On the incentives of firms, workers and cheaters

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I, Celia Blanco declare that:

- The work in this thesis was composed by myself.
- Where the research was carried out alongside others, or where information has been derived from other sources, I confirm that this has been indicated in the thesis.
- This work has not been submitted for any other degree or professional qualification

Dark times lie ahead of us and there will be a time when we must choose between what is easy and what is right

- A. Dumbledore

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2 Abstract

In this thesis I examine the incentives in three different fields: firms FDI relocation, dishonest behaviour, and workers productivity.

Extrinsic incentives, contrary to the intrinsic ones, are the ones that come from outside, typically in the form of financial reward, but also in the form of status or others perceptions on the subject. When it comes to money, we tend to think that the more the merrier, but there are some other factors that affect our reaction to monetary incentives, which are not always predictable. This could be the case of risk aversion, social preferences, or physycally manipulating money. These factors are highly relevant, as I will show, for the design of incentives on the workplace, information disclosure and environmental policy. I examine these incentives in my three chapters.

Chapter 1 examines the effects of risk incentives in the workplace. For that, we design an experiment in which we compare the performance of subjects participating in the slider game in a 5 period setting. Participants are allocated in groups of 5, but work individually. In the first treatment, subjects receive a bonus in the form of a piece rate for performing above a minimum. In the second treatment, subjects receive a bonus that is 5 times higher than in the piece rate, but will only be received with a probability of 1 in 5. Lastly, in the third treatment, we combine all the bonuses earned by the 5 players in the group in a single lottery prize, which is randomly allocated. Nonetheless, the probability of receiving the prize increases with relative performance. In all treatments subjects are anonymous and able to observe the productivity of the other members or the group. Although we do not obtain significant difference between the three treatments in the point estimates, the productivity growth in both lottery treatments is significantly higher trough the periods. We speculate that seeing someone earning a high prize incentivises subjects to exert more effort, although risk averseness and observing a high performance from their peers work as discouraging factors in the group lottery treatment.

Chapter 2 examines the effects of a gain and a loss domain, combined with a setting with and without money manipulation in the dishonest behaviour of subjects. Subjects participate in the dice game, where they anonymously report the result from rolling a 10-sided dice. Since the design is anonymous, we can only observe cheating on average. We examine 2 dimensions: Gain and Loss, and Money-Manipulation and No-Manipulation. In the Loss treatment, subjects receive an initial endowment of 5 Euros in advance,

while in the Gain treatment they can earn 5 pounds depending on the reported outcome. Gain and Loss then differ in the way we frame the gains: as amounts that subjects can earn or return from an initial endowment. We additionally implement a treatment where subjects are paid a flat fee regardless of the reported outcome. Both the gain and loss frames are carried out with and without money manipulation. In the money manipulation design, subjects receive a 5 Euro note before the loss frame, and take the money from an envelope in the gain frame. We observe that the effect of the gain and loss frame depends on whether subjects physically handle money or not, and we discuss the psychological effects of manipulating money on the moral cost of cheating.

Chapter 3 examines the effects of the environmental regulation in a host country on a multinational firms incentives to engage in foreign direct investment (FDI). I develop a theoretical model of trade with 2-country setting (North and South), and focus on the Southern market. I demonstrate that the incentives for a firm to internationalise do not only depend on the environmental regulation of the recipient country but also in the mode of entry. This means that setting a new factory (Greenfield) and buying an existing one in the host country (Mergers and Acquisitions), have different sensitivity towards the strictness of the environmental regulation, and its effects are not always straightforward. I conclude that, in accord with the empirical findings in other studies, a more strict environmental regulation does not always deter FDI when we take into account the entry mode.

To my aunt Pepi, who passed away during the production of this work.

Contents

3 CHAPTER 1

Risky Incentives in Labour Contracts: An Experiment

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3.1 Introduction

It is not uncommon for lotteries to be used as incentive mechanisms for participation in tasks; participation in online surveys is often incentivised at the extensive margin by entry to a prize draw to win an iPad, or a large face value in vouchers, for example. If would-be participants were offered the cash equivalent expected value of such lotteries for their time, it is unlikely they would participate: although we know that the expected value is infinitesimally small, we tend to neglect the cost of our effort at the prospect of winning a valuable prize Rachlin (1990).

But real life examples of such lottery incentive mechanisms are less easy to think of at the intensive margin. In particular, can lotteries be used as an incentive mechanism to induce high effort (and thus productivity)? There is an extensive literature within personnel economics on mechanisms to induce optimal effort for the firm, which we summarise below (Lazear 1986, and Freeman, 1998 among others), though surprisingly little research exists on mechanisms through which lotteries might incentivise effort.

One of the most utilised theoretical models in the personnel economics literature is the agency theory model, which assumes that a worker (agent) bears some disutility of effort, while the firm (principal) sets a wage that seeks to incentivise an optimal effort level such that profit is maximised (Ross, 1973; Stiglitz, 1989). If both parties incentives are not aligned, this can result in the agent selecting to exert suboptimal effort, and thus the firm obtains suboptimal profits. Many solutions to this problem have been proposed , however it is often found to be prohibitively expensive for the firm to incentivise effort over and above the reservation level in equilibrium.

Various mechanisms have been proposed to optimally incentivise high effort in a manner that is profitable for the firm, most notably efficiency wages and piece rates (Prendergast, 1999; Ariely et al., 2009; Lazear, 2000; Lazear, 1986). However such mechanisms have been found to be empirically problematic for two main reasons. Firstly, measuring individual worker productivity is not always practically possible, or can be costly to the firm where it is (Freeman, 1998). Secondly, because effort is imperfectly correlated with productivity, and it is productivity that is ultimately incentivised by the firm, the worker takes on some risk when exerting additional effort; to incentivise high effort the firm must therefore compensate both the workers disutility of effort and the risk the workers takes on (Pendergast, 2002). The costs to the firm of incentivising high effort are therefore often prohibitive when weighed against the productivity gains.

There is some suggestive evidence in the literature that workers effort response may be higher where productivity incentives involve risk (Bandiera et al., 2005; Rula et al., 2014; Celis et al., 2013). We contribute by reviewing this evidence, and testing it in a controlled laboratory experiment. For that, we propose an experiment in which subjects are randomly allocated to three treatments, in each of which subjects receive a fixed payment for achieving a minimum standard of effort, plus a bonus for productivity over and above that minimum standard. In the first treatment this takes the form of a piece rate bonus, in which subjects are paid a fixed value for each unit of productivity over and above the minimum threshold. In the second treatment, the bonus is paid in the form of an individual lottery, in which subjects add a value five times higher than the piece rate to their bonus pot with each additional unit of productivity, but only receive the bonus with 20% probability (such that the expected value is the same as the piece rate). The third treatment takes the form of a group lottery bonus, where each member of a group receives a lottery ticket with the same expected value as the piece rate bonus for productivity over and above the threshold, and a winning ticket is randomly drawn such that one subject wins the entire group bonus pot. Each treatment is played across five rounds (with bonuses allocated each round), and subjects can can observe other group members productivity. The experiment utilises a real effort task to ensure a strong positive relationship between effort and productivity.

We find that (i) lottery incentives are at least as effective as piece rates in incentivising effort; (ii) risk aversion affects positively the performance in the piece rates treatment comparative to lottery incentives (iii) other group members performance in the previous period is positively related to current subject performance in the piece rate treatment, but negatively related to performance in the group lottery treatment. When controlling for observables, we further find that the group lottery incentivises higher growth in productivity over time (comparative to piece rates), and we disseminate the causal behavioural factors influencing the overall result. Our objective is to propose a more efficient reward structure that could be optimally implemented in a real workplace environment.

The rest of the paper is organised as follows. In Section 2 we review the literature on effort incentive mechanisms; Section 3 presents the theoretical predictions; Section 4 sets out the experimental design; Section 5 presents the results of the experiment; Section 6 offers a discussion of the results, and the behavioural factors driving the overall effect; Section 7 concludes.

3.2 Literature review

According to contract theory, exerting high levels of effort is fatiguing to the worker, such that effort is costly in utility terms; the firms output is, however, positively related to effort. The incentives of employees and employers are clearly therefore not necessarily aligned, and so firms must design a compensation scheme that aligns these interests. This is the essence of principal agency theory.

Various compensation mechanisms exist in the personnel economics literature, which attempt to align these interests. Mechanisms such as delayed compensation and efficiency wages increase the value of retaining the job to the worker, while others such as piece rates and tournaments link compensation to absolute or relative performance. Incentives that directly link compensation to productivity are referred to as Pay for Performance, and there exists a substantial literature on the merits and demerits of such mechanisms (see Prendergast, 1999; Ariely et al., 2009; Lazear, 2000; Lazear, 1986; Gibbons, 1987).

There are a significant number of empirical studies on the effect of piece rate Pay for Performance mechanisms on worker effort. The main conditions for piece rates to be beneficial are low monitoring costs, accurate output measures, and heterogeneous ability amongst workers (Lazear, 1986). Freeman (1998) finds that a US shoe manufacturing firm, which switched from a piece rate payments to a rate per hour, increased profits by eliminating monitoring costs. He concludes that, when monitoring costs are high, piece rates may not always be the optimal payment method even if they do increase worker productivity. Conversely, Lazear (2000) analysed field data from an automotive glass installer which switched from an hourly payment regime to piece rate payment, finding a 44% increase in productivity under piece rates comparative to rate per hour (although half of this gain was found to be due to worker sorting). In this circumstance both wages and profit increased. This efficiency gain was largely due to a sophisticated computerised system that allowed the firm to directly measure productivity. Similarly, Paarsch (1996) finds that tree planters in British Columbia are more productive if paid piece rates comparative to fixed wages, although in this case all efficiency gains are attributed to increased effort, as there is no sorting effect. In a more recent experiment, Bandiera et al. (2005) compare a piece rate payment with a relative payment, where workers are paid according to their output comparative to the mean output that day; the authors find that piece rates lead to higher productivity.

A stream of the literature examines the impact on performance pay on educational outcomes. Lavy (2002) examines the effect of performance-based reward structure in a non-random sample of schools in Israel. He finds that providing both students and teachers with monetary incentives has a positive impact on student performance; positive results are also found where only teachers are incentivised, which proves more cost effective. Similarly, Muralidharan & Sundararaman (2009) find a positive and significant impact of providing performance-based incentives to teachers on student performance. Fryer et al. (2012) examine the effect of loss aversion on teachers, by paying teachers an advance for achieving a target student performance, and asking them to return the money if this is not fulfilled. The authors identify an increased students performance on a standardised maths test.

In general, the literature concludes that Pay for Performance mechanisms lead to increased productivity in most circumstances. This result can, however, be reversed where incentive payments are set at a sufficiently high rate such that workers can achieve their target wage with minimal effort (Ariely et al., 2009). However Bandiera, Barankay, & Rasul (2005) evaluate the piece rate payment comparative to relative incentives in a field experiment, and find no evidence of income targeting.

Although the literature shows that in most cases Pay for Performance mechanisms increase worker productivity, surprisingly little attention has been paid to pay per performance mechanisms that involve risk. This is perhaps surprising; as Zabojnik (2002) notes, this has direct relevance to industries in which bonuses are paid in share options. Further, recent research shows some suggestive evidence that such contracts might deliver greater efficiency gains than piece rates.

Zabojnik (2002) shows that if the assumption of global risk-averseness on the part of workers is dropped, and a Friedman-Savage quasi-convex utility function is instead assumed with respect to wages, the first best contract achieving full efficiency in a principal-agent setup is achieved using lottery payments. It is shown that in a locally convex section of the workers utility function there exists a lottery payment with an expected wage lower than a fixed wage achieving the same worker utility.

Brune (2015) builds on this hypothesis by comparing the effect of a lottery bonus to a piece rate bonus with the same expected value on productivity and attendance of workers at a large agricultural firm in Malawi. The study finds a statistically significant increase in labour supply by workers at the intensive margin twice as large as that for piece rates. A small and marginally significant (at 10% level) increase in productivity is identified for the lottery bonus, though the piece rate bonus was not statistically different from the baseline. However notably this result could conceivably be dampened by worker fatigue: because workers are working more at the intensive margin, the effects of fatigue could conceivably reduce the treatment effect with respect to productivity (e.g. see Schor, 1991). There is clearly therefore scope for an experiment in which a productivity outcome alone is incentivised.

Levitt et al. (2016) examines the effect of financial incentives on student performance, comparing a fixed conditional transfer payment to a lottery payment, and with varied treatments in which both students and parents are incentivised. The authors find that a lottery payment with parents as recipients was most effective, whilst a small but significant effect for a fixed payment with students as the recipients is also identified.

Another stream of literature focuses on lottery payments for micro tasks. These are the papers most related to ours, although we will contribute with a real effort task in a lab setting. Rula et al. (2014) compare outcomes using piece rate micro-payments and a lottery, where the payments were in the form of coffee shop gift cards. They obtain that piece rates had higher compliance and user effort, while the lottery treatment achieved higher recruitment. However there is the clear potential for these results to be driven by self-selection and heterogeneous preferences over the gift cards. Similarly, Rokicki et al. (2014) compare outcomes under competitive payments, piece rates, and lottery payments in Amazon Mechanical Turk. They obtained that an exponential piece rate payment outperforms a winner-takes-it all piece rate and lottery based payments in terms of accuracy, although the authors point out these results have potential to be driven by the relatively low value of rewards in the lottery treatment.

Celis et al. (2013) similarly compare a piece rate with a lottery payment for micro tasks in Amazon Mechanical Turk, where participants were tasked with the digitalisation of pieces of scrambled text. They find that lottery based payments lead to more accurate digitalisation, and workers spent more time on these tasks. Furthermore, a third of participants reported to prefer the lottery payment comparative to the piece rate.

Our paper attempts to clearly test the effects of a lottery setting in workers productivity via a real effort task, and contribute to the literature on financial incentives on productivity, more concretely build on the aforementioned small stream of the literature on incentives involving risk.

3.3 Experimental design

This experiment was conducted in the experimental lab at Royal Holloway, University of London between 29th November and 5th December 2017. Subjects were recruited from various undergraduate programmes at the university, including the Economics and Psychology programmes. Each session consisted on a single treatment, and lasted around one hour. Subjects were paid a show up fee of £4.

The task conducted is the Slider Task developed by Gill and Prowse (2012a), using zTree software (Fischbacher, 2007). This task was chosen for most direct comparability of results with other real-effort tasks in the recent experimental literature (e.g. Gill & Prowse, 2012; Gill, Prowse and Vlassopoulos, 2013; Doerrenberg & Duncan, 2014; Gill and Prowse, 2014; Abeler & Jager, 2015; Georganas, Tonin, & Vlassopoulos, 2015; Araujo et al, 2016; Buser & Dreber, 2016). The task was also chosen due to its advantages over other classic real effort tasks: it is simple to understand and communicate; unlike other tasks, the slider is exactly the same through repetitions; it involves little randomness and there is no scope for guessing. Also, there is a strong correlation between effort and productivity. The primary disadvantage of the slider task is that productivity is often found to be very tightly distributed, the lack of variation making significant results difficult to identify (Banuri & Keefer, 2015). This does, however, add power to significant results where they are identified.

