}[t + B] + 1 = 0$ and $\frac{\partial EU}{\partial \alpha \partial^2 D} = -\frac{\partial^2 \omega}{\partial^2 D}[t + B] < 0$.

Proof of result 2

If $D = L$ then (7) equals $\frac{\partial EU_{(t,p,D=L)}}{\partial \alpha_i} = U_{(W-P-L+t)} - U_{(W-P)} = 0$ if $t = L$ for every p, the same will happen if damage outweigh the simulated loss. So the audit probability $p_{(t,P,D^*)}^*$ that guarantee $\frac{\partial EU_{(p_{(t,P,D^*)}^*,D_{(p^*)}^*)}}{\partial \alpha} = 0$ will have the associated damage $D_{(p^*)}^* = L$ so $\omega_{\left(D_{(p^*)}^*\right)} = 0$. If $p < p_{(t,P,D^*)}^*$ then the expected utility will be positive.

Proof of result 3

If $D = L$ then (7) equals $\frac{\partial EU_{(t,p,D=L)}}{\partial \alpha_i} = U_{(W-L+t)} - U_{(W)} < 0$ if $t < L$ for every p, the same will happen if damage outweigh the simulated loss. So the audit probability $p_{(t,P,D^*)}^*$ that guaranties that $\frac{\partial EU_{(p_{(t,P,D^*)}^*,D_{(p^*)}^*)}}{\partial \alpha} = 0$ will have $D_{(p^*)}^* < L$ so $\omega_{\left(D_{(p^*)}^*\right)} > 0$. If $p < p_{(t,P,D^*)}^*$ then the expected utility will be positive because of (9).

Proof of result 4

The result can be demonstrated from equation (7) if it is assumed that $D = A$ which leads to the equation $\frac{\partial EU_{(t,p,D=L)}}{\partial \alpha_i} = U_{(W-L+t)} - U_{(W)} > 0$ if $t > L$ for every p.

Proof of result 5

From equation (17) it is evident that if $B > 0$ then the effective probability $\boldsymbol{p}^*\omega_{(D)}$ will be less than one, however, nothing guarantees that $p^*_{(t,P,D^*)}$ will be found into the feasible range.

Proof of result 6

It is assumed that there exists a damage level that maximizes the expected utility (13), which comes from the first order condition (15) and the second order one (23), then any damage higher or lower that this will imply an expected utility loss for a given audit level. Therefore, for a $\tilde{p}_{(t,P)}$ audit level it must be fulfilled that $\dfrac{\partial EU_{(\tilde{p}_{(t,P)},D^*_{(\tilde{p})})}}{\partial \alpha} > \dfrac{\partial EU_{(\tilde{p}_{(t,P)},D=0)}}{\partial \alpha} = 0$ and there must exist another audit level $p^*_{(t,P,D^*)}$ which guarantees $\dfrac{\partial EU_{(p^*_{(t,P,D^*)},D^*_{(p^*)})}}{\partial \alpha} = 0$. This audit level must be higher than in order to diminish the expected utility to the point of indifference.

Proof of result 7

If $p = 0$ then there will not exist self-harm motivations and effective probability will equal zero, on the other hand if $p = p^*_{(t,P,D^*)}$ guarantees a total damage and therefore $\boldsymbol{p}^*\omega_{(D^*=L)} = 0$. Between the two extremes mentioned it must be fulfilled that $\alpha = 1$ and $\omega_{(D^*)} \geq 0$ so there will be an audit level $\bar{p} \in (0, \boldsymbol{p}^*)$ which guarantee $\bar{p}\omega_{(D^*)} > 0$ and will maximize the effective probability

Proof of equilibrium 1

First, the case of $\alpha = 0$ is considered, which will occur when $p \geq \tilde{p}_{(t,P)}$. In that case the total cost will be minimized when $p = \tilde{p}_{(t,P)}$ and will be equal to (24)

$$C_a = \delta\big[t + \tilde{p}_{(t,P)}c\big] \tag{24}$$

The $\alpha = 1$ case will occur if $p < \tilde{p}_{(t,P)}$. Now the cost will be given by (25) which is lineal (increasing or decreasing) in p.

$$C_1 = \delta t + \delta pc + (1 - \delta)\sigma[(1 - p)t + pc] \tag{25}$$

$$C_n = t[\delta + \sigma(1 - \delta)] \tag{26}$$

If $p = \tilde{p}_{(t,P)}$ then (25) will be higher than (24). If $p = 0$ the associated cost will be (26) but nothing can be stated a priori about the relationship between (24) and (26). If it is considered the case $\alpha \in (0,1)$ with $p = \tilde{p}_{(t,P)}$ then the cost will continue to be greater than (24). So the minimum total cost will be $min\{C_a, C_n\}$.

Proof of equilibrium 2

Due to result 7, it cannot be stated that the costs will always be decreasing or increasing in relation to the audit level. In consequence, the new equilibrium must consider the possibility that there may exist an audit level $\bar{p}$ which minimize the cost function. The total cost if $\alpha = 0$ will occur if $p \geq p^*_{(t,P,D^*)}$ and will be minimum when $p = p^*_{(t,P,D^*)}$ as expressed in (29)

$$C_a = \delta\big[t + p^*_{(t,P,D^*)}c\big] \tag{29}$$

Now the case of $\alpha = 1$ is considered, which will occur if $p < p^*_{(t,P,D^*)}$, and will have an associated cost (30)

$$C = \delta t + \delta pc + (1 - \delta)\sigma\big[(1 - p\omega_{(D)})t + pc\big] \tag{30}$$

If $p = p^*_{(t,P,D^*)}$ then (30) will be greater than (29). But the deceit function by result 7 creates the possibility that there may exist an audit level $\bar{p}$ which minimizes the costs, C_m will be defined as the cost (30) when $p = \bar{p}$. A particular case of (30) will occur if there is no audit and the associated cost C_n will be equal to (26).

Cost minimization in C_m will imply that $C_m < C_a$ and $C_m < C_n$ so the limit audit cost c_0 will be $\frac{(1-\delta)\sigma(1-p\omega_{(D)})t}{\delta p^*_{(t,P,D^*)} - \bar{p}(\delta + (1-\delta)\sigma)} < c_0 < \frac{t(1-\delta)\sigma\omega_{(D_{(\bar{p})})}}{\delta - (1-\delta)\sigma}$, after simplification this result will imply that $\frac{(1-\sigma)\delta + \sigma}{\delta} < p^*_{(t,P,D^*)}\omega_{(D_{(\bar{p})})}$ which will never happens for $\sigma \in (0,1)$ and $\delta \in (0,1)$ because the left term is always greater than the unit and the right term is always lower. Therefore, the minimum possible costs will be given by $min\{C_a, C_n\}$ as in equilibrium 1.