At the beginning of each session, subjects were allowed into the lab in groups of five and each subject was randomly allocated to a workstation. Subjects were given around 15 minutes to read the task instructions fully and answer the control questions. Once finished, subjects control questions were checked individually to ensure complete understanding of the task, and any doubts were clarified. A verbal summary of the instructions was then read to the entire group.

This real effort task consists of a screen with 51 sliders, all initially positioned at 0. Participants were tasked with dragging each slider to position 50 with their mouse; the slider could be adjusted to any position between 0 and 100, as many times as desired. The goal of the task is to correctly position as many sliders as possible at 50 within an allotted time of two minutes. Subjects could see a running total of correct sliders achieved in the current round, and the remaining time available. Five paid rounds were conducted for each treatment.

At the beginning of each treatment, subjects were assigned a subject number and randomly allocated into groups of five. Grouping subjects was necessary in order to identify peer effects. Each treatment consisted of 50 subjects.

All communication subjects received about their group members was provided in terms of subject numbers, thus keeping real identities anonymous. Two practice rounds were conducted prior to the paid rounds in order to familiarise subjects with the task; subjects performance in these rounds did not affect the final payoff.

Our three treatments differed only in terms of the bonus payoff mechanism. In each, for achieving a minimum threshold of 15 correctly positioned sliders, subjects received a fixed payoff of 10 ECU (experimental currency units). The payoffs for each round were independent, and the subjects received feedback on their own performance and the performance of the other members of their group at the end of each round.

In the piece rate treatment, each correctly positioned slider over and above the minimum threshold of 15 earned the subject a 1 ECU bonus. Each ECU is equivalent to £0.30. The individuals payoff can be expressed as follows:

$$\Pi_{ir} = \begin{cases} 10 + 1 \cdot (N_{ir} - 15), & N_{ir} \geq 15 \\ 0, & N_{ir} < 15 \end{cases}$$

Where π_{ir} is the payment for subject i in round r, and N_{ir} is the corresponding amount of correctly positioned sliders.

In the Individual lottery treatment, each correct slider over and above the minimum threshold added 5 ECU to the subjects bonus pool; at the end of each round the subject received the bonus pool with probability 1/5.

The individuals expected payoff can be described as follows:

$$E(\Pi_{ir}) = \begin{cases} 10 + [5 \cdot (N_{ir} - 15)] \cdot \frac{1}{5}, & N_{ir} \geq 15 \\ 0, & N_{ir} < 15 \end{cases}$$

$$\equiv \begin{cases} 10 + 1 \cdot (N_{ir} - 15), & N_{ir} \geq 15 \\ 0, & N_{ir} < 15 \end{cases}$$

In the group Lottery treatment, each correctly positioned slider over and above the minimum threshold earned the subject 1 lottery ticket with a face value of 1 ECU. At the end of each round, all lottery tickets in each group were added into a group bonus pool. The computer randomly selected one ticket in every group, and the winner earned the whole bonus pool. Hence, there was one winner of the entire bonus pool in each group per round. As before, earnings in one round did not affect the earnings in the following rounds.

The individuals expected payoff can be described as follows:

$$E(\Pi_{ir}) = \begin{cases} 10 + \left[\frac{(N_{ir} - 15)}{\sum_{i=1}^{5}(N_{ir} - 15)} \cdot 5 \cdot \sum_{i=1}^{5}(N_{ir} - 15)\right], & N_{ir} \geq 15 \\ 0, & N_{ir} < 15 \end{cases}$$

$$\equiv \begin{cases} 10 + 1 \cdot (N_{ir} - 15), & N_{ir} \geq 15 \\ 0, & N_{ir} < 15 \end{cases}$$

As is demonstrated above, each individual is expected payoff π for a given number of correctly positioned sliders in round r, $E(\pi_{ir})$ is constant across treatments; behavioural differences across treatments are therefore interpretable as a treatment effect of the compensation mechanism alone.

There was a 35 second pause in between each round, during which time subjects received feedback on the number of sliders achieved by themselves and their group members. They also received their personal payoff information, and that of other members of their group (including the winner in the case of the group lottery).

At the end of each session, participants were asked to complete a short questionnaire, Including measure of risk preferences as per Holt and Laury (2002), an social peferences as per Bartling et al. (2009)[1] . Choices in the questionnaire were not monetarily incentivised. All subjects were paid in cash at the end of every session.

3.4 Hypotheses

3.4.1 Risk preferences

Consider the first piece rate treatment. If we assume that the effort is highly correlated with the output, there is no risk involved in the task. Hence, we can assume that a risk neutral individual will perfom similarly to a risk loving and a risk averse one, taking into account their own preferences and cost of effort.

Hypothesis 1: In the piece rate treatment, three subjects that only differ in their risk preferences, these being risk neutral, risk loving and risk averse, will exert the same ammount of effort.

In the inidividual lottery treatment, subjects percieve the total bonus with a probability, where the expected payoff of every extra unit is the same as in the piece rate.

Hypothesis 2: In the individual lottery treatment, a risk neutral individual will exert an equal amount of effort as in the piece rate treatment, a risk loving individual will exert more, and a risk averse individual will exert less.

In the group lottery, the expected payoff of an aditional unit will depend on the performance of other

[1]See appendix 2

subjects in the group as well as the subject's own productivity. If we consider this as an additional layer of risk, we expect risk averse subjects to exert less effort than in the two previous treatments and risk loving sujects to exert more.

Hypothesis 3: In the group lottery treatment, a risk neutral individual will exert an equal amount of effort as in the piece rate and the individual lottery treatment, a risk loving individual will exert more effort than in two other treatments, and a risk averse individual will exert less.

3.4.2 Social preferences

We measure social preferences in terms of prosociality and envy. Since in the first two treatments one subject action's wont affect the other's payoffs, we expect social preferences to have no effect on the productivity.

Now consider the group lottery treatment; an increase in a subject's effort increases its own relative chance of winning and drecreases the other subjects' chance of winning. At the same time, it increases the total prize that another subject may get if she is not chosen as winner. Hence, we need to make some assumption about what subjects care about. Subjects may only care about expected individual utility; in this case, a procosocial subject may want to decrease her effort in order to increase the relative chance of winning of the other subjects, while an envious subject will want to increase her effort.

Alternatively, it seems reasonable to assume that subjects may only care about the total utility, which will be measured as the total prize. In this case, a prosocial subject may want to increase her effort and hence increase the total prize, regardless of individual winning chances. Contrarily, an envious subject may want to decrease the total prize, and a decrease in her winning chanes is the paid price.

Hypothesis 4: If a subject cares about individual utility, prosociality preferences will decrease subject's incentives to exert effort, while envy preferences will increase them.

Hypothesis 5: If a subject cares about total utility, prosocial preferences will increase subject's incentives to exert effort, while envy preferences will decrease it.

3.4.3 Other

Subjects in our three treatments observe their group's effort in the previous round. Now, how this will affect performance will depend on whether subejct's expected payoff is affected by other's performance. In the piece rate treatment and in the individual lottery, expected payoff is not affected by others's performance, and since it seems reasonable to assume that subjects do not want to perform worse than others, we expect previous observed effort positively affect subject's effort in the current period.

Hypothesis 6: Observed previous group performance will increase effort in the previous period for subjects in the piece rate treatment.

Hypothesis 7: Observed previous group performance will increase effort in the previous period for subjects in the individual lottery treatment.

In the group lottery treatment subject's payoff is affected by other's performance. How this will affect performance is not straigthforward. Again, an individual that cares about the individual utility may perceive previous group effort as a decrease in own's chances of winning, while an individual that cares about total utility may perceive previous group effort as an increase of the prize in the event of winning.

Hypothesis 8: If individuals care about expected utility, observed group effort will have a negative impact on current performance Alternatively, if individuals care about total utility, observed group effort will have a positive impact on currect effort.

3.5 Results

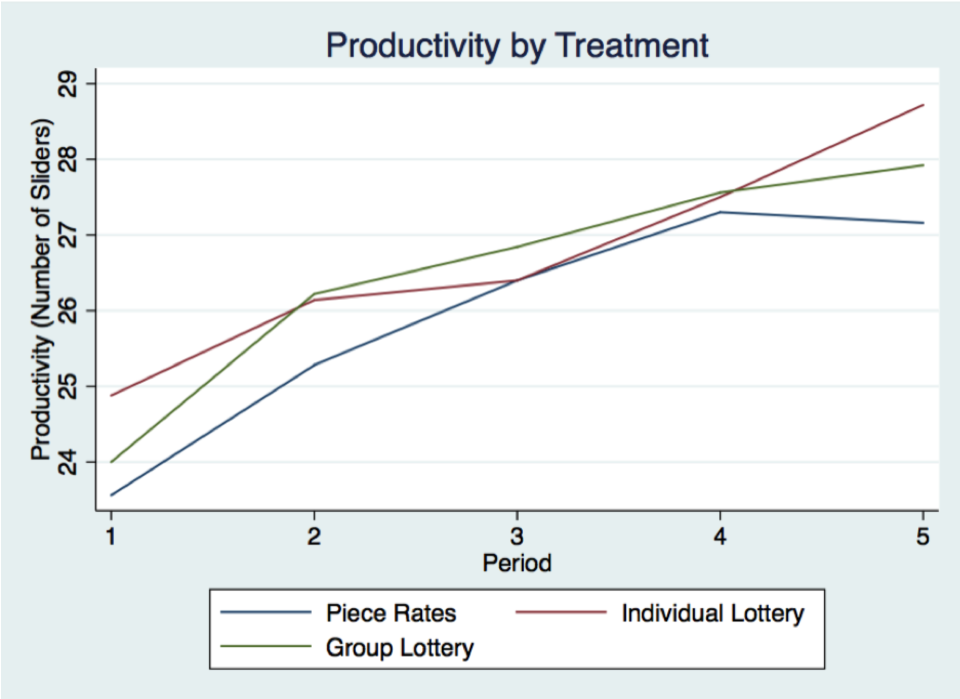

Table 1

	Periods				
Productivity (sliders)	1	2	3	4	5
Piece Rate	23.56	25.28	26.40	27.29	27.16
(T1)	(4.26)	(5.48)	(4.80)	(5.21)	(5.36)
Individual	24.88	26.14	26.40	27.50	28.71
Lottery (T2)	(7.11)	(7.15)	(7.13)	(6.93)	(6.25)
Group Lottery	24.00	26.22	26.84	27.56	27.92
(T3)	(6.03)	(6.52)	(6.22)	(6.02)	(6.84)

Standard deviations in parentheses

Figure 1

Figure 1 compares productivity in each treatment and its evolution over time; Table 1 shows the corresponding mean productivity for each treatment in each time period, and the associated standard deviations. The group lottery is uniformly more productive than piece rates (though it is shown below that we cannot reject the null that the two series are equal); productivity in the group lottery is uniformly more widely distributed than piece rates. Both the group lottery and piece rate productivity trends are concave, indicative of a decrease in the rate of learning over time, and/or fatigue. Participants in the individual lottery are at least as productive as the group lottery with the exception of Period 3.

We first conduct Kolmogorov-Smirnov and Mann-Whitney non-parametric tests on data aggregated at the group level for each period to test the null hypothesis that group productivity in both lottery treatments are drawn from the same distribution as the piece rate treatment. The p-values generated are presented in Table 1.

Productivity in the group lottery is consistently slightly above, but not to be significantly different from piece rates in both non-parametric tests when observations are pooled by group. Productivity differentials are globally larger for the individual lottery, but the null hypothesis of no effect cannot be rejected for any period.

	Mann-Whitney	t-test	Kolmogorov-Smirnov
T1 = T2	0.7624	0.4411	0.976
T1 = T3	0.7623	0.5072	0.660
T2 = T3	0.9397	0.7918	0.660

Table 2

It should be noted that an established characteristic of the slider task is that variation in productivity is typically very tightly distributed, such that significant results are hard to identify (e.g. Banuri & Keefer, 2015); this problem is compounded by the within-group variation lost when pooling across groups.

In the ensuing analysis we therefore further employ various parametric specifications at the individual level to establish the extent to which the lack of statistical significance in the non-parametric tests may be driven by this uncaptured variation; this also allows for the inclusion of relevant covariates to disseminate the factors driving the outcomes.

We first estimate the treatment effect by estimating iterations of Equation 1 by OLS. Y_{it} is output (or equivalently effort) by individual i in period t.   is a continuous measure for time, measured in periods such that $\tau \in R[1,5]; \tau^2$ is specified to capture concavity. T_i^L is a set of treatment dummies, where $L = (1,2,3)$ for piece rate, individual lottery, and group lottery treatments respectively. $\hat{\beta}_2$, therefore, estimates the Average Treatment Effect (ATE) on the Y intercept for the individual lottery, and $\hat{\beta}_3$ for the group lottery, comparative to the piece rate baseline. $\hat{\gamma}_2$ and $\hat{\gamma}_3$ respectively identify the impact of individual and group lotteries in productivity growth over time. $\bar{Y}^{-i}_{gi(t-1))}$ measures a one-period lag of mean productivity of individual is group members, excluding individual i; δ_L therefore estimates at the margin the impact of higher group productivity on individual is productivity in the following period, for each treatment (including the piece rate baseline).

Despite random allocation of subjects to each treatment, we find some heterogeneity in key characteristics that have a theoretical effect on productivity or response to treatment (see Table 3). For instance, 50% of subjects in the individual lottery are male, as opposed to 30% in the piece rate treatment, and 38% in the group lottery; individual lottery subjects spent nearly twice as many hours playing video games as in the other treatments, and prosocial preferences are significantly more prevalent for piece rate subjects. As such we include two additional specifications controlling for explanatory variables to account for this between-treatment heterogeneity. $R_i \in R[0, 10]$ is a continuous measure of risk aversion as per Holt and Laury (2002), such that preferences for risk are increasing in R_i; $\hat{\theta}_L$ therefore estimates the marginal increase in productivity resultant of a one unit increase in preferences for risky gambles, again for each treatment. S_i is a matrix of social preference dummies for revealed social preferences for group envy and pro-sociality, for each individual i;   is therefore a vector of estimators of the impact of each social preference classification on productivity, estimated separately for each treatment (including the piece rates). X_i is a (k N) matrix of k explanatory covariates, consisting of a sex dummy, dummies indicating whether the subject is reading Psychology or Economics, and the (self-reported) mean number of hours the subject spends playing video games. $\hat{\epsilon}_{it}$ is a residual error term, assumed to be mean zero and normally distributed. Results are presented in Table 4.

$$Y_{it} = \hat{\alpha}_0 + \hat{\alpha}_1\tau_t + \hat{\alpha}_2\tau_t^2 + \sum_{L=2}^{L=3}\hat{\beta}_L T_i^L + \sum_{L=2}^{L=3}\hat{\gamma}_L(T_i^L \cdot \tau_t) + \left[\sum_{L=1}^{L=3}\delta_L\left(\bar{Y}^{-i}_{gi(t-1)} \cdot T_i^L\right)\right]$$
$$+ \left[\sum_{L=1}^{L=3}\hat{\theta}_L(R_i \cdot T_i^L)\right] + \left[\sum_{L=1}^{L=3}(\mathbf{S}_i \cdot T_i^L)\hat{\vartheta}\right] + \mathbf{X}_i\eta + \hat{\varepsilon}_{it}$$

Equation 1

	T1	T2	T3
Productivity	23.951	25.063	24.740
	(6.136)	(7.364)	(6.813)
Psychology	0.060	0.040	0.000
	(0.238)	(0.196)	(0.000)
Economics	0.220	0.260	0.040
	(0.415)	(0.439)	(0.196)
Male	0.300	0.500	0.380
	(0.459)	(0.501)	(0.486)
videogames	2.796	4.540	2.786
	(5.839)	(7.585)	(5.028)
Risk	4.900	4.800	4.920
	(2.035)	(2.023)	(1.981)
Pro Soc	0.960	0.920	0.860
	(0.196)	(0.272)	(0.347)
Envy	0.680	0.740	0.700
	(0.467)	(0.439)	(0.459)

Mean values for productivity and covariates (standard deviations in parenthesis)

Table 3

	(1)	(2)	(3)	(4)
VARIABLES	Raw diffs	Lags	Lags Covs & Risk Prefs	Lags Covs Social & Risk Prefs
Growth T2	-0.0180	0.833	0.754	0.776
	(0.373)	(0.550)	(0.523)	(0.515)
Growth T3	-0.00400	1.374**	1.144**	1.143**
	(0.361)	(0.591)	(0.554)	(0.551)
Treatment 2	0.842	0.270	-4.179*	-0.575
	(1.250)	(2.015)	(2.358)	(3.295)
Treatment 3	0.580	5.151***	-0.260	0.399
	(1.163)	(1.851)	(2.703)	(3.809)
Period	1.893**	0.454	0.502	0.537
	(0.810)	(1.760)	(1.680)	(1.670)
Period^2	-0.162	-0.0879	-0.0763	-0.0795
	(0.133)	(0.245)	(0.234)	(0.232)
Lag T1		0.165***	0.144***	0.142***
		(0.0256)	(0.0237)	(0.0233)
Lag T2		0.0671*	0.0514	0.0408
		(0.0342)	(0.0322)	(0.0332)
Lag T3		-0.154***	-0.123***	-0.126***
		(0.0407)	(0.0373)	(0.0386)
Psychology			-3.048***	-2.745**
			(1.138)	(1.146)
Economics			0.348	-0.0324
			(0.629)	(0.638)
Male			1.734***	2.163***
			(0.559)	(0.592)
videogames			0.162***	0.116*
			(0.0543)	(0.0590)
Risk T2			0.299	0.262
			(0.185)	(0.190)
Risk T3			0.423	0.444
			(0.318)	(0.292)
Risk T1			-0.480***	-0.593***
			(0.143)	(0.149)
Pro Soc T1				4.281***
				(1.098)
Pro Soc T2				0.750
				(1.108)
Pro Soc T3				2.651
				(1.710)
Envy T1				-1.051
				(0.771)
Envy T2				-1.453
				(1.286)
Envy T3				-0.371
Constant	22.04***	21.57***	23.44***	21.86***
	(1.119)	(2.957)	(2.962)	(3.316)
Observations	750	600	592	592
R-squared	0.048	0.086	0.170	0.210

Table 4. Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

In specification (1) we estimate Equation 1 without covariates to establish raw differentials; similarly to the non-parametric specifications presented above, there is no statistically significant productivity difference between either lottery treatment and the piece rate. Though not significantly different from zero, point estimates for β_1 and β_2 and small and positive. This confutes the standard theoretical predictions discussed above: subjects are not found to be adversely disincentivised by risky incentives comparative to a riskless incentive with comparative expected value.

We therefore disseminate the behavioural factors driving this result. Firstly we add the lagged term $\bar{Y}^{-i}_{gi(t-1))}$ to the raw differential estimation in specification (2) [2]. A large and significant (at 1% level) marginal impact of other group members productivity in the previous period is identified for the piece rate treatment, and a negative effect of similar magnitude is identified for the group lottery; point estimates of the effect of the individual lottery are close to zero and not statistically significant. Without controls, specification (2) identifies a significant (at 5% level) increase in productivity growth of 1.37 in the group lottery comparative to piece rates over time; a smaller positive (though not significant) difference in productivity growth is identified for the individual lottery. The point estimate for the group lottery ATE becomes very large and significant in (2), though this disappears when control is added, indicative of omitted variable bias in (2).

Specification (3) adds controls for risk preferences (interacted with each treatment), sex, number of weekly hours spent playing video games, and dummies for students reading Economics and Psychology respectively. More risk-seeking subjects are found to be less productive in the piece rate treatment (significant at 1%); coefficients are positive for both group lotteries but are not significantly different from zero. Males are found to be more productive than females, and psychology students are found to be much less productive than other subjects (both significant at 1%); hours reported spent playing video games has a small positive impact on productivity. Notably, the point estimate on the group lottery ATE returns to being small and insignificant when control is added, though the productivity growth differential between the group lottery and piece rates remains of similar magnitude to (2).

[2] Inclusion of lags does introduce serial autocorrelation (as measured by the Wooldridge Test), hence reporting of robust standard errors. Assumed strict exogeneity in OLS estimation requires that each regressor is orthogonal to the error term for all observations for coefficient estimates to be unbiased; whilst there is clearly a correlation between prior performance of other group members and current performance for subject i, this correlation is of small magnitude and there is no reason to assume is is systematically correlated with current period error. In fact, specification of regressors correlated with lags of the dependent variable are commonly employed as instruments, e.g. Arellano & Bond (1991).

Specification (4) controls for social preferences, as measured by Bartling et al., (2009), with dummies for envy, costly envy, pro-sociality, and costly pro-sociality interacted with each treatment. Costly envy is found to have a large positive (significant at 1%) impact on productivity for piece rates, and a large negative (though only significant at 10%) productivity impact for the group lottery. Envy is found to have a large negative (significant at 1%) impact on productivity in the piece rate treatment, whilst costly envy is found to have a positive effect (significant at 5%) on piece rate productivity. ATE estimates for both lottery treatments remain small and insignificant; the productivity growth estimate remains of similar magnitude and significant at 5% for the group lottery comparative to piece rates. The coefficient for individual lottery productivity growth comparative to piece rates becomes (just) significant at the 10% level, while the coefficient for group lottery growth remains positive and significant at the 5% level.

For robustness, we re-estimate Equation 1 using cluster-robust standard errors to account for heteroskedasticity specifically arising from heterogeneous within-group or between-group variances, which one might reasonably assume arise from individual heterogeneity in response to treatment, or at the group level due to peer effects. Results with standard errors clustered at the individual level are presented in Table 5, and at the group level in Table 6. Point estimates (by definition) are unchanged in both specifications, however growth estimates for the individual lottery comparative to piece rates become significant at the 5% level with individual level clustering, and 1% level with group level clustering, for all covariate specifications.

Caution should, however, be exercised in interpreting the z-statistics in Table 6 (group-level clustering); there exists potential for downward bias in clustered standard error estimates where the number of clusters is finite, thus inflating z-statistics. Rogers (1993) finds this bias is negligible so long as no single cluster contains more than 5% of observations in the population (each of ours contain exactly 5%), however Kzdi (2004) argues there must be at least fifty clusters in a sample for clustered standard errors to be unbiased (comparative to our thirty).

VARIABLES	(1) Raw diffs	(2) Lags	(3) Lags Covs & Risk Prefs	(4) Lags Covs Social & Risk Prefs
Growth T2	-0.0180	0.833**	0.754**	0.776**
	(0.184)	(0.364)	(0.345)	(0.332)
Growth T3	-0.00400	1.374***	1.144**	1.143**
	(0.224)	(0.526)	(0.496)	(0.504)
Treatment 2	0.842	0.270	-4.179	-0.575
	(1.257)	(1.656)	(2.861)	(4.668)
Treatment 3	0.580	5.151***	-0.260	0.399
	(1.161)	(1.539)	(3.958)	(6.334)
Period	1.893***	0.454	0.502	0.537
	(0.385)	(0.858)	(0.834)	(0.833)
$Period^2$	-0.162***	-0.0879	-0.0763	-0.0795
	(0.0588)	(0.111)	(0.110)	(0.110)
Lag T1		0.165***	0.144***	0.142***
		(0.0432)	(0.0383)	(0.0363)
Lag T2		0.0671	0.0514	0.0408
		(0.0626)	(0.0577)	(0.0597)
Lag T3		-0.154***	-0.123**	-0.126**
		(0.0589)	(0.0541)	(0.0582)
Psychology			-3.048	-2.745
			(1.894)	(1.899)
Economics			0.348	-0.0324
			(1.129)	(1.137)
Male			1.734*	2.163**
			(1.011)	(1.058)
videogames			0.162*	0.116
			(0.0957)	(0.103)
Risk T2			0.299	0.262
			(0.323)	(0.332)
Risk T3			0.423	0.444
			(0.604)	(0.545)
Risk T1			-0.480*	-0.593**
			(0.246)	(0.248)
Pro Soc T1				4.281***
				(1.300)
Pro Soc T2				0.750
				(1.853)
Pro Soc T3				2.651
				(3.311)
Envy T1				-1.051
				(1.327)
Envy T2				-1.453
				(2.439)
Envy T3				-0.371
				(1.698)
Constant	22.04***	21.57***	23.44***	20.65***
	(0.752)	(1.556)	(2.149)	(2.826)
Observations	750	600	592	592
R-squared	0.048	0.086	0.170	0.188

Table 5. Cluster-robust (individual level) standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$

VARIABLES	(1) Raw diffs	(2) Lags	(3) Lags Covs & Risk Prefs	(4) Lags Covs Social & Risk Prefs
Growth T2	-0.0180	0.833***	0.754***	0.776***
	(0.175)	(0.256)	(0.214)	(0.224)
Growth T3	-0.00400	1.374**	1.144**	1.143**
	(0.196)	(0.570)	(0.490)	(0.492)
Treatment 2	0.842	0.270	-4.179	-0.575
	(1.484)	(1.714)	(2.768)	(4.580)
Treatment 3	0.580	5.151**	-0.260	0.399
	(1.245)	(2.217)	(5.009)	(7.136)
Period	1.893***	0.454	0.502	0.537
	(0.389)	(1.064)	(1.041)	(1.050)
$Period^2$	-0.162**	-0.0879	-0.0763	-0.0795
	(0.0590)	(0.146)	(0.143)	(0.142)
Lag T1		0.165***	0.144***	0.142***
		(0.0308)	(0.0235)	(0.0281)
Lag T2		0.0671*	0.0514*	0.0408
		(0.0351)	(0.0254)	(0.0279)
Lag T3		-0.154*	-0.123*	-0.126*
		(0.0823)	(0.0692)	(0.0671)
Psychology			-3.048	-2.745
			(1.981)	(1.962)
Economics			0.348	-0.0324
			(1.171)	(1.159)
Male			1.734**	2.163**
			(0.817)	(0.951)
videogames			0.162	0.116
			(0.0995)	(0.119)
Risk T2			0.299	0.262
			(0.270)	(0.297)
Risk T3			0.423	0.444
			(0.633)	(0.608)
Risk T1			-0.480**	-0.593**
			(0.233)	(0.254)
Pro Soc T1				4.281***
				(0.902)
Pro Soc T2				0.750
				(1.424)
Pro Soc T3				2.651
				(2.886)
Envy T1				-1.051
				(1.386)
Envy T2				-1.453
				(1.935)
Envy T3				-0.371
				(1.597)
Constant	22.04***	21.57***	23.44***	20.65***
	(0.793)	(2.219)	(2.690)	(3.032)
Observations	750	600	592	592
R-squared	0.048	0.086	0.170	0.188

Table 6. Cluster-robust (group level) standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, *$p < 0.1$

The most notable difference when clustering the errors is that the slope effect for the individual lottery becomes significant (at the 5% level for individual-level clustering, and 1% level for group-level clustering) for specifications (2)-(4), though it remains smaller than the growth for the group lottery. Hence we conclude that, although there is no difference in the ATE for the lottery treatments compared to the piece treatment, the productivity growth over time is larger in the lottery treatments compared to the piece rate treatment.

3.6 Discussion

Contrary to the standard theoretical prediction that subjects will exert less effort where incentives involve risk comparative to riskless incentives, our experiment shows that lottery incentives perform at least as well as piece rates in inducing effort, with some suggestive evidence that a group lottery outperforms piece rates in terms of evolution of productivity over time. Productivity growth in the group lottery setting is higher than in the piece rate setting when controlling for observables. This is consistent with the findings obtained by Celis et al. (2013), Rula et al. (2014), Rokicki et al. (2014), and Levitt et al. (2016), where lottery incentives are found to have a positive effect on outcomes comparative to riskless alternatives.

Contrary to the theoretical suggestions in Zabojnik (2012), in which a quasi-convex utility is assumed on the part of the agent to assert that lottery contracts perform better because of a risk-seeking element in the locally convex portion of the workers utility function, we do not find that risk-seeking preferences significantly drive performance in the lottery treatments. We do, however, find that more risk-seeking agents perform slightly (but signifcant to 1% level) worse in the piece rate treatment comparative to their peers. This is in line with our hypothesis 1, 2 and 3. More risk loving individuals perform better in riskier scenarios, which is also consistent with standard theory.

The prior effort of other group members is positively related to current period effort in the piece rate treatment, which is compatible with out hypothesis 6. This is also conceptually compatible with peer effects, where there is an imitation effect, or an increase of optimism, arising where a subject observes her peers performing well. This is also explainable by competition effects, where the subjects may conceivably seek to retain or improve their group ranking. Notheless, the effect for the group lottery treatment is not signifficant, which contradicts our hypothesis 7. This could be due to the fact that, due to the risky nature of the payoff structure, higher effort does not necessarily correspond with higher payoff, hence risk aversion counteracts this peer effect.

Contrary to hypothesis 4, we find that those with prosocial preferences are significantly more productive than their peers in the piece rate treatment; productivity coefficients for pro-social prefererence dummies are also positive, though neither effect is found to be statistcially different from zero. We propose that the positive pro-sociality coefficient in the piece rate treatment is in fact due to pro-social subjects being incentivised by an equitable distribution of payoffs, which arguably characterises the piece rate payment mechanism.

The converse effect is observed in the group lottery treatment, where the prior effort of other group members has a negative effect on current worker effort, which is compatible with our hypothesis 7. Notably here the total bonus pool in any given period is positively related to other group members effort, though the probability of winning is negatively related to other group members effort. This is indicative of the workers effort being more strongly incentivised by the probability of winning than the size of the total prize, which is compatible with hypothesis 7, meaning that individuals care mainly about their own individual expected payoff.

Our results must then be driven by the presence of an element that is only present in the lottery treatments, and more so in the group lottery. Since preferences do not seem to be driving the difference, we propose that it is the observation of someone winning a prize the incentive that is provoking a growth in performance that is higher for the lottery treatments. For the case of the group lottery, this effect pulls the productivity up, compensating for the effects that pull it down, as it is risk aversion and observing other groupmates effort in the case of the group lottery.

3.7 Conclusion

Although standard theory posits that subjects should optimally exert less effort where incentives involve risk, we find that people perform at least as well with a lottery incentive comparative to piece rates with equivalent expected values, with some suggestive evidence that productivity growth over time is higher in a group lottery.

We disentangle the driving factors behind the overall effect, finding that risk-seeking behaviour has surprisingly little explanatory power on lottery productivity. Peer effects are found to be negative in the group lottery, but positive under piece rates, though positive peer effects in the piece rate treatment are countered by significantly worse productivity by risk-averse subjects.

We propose this result is driven by lottery treatment subjects observance of one of their peers subject obtaining a prize. Conceivably, if a subjects desire to win a prize increases after observing a peer within their group group winning a prize, this provides incentive to learn, thus increasing growth in effort over time. Nonetheless, the mechanism between increased learning in the lottery settings and inequality aversion is not clear, and there is scope for further this field that directly tests for this relationship, as well as the effects of competition in repeated games. It is further possible that an adaptation of this experiment with a higher number of rounds would find a larger and statistically significant treatment effect, as an increased rate of learning increases the point difference in productivity over time.

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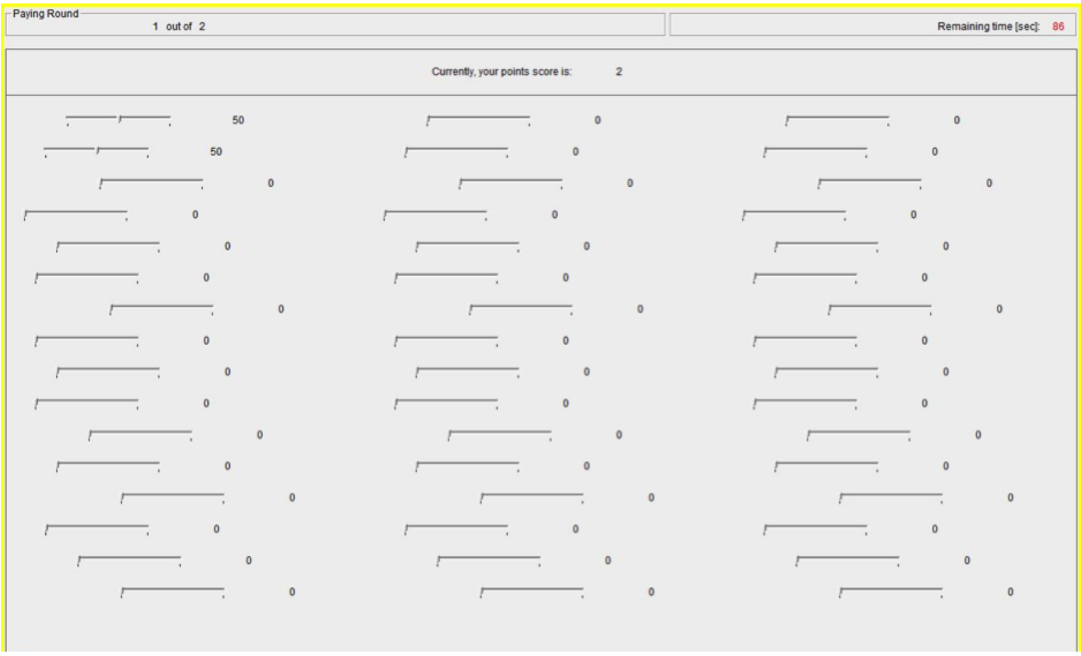
3.9 Appendix 1: Experimental instructions

PIECE RATE TREATMENT

Welcome to the experiment!

You are about to take part in a study on economic decision-making. The study will last about one hour. We are very grateful for your participation. You will be paid a guaranteed show-up fee of £4 for participating in the experiment. This is independent of your actions during the experiment. You will also have the opportunity to earn additional money. The final amount you earn will depend on your actions.

THE TASK
In each round, you will see 48 sliders on the screen.



Your task is to set the position of each slider to the centre. Each slider is initially positioned at 0 and your task is to set as many sliders as possible to 50.

You have 3 minutes to set as many sliders as possible to 50.

Each slider has a number to its right showing its current position. You should use your mouse to move each slider. You can readjust the position of each slider as many times as you wish. If you click on the slider, it will jump, hence it needs to be dragged.

At the top of the screen you see the time remaining and your points score in the task so far.

EARNINGS
Your payment in each round depends on the number of sliders you positioned. If you position 10 or more sliders at 50, you will receive a fixed payment of £0.60 per round. If you correctly position less than 10 sliders, you will not receive any payment for that round (save for the show-up fee).

After you correctly position 15 sliders, each extra correctly positioned slider will pay you an additional bonus of £0.06 each.
Therefore, if you position at least 10 sliders correctly in all rounds, you can earn a total fixed pay of £3 (5 * £0.60) plus your bonus in each round.

ROUNDS
You will play 5 rounds of this task. Before these commence, you will have 2 additional practice rounds that will allow you to familiarise yourself with the task. Your performance in the practice rounds will not influence your final payoff.

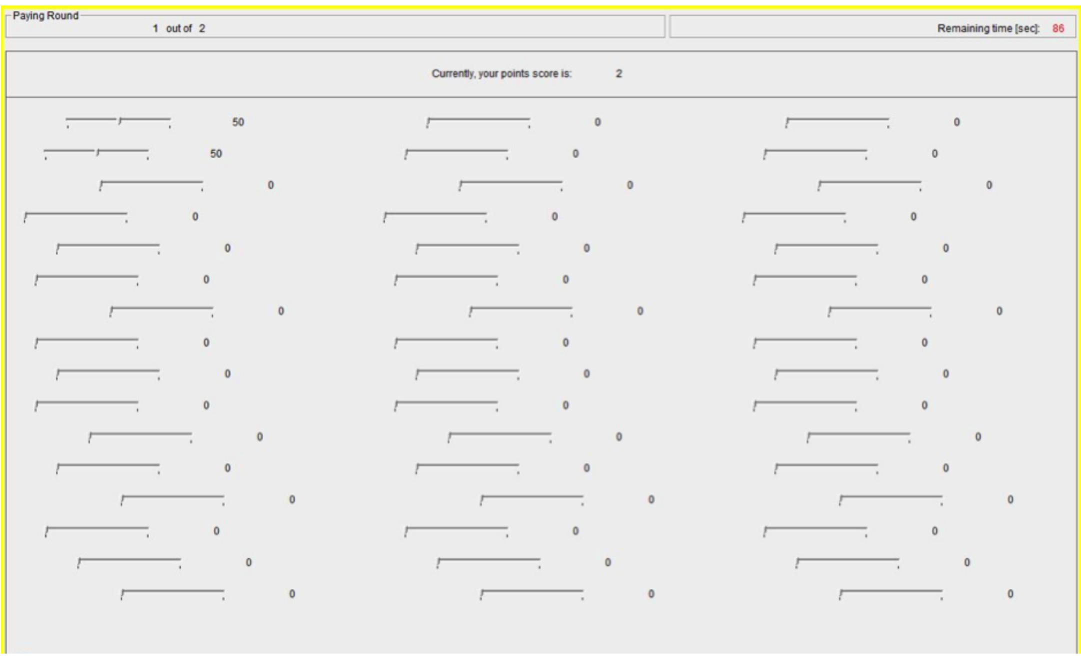
Please raise your hand if you have any questions.

INDIVIDUAL LOTTERY TREATMENT

Welcome to the experiment!

You are about to take part in a study on economic decision-making. The study will last about one hour. We are very grateful for your participation. You will be paid a guaranteed show-up fee of £4 for participating in the experiment. This is independent of your actions during the experiment. You will also have the opportunity to earn additional money. The final amount you earn will depend on your actions.

THE TASK
In each round, you will see 48 sliders on the screen.



Your task is to set the position of each slider to the centre. Each slider is initially positioned at 0 and your task is to set as many sliders as possible to 50.

You have 3 minutes to set as many sliders as possible to 50.

Each slider has a number to its right showing its current position. You should use your mouse to move each slider. You can readjust the position of each slider as many times as you wish. If you click on the slider, it will jump, hence it needs to be dragged.

At the top of the screen you see the time remaining and your points score in the task so far.

EARNINGS

Your payment in each round depends on the number of sliders you positioned. If you position 10 or more sliders at 50, you will receive a fixed pay of £0.60 per round. If you correctly position less than 10 sliders, you will not receive any payment for that round (save for the show-up fee).

After you correctly position 15 sliders, each extra correctly positioned slider add £0.30 to your bonus pool. At the end of each round, you may receive this bonus pool, with 20% probability.

Therefore, if you position at least 10 sliders correctly in all rounds, you can earn a total fixed pay of £3 (5 * £0.6) plus your bonus in each round.

ROUNDS

You will play 5 rounds of this task. Before these commence, you will have 2 additional practice rounds that will allow you to familiarise yourself with the task. Your performance in the practice rounds will not influence your final payoff.

Please raise your hand if you have any questions.

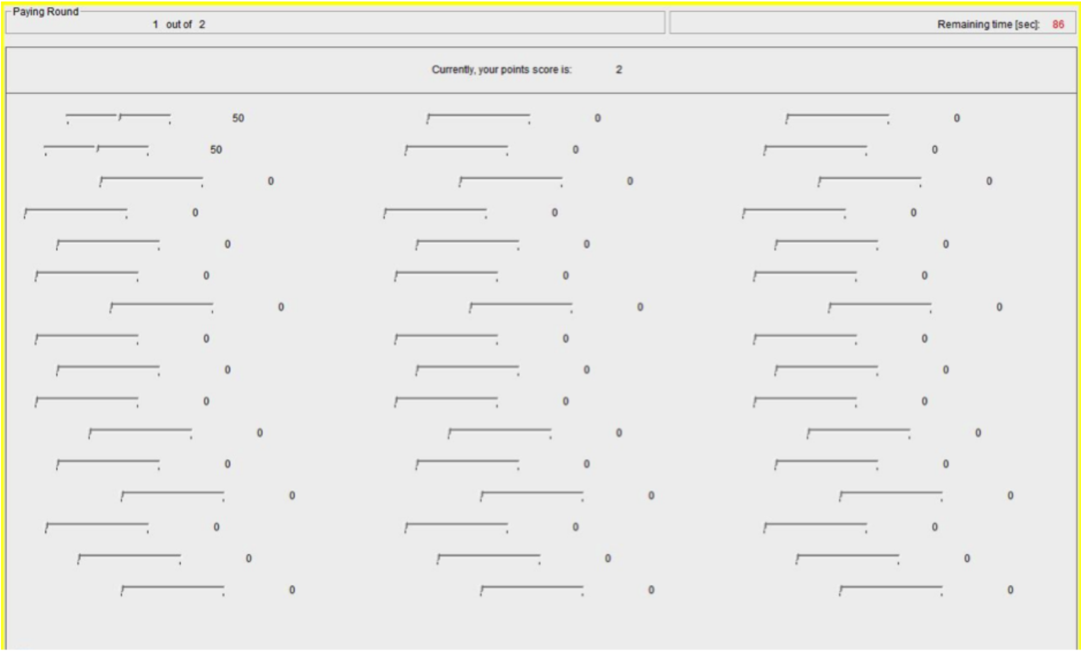
GROUP LOTTERY TREATMENT

Welcome to the experiment!

You are about to take part in a study on economic decision-making. The study will last about one hour. We are very grateful for your participation. You will be paid a guaranteed show-up fee of £4 for participating in the experiment. This is independent of your actions during the experiment. You will also have the opportunity to earn additional money. The final amount you earn will depend on your actions.

THE TASK

In each round, you will see 48 sliders on the screen.



Your task is to set the position of each slider to the centre. Each slider is initially positioned at 0 and your task is to set as many sliders as possible to 50.

You have 3 minutes to set as many sliders as possible to 50.

Each slider has a number to its right showing its current position. You should use your mouse to move each slider. You can readjust the position of each slider as many times as you wish. If you click on the slider, it will jump, hence it needs to be dragged.

At the top of the screen you see the time remaining and your points score in the task so far.

EARNINGS

You will be working in a fixed group of 5 people.

Your payment in each round depends on the number of sliders you positioned. If you position 10 or more sliders at 50, you will receive a fixed payment of £0.60 per round. If you correctly position less than 10 sliders, you will not receive any payment.

After you correctly position 10 sliders, each extra correctly positioned slider will add £0.06 to the group bonus pool, and earn you a lottery ticket to win the entire pool. At the end of each round, one of the lottery tickets will be selected, and its owner will earn the total prize. Note that more lottery tickets implies a higher chance of winning the total prize.

Thus, if you position at least 15 sliders correctly in all rounds, you can earn a total fixed pay of £3 (5 * £0.60) plus your lottery earnings in each round.

ROUNDS

You will play 5 rounds of this task. Before these commence, you will have 2 additional practice rounds that will allow you to familiarise yourself with the task. Your performance in the practice rounds will not influence your final payoff.

Please raise your hand if you have any questions.

3.10 Appendix 2: Social preferences eliciation game

We use the social preference game developed in Bartling et al., 2009. Our participants are asked to imagine a hypothetical scenario where they are allocated with another another anonymous participant, and have to choose between two binary allocations for each social preference principle. The first allocation corresponds to an egalitarian distrbibution in all games, while the second allocation favours the decision maker (other participant) in the prosociality (envy) and costly prosociality (costly envy) game.

All payoffs are in pounds.

(I) Pro-sociality 2: 2, 2: 1
(II) Costly pro-sociality 2: 2, 3: 1
(III) Envy 2: 2, 2: 4
(IV) Costly envy 2: 2, 3: 5

For our results, we consider the four principle variables as dummies that take value 1 when the first allocation is selected, and 0 when the second allocation is selected.
This task is not monetarily incentivised.

3.11 Appendix 3: Risk Preferences elicitation

We use the task developed by Holt and Laury (2002) and measure it as the selected amount of non safe options, hence a higher coefficient indicates a higher risk loving preference. This task is not monetarily incentivised.

Option A	Option B	Expected payoff difference
1/10 of \$2.00, 9/10 of \$1.60	1/10 of \$3.85, 9/10 of \$0.10	\$1.17
2/10 of \$2.00, 8/10 of \$1.60	2/10 of \$3.85, 8/10 of \$0.10	\$0.83
3/10 of \$2.00, 7/10 of \$1.60	3/10 of \$3.85, 7/10 of \$0.10	\$0.50
4/10 of \$2.00, 6/10 of \$1.60	4/10 of \$3.85, 6/10 of \$0.10	\$0.16
5/10 of \$2.00, 5/10 of \$1.60	5/10 of \$3.85, 5/10 of \$0.10	−\$0.18
6/10 of \$2.00, 4/10 of \$1.60	6/10 of \$3.85, 4/10 of \$0.10	−\$0.51
7/10 of \$2.00, 3/10 of \$1.60	7/10 of \$3.85, 3/10 of \$0.10	−\$0.85
8/10 of \$2.00, 2/10 of \$1.60	8/10 of \$3.85, 2/10 of \$0.10	−\$1.18
9/10 of \$2.00, 1/10 of \$1.60	9/10 of \$3.85, 1/10 of \$0.10	−\$1.52
10/10 of \$2.00, 0/10 of \$1.60	10/10 of \$3.85, 0/10 of \$0.10	−\$1.85

4 CHAPTER 2

Cheating, incentives, and money manipulation

With Gary Charness [1], Lara Ezquerra, [2] Ismael Rodriguez-Lara[3]

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4.1 Introduction

Many economic interactions require that individuals disclose information that they possess. Examples include a car dealer selling a used car, a broker giving advice on the best mortgage, or a professor writing a reference letter for a student or a colleague. In all these environments with asymmetric information, it may be socially-optimal for individuals to reveal their information truthfully. However, economic and personal incentives may lead people to deliberately misreport such information. One may shade the truth (so common in reference letters as to be the norm) or simply prevaricate. Such dishonesty is a form of cheating behavior, a term that also includes activities such as theft, embezzlement, and bribery.

There are noteworthy economic consequences associated with cheating behavior. Indeed, Cohn, Fehr and Marchal (2014) point to cheating in the business culture as a force that is plausibly responsible (at least in part) for the all-too-common scandals in business and politics. Tax evasion and avoidance led to diminished tax revenue of approximately 1 trillion in the Eurozone, according to the European Commission, and the IRS estimates the overall tax gap in the U.S represents about 16 percent of the estimated actual tax liability. In the developing world, corruption and cheating are quite prevalent; numerous dictators (e.g., Suharto, Marcos, and Duvalier) have shamelessly looted their countries, which have suffered greatly after the fall of the dictatorship; such corruption hinders investment and growth. In addition, recent experimental evidence has demonstrated that setting goals (Schweitzer, Ordez and Douma, 2004) or using policies such as team incentives (Conrads et al., 2013), random bonuses (Gill , Prowse and Vlassopoulos, 2013), or performance-based bonuses (Jacob and Levitt, 2003; Martinelli et al., 2017) can exacerbate cheating behavior.

In this paper, we study the effects of incentives on cheating behavior in both the loss and gain domains when people are asked to reveal a piece of private information. This information concerns a state of the world, whose report may only determine the payoff of the reporting agent. We focus on behavior when the money to be received is framed alternatively as a gain or a loss. There is evidence that loss contracts (i.e., up-front bonuses that workers can lose) increase workplace productivity (Brooks, Stremitzer and Tontrup, 2012; Hossain and List, 2012; Fryer et al., 2012). Further, workers might prefer loss contracts as a way to improve their performance and thus increase their expected earnings (Imas, Sadoff and Samek, 2016). However, Cameron and Miller (2009) and Grolleau, Kocher and Sutan (2016) find that subjects cheat more in a loss frame when reporting their own performance on a real-effort task. Cameron, Miller and Monin (2010) argue that paying people in advance for performing a task might induce a feeling of entitlement, and this might facilitate or even encourage unethical behavior.

We investigate whether people cheat more in a loss frame when their private information concerns the state of the world. Since a loss contract usually requires that people receive the money in advance, we conducted treatments (in the gain and the loss frame) with and without money manipulation, as this may affect the sense of ownership and what could be termed the moral cost of lying. This device helps us to tease apart the effects of the frame and the manipulation of money on cheating behavior.

We consider an environment where the outcome is independent of ones level of talent or ability, so that there should in principle be no measure of ones worth attached to the report (of course considerations of self-image and social image may still affect the reports). We use a variant of the seminal design developed by Fischbacher and Fllmi-Heusi (2013). Each participant is asked to privately roll a die (6-sided in the original experiment, 10-sided in ours), so that the experimenter cannot determine the veracity of the subsequent report [3]. The beauty of this design is that while the experimenter cannot know whether an individual is lying, statistical tests on the aggregate data show the extent to which the experimental population distorts the truth. Standard economic models predict that people will cheat in the absence of punishment when there is incentive to do so, but will otherwise be indifferent regarding telling the truth.

[3] We use a 10-sided die to increase the number of possible outcomes. Studies by, e.g., Greene and Paxton (2009), Hao and Houser (2010), Shalvi et al. (2011), Conrads et al. (2013), Gravert (2013), Jiang (2013) and Ploner and Regner (2013) have also used the die-rolling task. See Abeler, Nosenzo and Raymond (2016) for a recent meta-study. Other studies have used the sender-receiver game where cheating is strategic (i.e., the sender needs to send a message to the receiver about the real state of the world and the receiver may believe it or not). This includes, among others, Gneezy (2005), Sutter (2009), Lundquist et al. (2009), Erat and Gneezy (2012), Erat (2013) and Vanberg (2015).

We first compare behavior in a Baseline treatment where subjects receive a fixed amount regardless of their report with the behavior of people when their financial payoff depends on the reported outcome. To our knowledge, this is the first paper that directly tests whether subjects lie in the absence of incentives when their behavior does not impose any payoff externality on others. We then proceed to examine behavior in the loss and the gain domains, since the notion of loss aversion (Kahneman and Tversky, 1979) is so pervasive. In our standard treatments, we give subjects their earnings in a closed envelope at the end of the session, but we change the reference point. In the gain setting, the reported number determines the amount to be placed (by the experimenter) into the envelope, while in the loss setting all envelopes contain the maximum possible earnings and we subtract an amount that depends on the reported number. Arguably, loss aversion would predict more cheating with the loss framing, since giving up money would seem to be more unpleasant than simply not receiving money[4]. Finally, having observed our results in these treatments, we implemented treatments in which the participants either took their earnings from an envelope (gain treatment) or put money into an envelope after having received the maximum possible payoff at the beginning of the session (loss treatment).

How would loss aversion actually apply in a cheating environment? As mentioned above, Cameron and Miller (2009), Cameron, Miller and Monin (2010) and Grolleau, Kocher and Sutan (2016) observe that loss aversion encourages cheating in real-effort tasks. Their tasks differ from ours in that one would expect more concern about ones social image when ones ability (or honor) is at stake. Previous experimental evidence (e.g., Ertac, 2011; Charness, Rustichini, and van de Ven, 2013) shows that people are much less accurate in processing information when this information is self-relevant than when it concerns an outcome that is unaffected by ones level of talent. Thus, we might expect more cheating in a self-relevant performance task than in our task (Gravert, 2013).

The closest paper to ours is Schindler and Pfattheicher (2017). They ask subjects to roll a 6-sided die 75 times and then report the number of 4s they have obtained. While subjects report more 4s in the loss frame, the authors find no evidence of cheating in the gain frame, contrary to other experimental evidence (Abeler, Nosenzo and Raymond, 2016). Another salient difference between our designs is that we ask

[4]Garbarino, Slonim, and Villeval (2016) derive a prediction that people will lie more frequently when the probability of a (the) bad outcome is lower, since the higher expected payoff means that the loss avoided by lying compared to reference point is greater. They find support from an analysis of studies in the literature as well as new experiments. See also Abeler, Nosenzo and Raymond (2016) and Gneezy, Kajackaite and Sobel (2016) for other experiments that vary the probability of a (the) bad outcome.

subjects to report the outcome of a die roll, while the multiple die rolls in Schindler and Pfattheicher (2017) allows subjects to cheat more than once (see also Shalvi et al. 2011, Fischbacher and Fllmi-Heusi 2013)[5]. In addition, we complement their findings by looking at the moral costs and the effects of money manipulation on the reported outcomes.

We expect that moral concerns and social norms will interact with the motivation to cheat. With the mounting evidence on cheating behavior, some recent models include a term for the moral cost of lying but restrict this to be a function of the distance between the material payoff from cheating and that from not cheating (e.g., Lundquist et al.; 2009, Garbarino, Slonim, and Villeval, 2016). However, it is likely that other elements should be present in the arguments of a function reflecting the moral cost of cheating. For example, Utikal and Fischbacher (2013) find that nuns tend to under-report the die roll, perhaps wishing to appear modest in their demands. Subjects also refrain from cheating when the opportunity is made salient (Mazar, Amir and Ariely 2008; Gino, Ayal and Ariely 2009). The meta-study in Abeler, Nosenzo and Raymond (2016) indeed concludes that the desire to appear honest may be a key driving force in explaining cheating behavior in the die-rolling task[6].

In our setting, if you are given money and hold it in your possession, you may feel that you have been trusted (the mental-cheating condition could be seen as being a strong demand effect). Keeping the money with which you have been entrusted may feel more like stealing than taking money that youve been invited to take[7]. Trust and morality are important and people may be sensitive to small clues and considerations (Mazar, Amir and Ariely, 2008). If one feels trusted, this could mean that one believes that the trustor believes that the trustee will behave in a trustworthy manner. If one doesnt, then one may experience guilt (Charness and Dufwenberg, 2006; Battigalli and Dufwenberg, 2007, 2009; Battigalli, Charness, and Dufwenberg, 2013). We attempt to better understand the interplay between incentives to cheat in the gain and loss domain and the moral costs of cheating.

In fact, some of our experimental results will surprise many readers. We do find evidence across many

[5]Schindler and Pfattheicher (2017) consider a second study in mTurk, where subjects self-report the outcome of tossing a coin (Bucciol, and Piovesan, 2011). In this task, where cheating is a binary decision, Schindler and Pfattheicher (2017) find that cheating occurs in both the gain and the loss frame, with more cheating being observed in the later.

[6]See also Rosenbaum, Billinge and Stieglitz (2014), Kajackaite and Gneezy (2017), Gneezy, Kajackaite and Sobel (2016), and Dufwenberg and Dufwenberg (2016) for related evidence, and Mazar, Amir and Ariely (2008) for a theory of self-concept maintenance.

[7]This resembles the idea of omission-commission in Spranca, Minsk and Baron (1991). However, participants in our experiment are asked to enter the number they have obtained in the computer screen, thus cheating requires acts of commission even in the loss condition (Cameron and Miller, 2009)

of our treatments that cheating is more frequent when this affects the reporters material payoffs than when it doesnt. However, in the standard treatments where participants simply receive their payoffs in an envelope, we find no evidence of more cheating with a loss frame than with a gain frame. We felt that two elements could have helped to induce this finding. First, reports are constrained to be one of the 10 possible outcomes of the die roll. If subjects cheat maximally in the gain treatment (given their moral costs), one shall not observe more cheating in the loss frame. Second, the sense of ownership might have been too weak in this design. We addressed these points by affecting the moral costs of cheating and implement treatments in which the participants actually physically handle the money. Indeed, requiring the participants to engage in money manipulation led to less cheating. To our surprise, however, we find substantially less cheating in this loss treatment than in the corresponding gain treatment. In fact, there is no significant difference between behavior in the baseline treatment and in the loss treatment with money manipulation.

Thus, we find ourselves swimming upstream with our experimental results. We do interpret our results as reflecting differences in perceived trust and beliefs. We suspect that there were different moral costs and beliefs in different treatments. Specifically, people in the money-manipulation loss treatment might have been more likely to feel that they had been trusted with the full potential payoff in the beginning and might have had different beliefs about the beliefs of the experimenter than people in the corresponding gain treatment. Further, the decision to return money in the loss framing could be seen as warm-glow giving (Andreoni, 1989, 1990), especially in the money-manipulation loss treatment, where subjects had to place the amount to be returned in an envelope. Hence, it seems unrealistic to ignore the psychological (moral) costs and benefits that are likely to be involved in deciding whether (and by how much) to cheat.

The remainder of the paper is organized as follows. We present the experimental design, implementation, and hypotheses in Section 2, and describe the experimental results in Section 3. We provide some discussion and conclude in Section 4.

4.2 Experimental Design and hypotheses

4.2.1 Experimetnal design

A total of 426 subjects were recruited to participate in our experiment. We use the procedures in Fischbacher and Follmi-Heusi (2013) and add our experiment at the end of a previous experiment that took around 90 minutes[8]. All sessions were run at the Laboratory for Research in Experimental Economics (LINEEX) at the University of Valencia.

At the beginning of our experiment, subjects received a 10-sided die and a copy of the experimental instructions. [9]Their task consisted of rolling the die privately in their cubicles and reporting the number from the first roll on the computer screen. Subjects could roll the die as many times as desired, but were told that only the first throw was relevant for their payment.

Table 1: Payoffs (in Euros) in each treatment depending on the reported number (0 to 9)

Reported number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Baseline	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Gain treatments	0	1	1.5	2	2.5	3	3.5	4	4.5	5
Loss treatments	-5	-4	-3.5	-3	-2.5	-2	-1.5	-1	-0.5	0

We had five different treatments , which varied the payoffs that subjects received for reporting the outcome of the dice (see Table 1) and the extent to which subjects manipulated their potential earnings.

- Baseline treatment (Baseline): At the end of the session, subjects received a sealed envelope with a fixed amount (2.5), regardless of the number they reported.

- Gain with no money manipulation (Gain-NO): As in the baseline, subjects received their earnings in a sealed envelope at the end of the session. In this treatment, earnings ranged between 0 (when reporting 0) and 5 (when reporting 9).

- Loss with no money manipulation (Loss-NO): Before starting the session, subjects were informed that they had been allocated with an initial endowment of 5 to be kept in an envelope by the experimenter. Subjects were told that this would be used in a subsequent experiment. After

[8]Subjects in our experiment did not receive any feedback about the previous one until the end of the session. Our experiment was presented as an independent task to subjects, in which they could earn some additional money (all subjects decided to participate). This procedure is frequently used in the literature due to the short nature of the task.

[9]A translated version of the instructions can be found in Appendix A.

finishing the first experiment (90 minutes), subjects were reminded about their 5 and presented with our task. Subjects knew that the reported number would determine the amount to be deducted from the envelope. This was given to subjects at the end of the session.

- Gain with money manipulation (Gain-MM): Again, earnings increased with the reported number but subjects had an envelope with 5 on their desk before rolling the die. Each subject had to extract their earnings from the envelope upon rolling the die and reporting the outcome on the computer screen.
- Loss with money manipulation (Loss-MM): Subjects received the initial endowment (5) at the beginning of the session. They could keep this endowment on their table or put it in their pockets[10]. After finishing the first experiment (90 minutes), subjects were asked to take their initial endowment and put it on their table. Subjects were given an empty envelope. They rolled the die, reported the outcome, and placed the amount to be returned in the envelope before leaving the room.

Before proceeding to the hypotheses, there are some aspects of our experimental design that worth mentioning. First, earnings associated with each reported number were equivalent in the Gain and the Loss treatments. Second, we announced the initial endowment at the beginning of the session to subjects in the Loss treatments to trigger loss aversion. Finally, subjects in money-manipulation treatments had a second opportunity to cheat by misreporting the amount of money they had to take from or leave in the envelope. In this respect, our evidence is consistent with Cameron and Miller (2009) or Schindler and Pfattheicher (2017); we do not find that subjects recorded an outcome that did not correspond to the amount of money they took from or left into the envelope.

4.2.2 Hypotheses

Consider first the Baseline treatment. If people have standard preferences, we should expect reports to follow an equal distribution. We should also expect an equal distribution of reported numbers if lying has a cost. Even if one cares about social image, it is not obvious that rolling a higher number is better. Since we are not aware of any paper that directly tests for cheating behavior in the absence of economic incentives, our first prediction is:

[10] Roughly 1/3 of the subjects decided to leave the money on the table. The rest put it in their pockets.

Hypothesis 1: The distribution of reports in the Baseline treatment is not significantly different from the uniform distribution.

In all of our treatments except the Baseline, people have a financial incentive to cheat (Fischbacher and Fllmi-Heusi 2013, Shalvi et al. 2011, Abeler, Nosenzo and Raymond 2016). If people value money and the cost of lying is not extreme, we should expect to see reports in the Gain and Loss treatments that are significantly higher than that from either the uniform distribution or the Baseline. Thus, our second hypothesis is:

Hypothesis 2: The numbers reported in the Gain and Loss treatments will be significantly higher than those in the uniform distribution and in the Baseline.

In line with the literature on loss aversion (Kahenman and Tversky, 1979) and a plausible link between loss aversion and choices made with gain and loss frames, we expected more cheating with loss framing, leading to our third hypothesis:

Hypothesis 3: The numbers reported in a Loss treatment will be significantly higher than those reported in the corresponding Gain treatment.

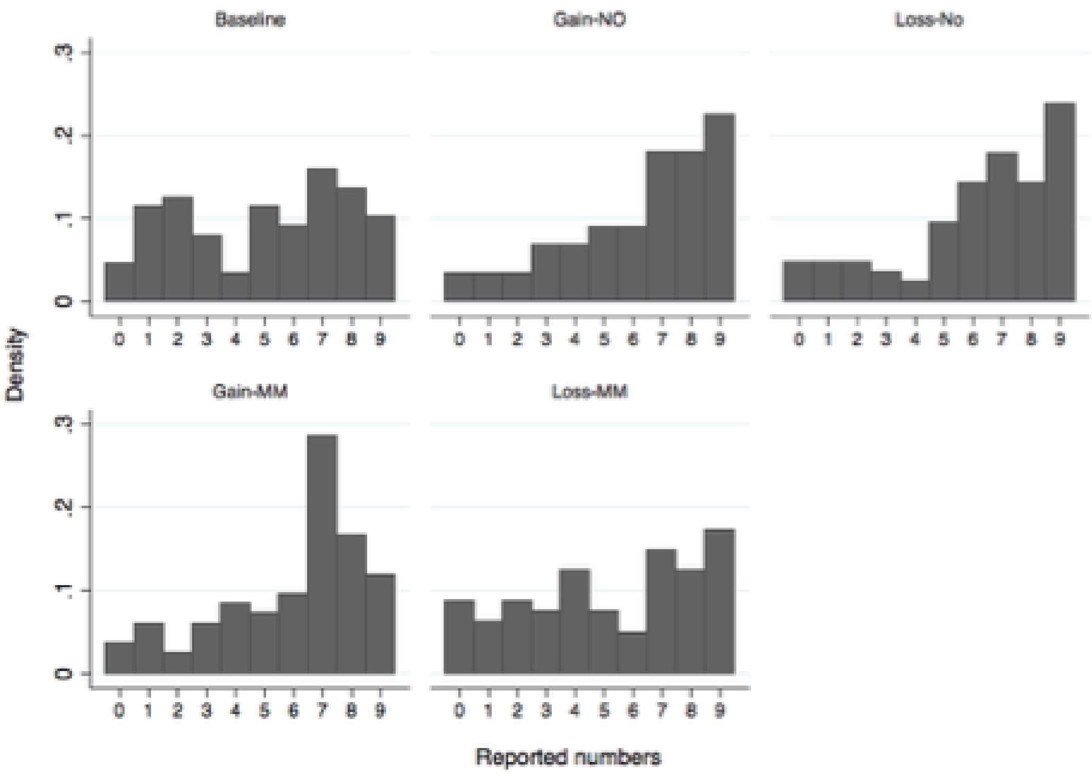
While cheating has clear financial benefits in the Loss and Gain treatments, it may also have a moral cost, e.g., subjects might be averse to cheat due to an intrinsic motivation to be honest (e.g., Lundquist et al., 2009), social image (the choice is observed by the experimenter) (e.g., Gneezy, Kajackaite and Sobel, 2016), a desire to hold a positive self view (e.g., Mazar, Amir and Ariely, 2008), or some form of guilt aversion (e.g., Battagalli and Dufwenberg, 2007, 2009). A moral cost of cheating has been useful to explain why we observe truth-shading rather than universal reporting of either the true value or the maximum value in previous experiments. We therefore feel that entrusting people with money (on their desk or at the beginning of the session) will increase the moral cost of lying, leading to our final hypothesis:

Hypothesis 4: The numbers reported in the money-manipulation treatments will be lower than in the corresponding treatments without money manipulation.

4.3 Results

Figure 1 displays the distribution of the reported numbers in each of the treatments. Table 1 summarizes our data by including information on the frequency and cumulative distribution of reported numbers. The average reported number is above the mean expected outcome (that predicted by the uniform distribution) of 4.5 in all the treatments. In fact, more high numbers (5-9) are reported than low numbers $(0 - 4)$ in all treatments. Consistent with previous findings (Fischbacher and Fllmi-Heusi 2013, Utikal and Fischbacher 2013, Shalvi et al. 2011, Abeler, Nosenzo and Raymond 2016), there is no single large spike at the payoff-maximizing outcome[11] .

Figure 1: Distribution of reported numbers per treatment



[11]We also note that there is no significant gender difference in any of the five treatments. The overall average number reported by males (females) was 5.849 (5.633). The overall proportion of zeroes reported by males (females) was 0.050 (0.048), while the proportion of nines reported by males (females) was 0.171(0.172). See, among others, Cappelen Sorensenand and Tungodden,(2012), Childs (2012), Gylfason Arnardottir and Kristinsson (2013) and Pascual-Ezama, Prelec and Dunfield (2015) for other studies showing no gender differences in cheating behavior.

Table 1: Descriptive statistics

Frequency and cumulative distribution of reports

Treatment	Obs.	Mean	SE	0	1	2	3	4	5	6	7	8	9
Baseline	88	4.977	0.304	4 (.046)	10 (.159)	11 (.284)	7 (.364)	3 (.398)	10 (.511)	8 (.602)	14 (.761)	12 (.898)	9 (1.00)
Gain-NO	89	6.281	0.270	3 (.034)	3 (.067)	3 (.101)	6 (.168)	6 (.236)	8 (.326)	8 (.416)	16 (.596)	16 (.775)	20 (1.00)
Loss-NO	84	6.214	0.291	4 (.048)	4 (.095)	4 (.143)	3 (.179)	2 (.202)	8 (.298)	12 (.440)	15 (.619)	12 (.761)	20 (1.00)
Gain-MM	84	5.952	0.271	3 (.036)	5 (.095)	2 (.119)	5 (.179)	7 (.262)	6 (.333)	8 (.429)	24 (.714)	14 (.881)	10 (1.00)
Loss-MM	81	5.198	0.332	7 (.086)	5 (.148)	7 (.235)	6 (.309)	10 (.432)	6 (.506)	4 (.556)	12 (.704)	10 (.827)	14 (1.00)

Notes: Frequency is in whole numbers and cumulative distribution is in parentheses. SE = standard error.

We proceed to test our hypotheses with both non-parametric tests and regression analysis. First, the Kruskal-Wallis test rejects the hypothesis that observations in the different treatments come from the same distribution ($X_4^2 = 14.95, p = 0.005$), thus monetary incentives and/or the manipulation of money seems to affect the reported outcomes. The results of out non-parametric analysis are summarized in Table 2. We first investigate whether the reported outcomes in each of treatment differ from the actual expected outcomes (i.e., the equal distribution) using a ^{2} test. Using Wilcoxon rank-sum and Kolmogorov-Smirnov tests, we compare the reports in the Gain and Loss treatments with those in the Baseline (where subjects have no incentives to cheat).

Table 2: Non-parametric analysis on cheating behavior

	Expected outcomes	Baseline outcomes	
Treatment	χ^2test	Wilcoxon rank-sum (Z)	Kolmogorov-Smirnov (KS)
Baseline	12.00 (0.213)	-	-
Gain-NO	38.98 (0.000)	3.128 (0.001)	0.195 (0.024)
Loss-NO	39.57 (0.000)	2.880 (0.002)	0.213 (0.013)
Gain-MM	45.11 (0.000)	2.165 (0.015)	0.070 (0.039)
Loss-MM	11.72 (0.230)	0.610 (0.271)	0.185 (0.488)

Note: p-values (in parentheses) reflect one-tailed tests.[10] The χ^2 test compares expected to actual outcomes.

Hypothesis 1 states that there will be no difference between reports in the Baseline treatment and the expected outcomes of the die roll. In fact, while we do see a slight tendency towards reporting higher numbers, the ^{2} test shows no significant difference between the reports in the Baseline and the actual expected outcomes ($p = 0.213$)[12]. Thus, we see no significant evidence of distortion in the reports made when there is no financial incentive for misreporting.

Result 1. There is no evidence of cheating in the absence of economic incentives. We expected more cheating in our four treatments where there is a financial incentive to report a higher number than was actually rolled, as stated in Hypothesis 2. Indeed, the Gain-NO and Loss-NO treatments have much higher numbers than the expected true outcomes ($p < 0.001$) or the Baseline ($p < 0.024$). There is also evidence in the Gain-MM treatment of distortion relative to the expected outcomes (p ¡ 0.001) and the Baseline ($p < 0.039$). However, there is surprisingly little difference between the reports made in the Loss-MM and Baseline treatments or between the reports in Loss-MM and the expected actual outcomes ($p > 0.230$).

Result 2. Incentives affect cheating in all treatments except in the Loss-MM, where the distribution of reported numbers is very close to the expected actual outcomes and the Baseline distribution.

Hypothesis 3 predicts that presumed loss aversion will manifest in more cheating in reports made in the loss frame than those made in the gain frame. As suggested in the preceding paragraph, the observed patterns do not support this hypothesis. In fact, there is very little difference in the reports across the Gain-NO and Loss-NO; the average report is in fact only slightly higher in the Gain-NO treatment (6.281 versus 6.214). The respective one-tailed test statistics and p-values are Z$= -0.089$, $p = 0.536$ and $KS = 0.042$, $p = 0.500$. What may be even more surprising is that there is substantially less cheating in Loss-MM than in Gain-MM. In any case, we have strong evidence to reject Hypothesis 3 in the money-manipulation treatments.

Result 3. Incentives in the loss domain do not increase cheating behavior compared with incentives in the gain domain.

[12]Throughout the paper, we round all p-values to three decimal places. The interested reader on the comparison between the reported outcomes in each treatment and expected actual outcomes using the Wilcoxon rank-sum test or the Kolmogorov-Smirnov test of cumulative distributions can consult Appendix B (Table B1). This includes information on the fraction of subjects who cheat to avoid the worst possible outcome using the estimation method in Garbarino, Slonim and Villeval (2016).

Finally, Hypothesis 4 predicts that money manipulation will lead to less cheating due to an increased moral cost of lying. We find strong support for the hypothesis when we compare reports made in the Loss-MM and Loss-NO treatments. In fact, the median (modal) report in the Loss-MM treatment is 5(7), while the median (modal) report in the Loss-NO treatment is 7(9). The Wilcoxon test gives $Z = 2.128$, $p = 0.016$, while the Kolmogorov-Smirnov test gives $KS = 0.230$, $p = 0.008$, both one-tailed tests. The differences across the reports in the Gain-MM and Gain-NO treatments are considerably more modest and not statistically significant. Here the Wilcoxon test gives $Z = 1.144$,$p = 0.126$, while the Kolmogorov test gives $KS = 0.119$, $p = 0.254$, both one-tailed tests. Thus, we see that money manipulation makes a real difference with a loss framing, but much less of a difference with a gain framing.

Result 4. Money manipulation reduces cheating behavior, especially in the loss framing.

We now proceed to the regression analysis. In Table 3, we report the results of a Tobit analysis, where the set of independent variables include dummies for the gain frame and the manipulation of money, as well as the interaction term[13]. The reported standard errors (in parentheses) are clustered at the session level. Our first regression in column (1) uses the data from all treatments except the Baseline. Specifications (2) to (5) give the results for different Tobit models, depending on whether or not subjects manipulate the money and the frame. As already suggested, there is no evidence of loss aversion in our data. If there is no money-manipulation, the behavior in the Loss frame is not significantly different from the behavior in the Gain frame. Money-manipulation does reduce the reported outcomes, but the effect is only significant in the loss frame, in fact subjects cheat more in the Gain than in the Loss treatment with money-manipulation.

[13] In our Tobit analysis in Appendix B (Table B2) the set of independent variables include dummies for each of the treatment conditions, which are then compared with the Baseline reports. We note that ordinary least squares regressions provide qualitatively the same results and similar levels of significance. Our findings are also robust to controlling for the earnings of the previous experiment. While the subjects were not informed about such earnings when rolling the die, one might argue that they might had formed some beliefs to be used as a reference point. Table B1 presents the correlation between previous earnings and the reports, which is not statistically significant in any of the treatments ($p > 0.165$).

Table 3: Regression analysis

	(1) Pooled data	(2) No Manipulation	(3) Manipulation	(4) Gains	(5) Losses
Constant	6.624***	6.628***	5.368***	6.636***	6.678***
	(0.459)	(0.480)	(0.127)	(0.231)	(0.534)
Gain	0.061	0.061	0.757**		
	(0.505)	(0.527)	(0.365)		
Money-manipulation	-1.254***			-0.531	-1.285**
	(0.476)			(0.386)	(0.553)
Gain × Money-manipulation	0.696				
	(0.605)				
Sigma	3.350***	3.376***	3.326***	3.043***	3.685***
	(0.187)	(0.197)	(0.345)	(0.197)	(0.192)
Pseudo LL	-762.751	-380.477	-382.262	-386.015	-374.673
# of obs. (uncensored)	338 (257)	173 (126)	165 (131)	173 (137)	165 (120)

Notes: Specification (1) includes data from all treatments except the Baseline. Specification (2) includes data from only the Gain-NO and Loss-NO treatments, while (3) includes data only from the Gain-MM and Loss-MM treatments. Specification (4) includes data only from the Gain-NO and Gain-MM treatments, (5) includes only data from the Loss-NO and Loss-MM treatments. ** and *** indicate significance at the $p = 0.05$ and $p = 0.01$ levels, respectively, two-tailed tests.

4.4 Discussion

Our results confirm some expected patterns. For example, people do not lie when there is no financial incentive to report an outcome different from the one that actually occurred; we find no significant difference between the reports made in this environment and the expected distribution of actual outcomes. We also observe considerable dishonesty when there is a financial incentive to report a higher number, which is consistent with previous work. Finally, money-manipulation seems to affect the moral cost of cheating and thus the reported outcomes.

But our other results are largely surprising. We expected to find evidence of more cheating when earnings associated to the report were framed as a loss, but we found absolutely no evidence of this in a standard environment. When we conducted treatments where the participants were given envelopes with the funds and then had to physically handle the money, we observe less cheating in the loss frame than in the gain frame! In fact, there was only a modest and insignificant difference in the reports in the Baseline treatment and the loss frame with money manipulation. This last result would appear to turn conventional wisdom on its head.

What could explain these unexpected results? An important consideration regarding loss aversion is the reference point for gains and losses and this may be unclear in laboratory settings (Terzi et al. 2016). While loss aversion and reference dependence are widely accepted, the generality of loss-aversion seems less than universal. A number of studies (e.g., Erev, Ert, and Yechiam, 2008; Harinck et al., 2007; Kermer et al., 2006) examining the effect of losses in decision-making under risk and uncertainty in fact find no evidence of loss aversion, as it occurs in our standard treatments. It is possible that subjects in our gain and loss treatments were already cheating maximally (given their moral costs), thus the (constrained) task prevented us to find more cheating under loss aversion; the spikes are in fact at the maximum value in the standard treatments[14]. We decided to affect the moral costs of cheating by asking subjects to manipulate the money. The spikes at higher numbers other than the maximum value in the money-manipulation treatments suggest that many people who choose to lie do not wish to either be seen as a liar (in fact by far the highest spike in all of the data is the spike at 7 in the Gain-MM treatment).

To our surprise, however, our null result was not driven by a lack of a sense of ownership of the funds as we find evidence of reversed loss aversion in the money-manipulation treatments. Harinck et al. (2007) document also this effect in a series of experiments where subjects are asked to rate how (un)pleasant would be finding (losing) small amounts of money. They argue that the negative feelings associated with small losses may be outweighed by the positive feelings associated with equivalent small gains. In our experiment, these feelings are likely to be affected by the damage to ones image and the beliefs about what is expected.

We suspect that if one feels trusted, one is more likely to respond in an honest or trustworthy manner. It could be that it is more costly for subjects to cheat when they receive the money in advance because they feel they have been trusted. If the feeling of being trusted leads to different beliefs about what is expected, it could be the case that one believes that the trustor believes that one will behave in a trustworthy manner; otherwise, one may experience disutility from guilt[15]. Perhaps people in the money-manipulation treatments had different beliefs about the expectations of the experimenter than people in the other variable-pay treatments. Having been endowed with visible money in the beginning

[14]Some people seem to care about reporting a higher number in the Baseline treatment, since more high numbers (5-9) are reported than low numbers in this case more than 60% of the reports are high numbers. While there is no overall difference between the reports in the Baseline and the expected true values, it is nevertheless the case that this 60% is meaningful. The binomial test tells us the probability that 53 or more of 88 random draws in this treatment being high numbers is only 2.8%.

[15]This goes to the issue of whether one is more honest if one feels trusted. Some evidence is provided for this idea in Charness (2000). Additionally, Campbell (1935), May and Loyd (1993) and Haines et al. (1986) find that an honor system induces more honesty than does a proctor. See also Mazar, Amir and Ariely (2008) or Gino, Ayal and Ariely (2009) for the related evidence on the importance of honor codes on cheating behavior.

of an experiment in the loss frame may also make cheating more salient than having an envelope from which people can later take money. Mazar, Amir and Ariely (2008) and Gino Ayal and Ariely (2009) find that subjects cheat less when cheating is salient. By asking subjects to return the money in the loss treatment, we might also trigger impure altruism (Andreoni, 1989, 1990). Subjects can also have different attitudes towards losing the money in the loss treatments with and without the manipulation of money, as paper losses can be treated differently from those that are realized (Weber and Zuchel 2005; Imas, 2016); this can be due to mental accounting (Thaler, 1985).

One might nevertheless wonder why there was more cheating in the loss frame than in the gain frame in other studies. In our study, there is nothing regarding ones own ability, while the work of Cameron and Miller (2009), Cameron, Miller and Monin (2010) or Grolleau, Kocher and Sutan (2016) involves reporting ones own performance in a cognitive task. Ones judgment about own ability seems to be more malleable than ones judgment about events over which one has no control, as seen in the updating studies mentioned earlier. Indeed, lying is likely to have some moral cost, but one would like to appear talented or capable in the eyes of those who may be watching or even ones self; in fact, this may not even be a conscious tendency (see Charness, Rustichini, and van de Ven, 2014)[16]. Using the die-roll task, Schindler and Pfattheicher (2017) allows for multiple rolls of the die and find that reports are larger under loss aversion, but the authors do not find evidence that people cheat in a gain setting. We complement their findings by also looking at the effects of the moral costs, which seems to be a crucial element in understanding cheating behavior.

4.5 Conclusion

Our paper investigates cheating behavior when experimental participants are asked to reveal a piece of private information that does not reflect on their personal ability and where ones choice does not affect the financial payoffs of other participants. This information concerns the state of the world. In the Baseline treatment, there is no financial incentive for misreporting the state of the world and the reports made do not differ significantly from expected outcomes with random draws. On the other hand, reports when there are financial incentives to cheat generally show considerable evidence of lying on the

[16]Some people even seem to care about reporting a higher number in the Baseline treatment, since more high numbers (5-9) are reported than low numbers in this case more than 60% of the reports are high numbers. While there is no overall difference between the reports in the Baseline and the expected true values, it is nevertheless the case that this 60% is meaningful. The binomial test tells us the probability that 53 or more of 88 random draws in this treatment being high numbers is only 2.8%.

reports made. In addition, we study cheating in the absence of payoff externalities, in that only ones own material payoff is affected by reported outcome.

We do not find evidence that loss aversion translates into this environment. There is no difference in behavior across gain and loss frames when payment is simply made at the end of the session. More remarkably, when we endow participants with prospective payment in advance, there is substantially less cheating in the loss frame. We presume that the observed behavior represents differences in the moral cost of cheating, reflected by either some form of guilt aversion or a desire to have a favorable self-image or social image.

Our results represent a challenge for the more standard behavioral theories such as loss aversion and reference points. It seems that the moral cost of behavior is an element that must not be ignored. We expect more research will follow on this theme, as it is critical to understanding cheating and corruption in the world at large.

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4.7 Appendix A: Experimental Instructions (originally in Spanish)

BASELINE TREATMENT

Instructions (to be read aloud)

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices.

Next, you will receive the instructions and a 10-sided die. Instructions should be easy to follow. Please read the instructions carefully and raise your hand if you have any doubt, as it is important that you understand the instructions before starting the experiment.

Instructions

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices. Please do not think that we expect a particular behavior from you. However, take into account that your decisions along the experiment may affect your earnings. Below, you will find details of your task in this experiment. Please follow the instructions carefully, as it is important that you understand the experiment before starting. Talking with each other is forbidden during the experiment. If you have any questions, raise your hand and remain silent. You will be attended by the instructor as soon as possible.

What is the experiment about?

Your task consists on throwing the 10-sided dice that you received memorizing the number that you obtain in the first throw. This number will determine your earnings as is shown in the table below.

Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Amount	2.50 €	2.50 €	2.50 €	2.50 €	2.50 €	2.50 €	2.50 €	2.50 €	2.50 €	2.50 €

This means that you will earn 2.50 regardless of the number that you report. First, we ask you to roll the dice and memorize the number you obtain in the first throw. Then, introduce this number in the computer screen. You can throw the dice as many times as you want to test that it works properly. Still, your payment depends only on the number you report for the first throw. At the end of the experiment, you will receive your earnings (in an anonymous way) in a sealed envelope.

GAIN-NO TREATMENT

Instructions (to be read aloud after the first experiment)

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices.

Next, you will receive the instructions and a 10-sided die. Instructions should be easy to follow. Please read the instructions carefully and raise your hand if you have any doubt as it is important that you understand the instructions before starting the experiment.

Instructions (to be read privately)

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices. Please do not think that we expect a particular behavior from you. However, take into account that your decisions along the experiment may affect your earnings. Below, you will find details of your task in this experiment. Please follow the instructions carefully, as it is important that you understand the experiment before starting. Talking with each other is forbidden during the experiment. If you have any questions, raise your hand and remain silent. You will be attended by the instructor as soon as possible.

What is the experiment about?

Your task consists on throwing the 10-sided dice that you received memorizing the number that you obtain in the first throw. This number will determine your earnings as is shown in the table below.

Number	0	1	2	3	4	5	6	7	8	9
Amount	0 €	1 €	1.50 €	2 €	2.50 €	3 €	3.50 €	4 €	4.50 €	5 €

This means that you will earn 0 if the number you report is 0, 1 if the number you report is 1, 1.50

if the number you report is 2, so on, obtaining an amount of 5 if you report a 9.
First, we ask you to roll the dice and memorize the number you obtain in the first throw.
Then, introduce this number in the computer screen.
You can throw the dice as many times as you want to test that it works properly. Still, your payment depends only on the number you report for the first throw.
At the end of the experiment, you will receive your earnings (in an anonymous way) in a sealed envelope.

LOSS-NO TREATMENT

Welcome (to be read aloud at the beginning of the session)

Welcome to the lab! Today, you have received an initial amount of 5 Euros for participating in an experiment that follows the one that is about to start. From now, this money belongs to you. Next, we will explain to you the instructions of the first experiment.

(Subjects participate in the first experiment)

Instructions (to be read aloud after the first experiment) The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices.

Next, you will receive the instructions and a 10-sided die. Instructions should be easy to follow. Please read the instructions carefully and raise your hand if you have any doubt as it is important that you understand the instructions before starting the experiment.

What is the experiment about? Before starting the experiment you received 5 €.
Your task consists on throwing the 10-sided dice that you received memorizing the number that you obtain in the first throw. This number will determine your earnings as is shown in the table below.

Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Amount	-5 €	-4 €	-3.50 €	-3 €	-2.50 €	-2 €	-1.50 €	-1 €	-0.50 €	-0 €

This means that you will return 5 €. if the number you report is 0, 4 €. if the number you report is 1, 3.50€. if the number you report is 2, so on, returning an amount of 0 €. if you report a 9.
First, we ask you to roll the dice and memorize the number you obtain in the first throw.

Then, introduce this number in the computer screen. We shall subtract the amount that you need to return from your initial 5 Euros.
You can throw the dice as many times as you want to test that it works properly, still your payment depends only on the number you report for the first throw.
At the end of the experiment, you will receive your earnings (in an anonymous way) in a sealed envelope.

GAIN-MM TREATMENT

Instructions (to be read aloud after the first experiment)

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices.

Next, you will receive the instructions, an envelope with 5 Euros and a 10-sided die. Instructions should be easy to follow. Please read the instructions carefully and raise your hand if you have any doubt as it is important that you understand the instructions before starting the experiment.

(The envelope was left on the table when instructions were given to participants. We underline the sentence to highlight differences with respect to other treatments.)

Instructions (to be read privately)

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices. Please do not think that we expect a particular behavior from you. However, take into account that your decisions along the experiment may affect your earnings. Below, you will find details of your task in this experiment. Please follow the instructions carefully, as it is important that you understand the experiment before starting. Talking with each other is forbidden during the experiment. If you have any questions, raise your hand and remain silent. You will be attended by the instructor as soon as possible.

What is the experiment about?

Your task consists on throwing the 10-sided dice that you received memorizing the number that you obtain in the first throw. This number will determine your earnings as is shown in the table below.

Number	0	1	2	3	4	5	6	7	8	9
Amount	0 €	1 €	1.50 €	2 €	2.50 €	3 €	3.50 €	4 €	4.50 €	5 €

This means that you will earn 0 €if the number you report is 0, 1 €if the number you report is 1, 1.50€if the number you report is 2, so on, obtaining an amount of 5 €if you report a 9.

First, we ask you to roll the dice and memorize the number you obtain in the first throw.

Then, report this number using the computer screen. There is an envelope with 5 Euros on your table. Take the money that corresponds to your throw and sealed it.

You can throw the dice as many times as you want to test that it works properly, still your payment depends only on the number you reported for the first throw. At the end of the experiment, the instructor will pick up the sealed envelopes when you leave the room. Your earnings will be anonymous.

LOSS-MM TREATMENT

(Subjects are given 5 Euros when entering the room)

Welcome (to be read aloud at the beginning of the session)

Welcome to the lab! Today, you have received an initial amount of 5 Euros for participating in an experiment that follows the one that is about to start. From now, this money belongs to you. Next, we will explain to you the instructions of the first experiment.
(We observe that roughly 1/3of the subjects decided to leave the money on the table, while 2/3 of the subjects kept it in their pockets or bags. Subjects participate in the first experiment. After finishing the first experiment, we ask subjects to take their endowment and put it on the table.)

Instructions (to be read aloud after the first experiment)

The aim of this experiment is to study decision-making. We are not interested in your particular choices but rather on the individuals average behavior. Thus, all through the experiment you will be treated anonymously. Neither the experimenters nor the people in this room will ever know your particular choices.

Next, you will receive the instructions, an empty envelope and a 10-sided die. Instructions should be easy to follow. Please read the instructions carefully and raise your hand if you have any doubt as it is important that you understand the instructions before starting the experiment.

(The envelope was left on the table when instructions were given to participants. We underline the sentence to highlight differences with respect to other treatments.)

What is the experiment about? Before starting the experiment you received 5€. Your task consists on throwing the 10 sided dice that you received memorizing the number that you obtain in the first throw. This number will determine your earnings as is shown in the table below.

Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Amount	-5 €	-4 €	-3.50 €	-3 €	-2.50 €	-2 €	-1.50 €	-1 €	-0.50 €	-0 €

This means that you will return 5 €if the number you report is 0, 4 €if the number you report is 1, 3.50€if the number you report is 2, so on, returning an amount of 0 €if you report a 9. First, we ask you to roll the dice and memorize the number you obtain in the first throw. Then, introduce this number in the computer screen. Place the amount that you need to return in the envelope and sealed it. You can throw the dice as many times as you want to test that it works properly, still your payment depends only on number obtained on the first throw. At the end of the experiment, the instructor will pick up the envelopes. Your earnings will be anonymous.

4.8 Appendix B

In Section 3, we use a ^{2} test to investigate whether the reported outcomes differ from the expected ones (i.e., the equal distribution). In the first columns of Table B1, we show that our results are robust to the Wilcoxon rank-sum test (Z) and the Kolmogorov-Smirnov (KS) test of cumulative distributions, except for the Loss-MM treatment, where the one-tailed comparisons between the reports and the expected actual outcomes come close to statistical significance.

Treatment	*Z*	*KS*	% cheaters	Correlation
Baseline	1.099 (0.272)	1.810 (0.405)		-0.125 (0.245)
Gain-NO	4.095*** (0.000)	14.056*** (0.000)	62.43%	-0.148 (0.165)
Loss-NO	3.886*** (0.000)	15.454*** (0.000)	48.37%	-0.028 (0.802)
Gain-MM	3.296*** (0.001)	12.448*** (0.001)	60.12%	-0.068 (0.541)
Loss-MM	1.563* (0.059)	3.459* (0.089)	21.99%	-0.004 (0.971)

Notes. * and *** indicate significance at the $p = 0.10$ and $p = 0.01$ levels, respectively. p-values are reported in brackets.

The literature on cheating behavior has usually identified honest subjects as those who report the worst possible outcome (Fischbacher and Fllmi-Heusi, 2013). The third column of Table B1 reports the fraction of subjects who cheat to avoid the worst possible outcome (receiving nothing) using the estimation method in Garbarino, Slonim and Villeval (2016). The last column of Table B1 reports the correlation between the reported outcomes and the participants earnings in the previous experiment. While this is negative and never significant .

In Table B2, we report the results of a Tobit analysis, where the set of independent variables include dummies for our treatment conditions. The reported standard errors (in parentheses) are clustered at the session level.

Table B2: Regression analysis (using the Baseline as the benchmark)

	(1) Pooled data
Constant	5.079*** (0.203)
Gain-NO	1.602*** (0.392)
Loss-NO	1.541*** (0.502)
Gain-MM	1.046*** (0.372)
Loss-MM	0.289 (0.241)
Pseudo LL	-973.023
# of obs.	426
(uncensored)	(332)

In line with our previous analysis, we find that all treatments are statistically different from the

Baseline ($p < 0.01$) except for the Loss-MM treatment ($p = 0.231$). Pairwise comparisons confirm that there is no significant difference between reports in Gain-NO and Loss-NO ($p = 0.674$), while there is a significant difference between the reports in the Gain-MM and Loss-MM treatments ($p = 0.016$). We also see that there is a significant difference between the reports in the Loss-NO and Loss-MM treatments ($p = 0.003$), while the difference between the reports in the Gain-NO and Gain-MM treatments is weakly significant ($p = 0.062$), this suggesting that the manipulation of money can also have an effect in the Gain treatments in the expected direction.

5 CHAPTER 3

Environmental regulation and the firm's internationalization strategy

5.1 Introduction

Environmental regulation has been under the spotlight for a long time, but it has acquired particular relevance in recent years as public concern regarding both the environment itself and the wider impact of pollution on human health increases. The international community is increasingly scrutinising those countries that pollute the most, making this a particularly active area for policy research.

According to the Pollution Haven Hypothesis, firms which wish to relocate their production will seek to do so in countries where resources are cheaper; this includes the cost of pollution. Due to differing policy environments, firms from developed countries tend to relocate to less developed countries, where the labour is cheaper and the environmental laws are more lax. It is also in the interests of less developed countries to attract FDI, as this benefits such economies in terms of employment creation, tax revenues, technology transfers, and through numerous other mechanisms. Hence, LDCs have incentive to engage in a race to the bottom, undercutting one anothers standards to attract the FDI and capital inflows.

Consideration to such so-called pollution havens is of great importance in the formulation of environmental and international trade policies, but their existence is not always clear in the literature. Several publications find inconclusive evidence in support of a relationship between FDI and environmental regulation (Dean et al., 2009; Levison, 1996a,b; List et al., Brunnermeir and Levinson (2004); and Frederikson et al., 2003 among others). Recent developments in the literature link the pollution haven effect to a countrys institutional corruption (Beata and Wei, 2005), endogenous market structure (Frederik et al., 2003; Elliott and Zhou, 2013), and small market sizes (Dong et al., 2012), amongst other factors.

More recently, a small number of papers have emerged that model the process through which more stringent environmental regulations may not deter or induce local firms to relocate. Dijkstra et al. (2011) demonstrate in a Cournot duopoly setting (with an exogenous duopoly market structure in the host country) that FDI is more likely if higher regulation costs raise the costs for the domestic firm over and above those for the foreign firm. Sanna-Randaccio and Sestini (2012) show that when the market size of the home country is large, more stringent environ- mental regulation does not necessarily induce firms to relocate to foreign countries with lax environmental regulations. Elliott and Zhou (2013) also conclude that if the production is dirty enough, more stringent regulation can encourage FDI.

The mixed evidence for the existence of PHH may be driven by heterogeneity between investments, which is not accounted for in the aforementioned literature (Bialek, 2015). Levinson and Taylor (2013) also find evidence in support of this hypothesis. Accounting for this heterogeneity involves recognising that the FDI can take two forms: Greenfield and Mergers and Acquisitions (M&A). While Greenfield implies settling a new firm, MA means acquiring or merging with a firm already in existence in the LDC.

This difference might explain the inconclusiveness of evidence with respect to a relationship between FDI and environmental regulation; grandfathering policies, i.e. a policy environment whereby newly settled firms are subject to more stringent environmental regulations comparative to incumbent firms, which might be subject to older regulations. In general, newer regulatory frameworks are more stringent (Low and Yeats, 1992; Leonard, 1988; Kahn, 2000). This is an important characteristic of environmental policy: requiring all firms in operation to simultaneously adjust to a new regulatory framework would require a long implementation period, and would be more costly, hence it is common practice for only newly settled firms to be subjected to newer, more stringent, regulations. For example, one of the important innovations of the 1970 Clean Air Act (CAA or the Act) in the U.S., was the decision to regulate air pollution sources directly. However, recognising that companies had already invested capital in existing sources, and that the cost of retrofitting these sources with modern pollution controls is often prohibitive, Congress did not require owners of existing stationary sources to install air pollution control technology until these factories were modified or upgraded in a way that would increase air pollution.

One key point is that, in the case of M&A, the environmental regulation that the firm is subject to may affect the acquisition price. Indeed, MA are less sensitive to differences in international taxes than Greenfield investment, which is consistent with capitalisation of taxes in the acquisition price (Hebous et al., 2011). Hence, we expect Greenfield investment to be more sensitive to current environmental regulations.

As far as we know, the literature hitherto has not distinguished between the two modes of FDI (Greenfield and M&A) when studying the relationship between FDI and environmental policy stringency. Bialek and (2015) shows that investors preferences for environmental laxity depend strongly on both the mode of FDI and the pollution intensity of the sector, where stringency is only found to be significant for Greenfield investments, while increased restrictiveness of regulation has a positive effect on the probability of clean Brownfield investment in a given jurisdiction.

Moreover, in the case of an M&A investment, the acquisition price may already be a function of the regulation faced by the company. This is in analogy to the taxation literature which states that in a high tax country a portion of the tax burden may be capitalized, reducing the acquisition price (Hebous et al., 2011). Due to those reasons I expect that Greenfield projects have a significantly higher sensitivity with respect to environmental requirements than M&A investments.

As far as I know, the distinction between the two modes of entry has not been taken into account in the literature on the effects of environmental regulation on FDI location.

An exemption will be the empirical working paper by Bialek and (2015), where they show that investors preferences for environmental laxity depend strongly on both the mode of FDI and the pollution intensity of the sector, being the stringency only significant for Greenfield investments, while increased restrictiveness of regulation has a positive effect on the probability of clean Brownfield investment in a given jurisdiction.

Our results contribute to a possible explanation for the mixed evidence in the empirical literature and provide an illustration of the conditions under which environmental regulations in the host country can affect the location decision of foreign firms. I develop a North-South model under Cournot competition, where a The current article considers a unilateral FDI model with endogenously determined environmental standards, and FDI decisions. Hence, this article differs from existing papers in that the analytical framework is rich enough to accommodate the PHH, race-to-the-bottom, race-to-the-top, and regulatory chill phenomena. Second, I endogenize a firms FDI decision by allowing for its optimized choice betIen FDI Greenfield and M&A.
In this model, the game played is a one-shot Cournot market share game, that is, firms move before governments make policy decisions [17].

[17] This is where governments cannot commit and so set environmental policies after firms decide where to locate. Even in the Market Share Game firms may still base their location decisions on the environmental policies which they expect

This model is used by Dong et al. (2012), which is similar to ours. The environmental policy instrument in this model is emission standard. Emission standard, also called performance standard, is a kind of command and control (CAC) instrument. It does not bring government any fiscal revenue. Environmental tax, which generates revenues for the government on the other hand, is a typical type of market-based incentive (MBI) instrument. Fullerton (2001) has clarified that emission standard and environmental tax can achieve the same efficiency effect, i.e., they can improve the economic efficiency by the same level under symmetric information. Yet emission standard may be more efficient in monitoring and enforcement when information is asymmetric betIen the regulator and the regulated. The model of this article combines two modes of FDI that are differently affected by the environmental policy and optimal emission standards.

The main results of this article are that (i) The mode of FDI entrance will depend on the market size, level of pollution of the industry, emission standard and product substitutability, where the intuitive relative incentive -as lax current regulation, market size, strict old regulation, and highly pollutant industry encouraging Greenfield investment over the Brownfield one- only hold for sufficiently big market sizes or differentiated products (ii) a granfathering policy, where the standard for newly settled firms is more strict than the standard for old firms, is a strategic decision; (iii) a highly pollutant industry increases the gap betIen the old and the new pollution standards.

The rest of the article is organized as follows: Sect. 1 introduces the basic model, Sect. 3 analyses the equilibrium under exogenous pollution standards, Sect. 4 analyses the equilibrium under endogenous pollution standards, and Sec. 5 concludes the model with some discussions of policy implications.

5.2 Model

I consider an industry that has activity in two countries, one denoted by the North country and the other by the South country. Each country has its own separated market. The North market has one active firm, while the South one has two active firms. These firms will be denoted by N, S1 and S2 respectively. The firm in the North produces a different variety of the product produced in the South by

(rationally) governments to introduce after they have located.

the South firms. I want to study the incentives that one firm has to expand its sales to the other country either by (1) setting up a new factory there or (2) buying an existing firm. I assume there is no trade betIen the North and the South country, and I focus on the South market, where the firms compete a la Cournot. Then the North firm decides whether it does Foreign Direct Investment by setting a new factory (FDI Greenfield) or acquires an existing one (FDI Brownfield) in the South country to compete with the South firms. For this purpose I develop a one-shot game.

The main purpose of this paper is to analyse the effects of the Environmental regulation law in a host country on the internationalization strategies of abroad firms, more concretely the unitary pollution emission allowance, which I will refer to as the emission standard from now on.

First, I analyse how the decision of the abroad firm is affected by an exogenously determined emission standard. Then, I consider what the optimal emission standard will be if it is endogenously determined.

In the case of Brownfield investment, I assume that the existing firms are subject to different emission standards from the newly settled firms, being that the new firms are more restricted than the old ones. This fits with the fact that, in many countries, existing firms are excluded from abiding by new regulations. I model this situation as a sequential game with two players, which are the North firm and one of the South firms. I assume the acquaried South firm to be S2, while S1 stays in the market and competes with the acquirer.

The case of Greenfield investment is modeled as a sequential game with three players. I find the sub-game perfect equilibrium for the endogenous emission standard case, taken that the South country's government goal is to maximize the total Ilfare in the South country.

As already mentioned, two internationalization strategies are considered:

1. To undertake Greenfield FDI (denoted by G). This will entail building a factory in the host country and thus incurring in a set-up fixed cost, denoted by F_G.
2. To undertake Brownfield FDI (denoted by B). This will entail a fixed cost of buying one of the existing firms in the host country.

3. The third considered (outside) option for the North firm is choosing not to internationalise (denoted by "No int").

The game played in this model is the market share game, in which firms make decisions before governments do. Hence, my setup differs from the race-to-the-bottom game seen in several previous papers where governments make decisions on environmental policies first.
The inverse demand system for differentiated products is given by:

$$p_x = a - X - \gamma Y, \qquad p_y = a - Y - \gamma X \tag{1}$$

Where X denotes the total output sold of the product produced by the North firm, and Y denotes the total output sold of the product produced by the South firms. p_x and p_y are the prices of X and Y. I assume that the constant average cost of production for both products is c, with $c < a$. Since X and Y are imperfect substitutes, $\gamma \epsilon (0, 1)$ denotes the level of product substitution among both products. Products are independent when $\gamma = 0$, and perfect substitutes when $\gamma = 1$.

5.3 Emission standard is exogenous

I firstly consider the case of exogenous emission standards. X stands for the production of the North firm. I assume that the host country protects intellectual property. About Y; for Greenfield and duopoly $Y = y_{S1} + y_{S2}$, and for Brownfield $Y = y_{S1} + y_N$, where subscripts N, S_1 and S_2 refer to the firms origin. I assume that, when the North firm acquires a South firm, it also acquires the intellectual property and technology to produce Y. In the first stage, the North firm decides whether to engage in Greenfield FDI, acquire an existing firm or not to internationalise in the South market. Then one of the South firms (assumed to be S2) decides whether to sell its firm or not. This has implication on N firm's fixed costs, varieties produced and number of firms finally competing in the market.

I denote the emission standard in the South country by e, where $e_j \epsilon \{0, 1\}$ is the per-unit emission level allowed by the South country, being e_0 the permission for the stablished firms, and e_1 the permission for the newly stablished firms.
I assume that the marginal cost function of firm i is $c_i(e_j) = c + (\theta - e_j)$, where $i \epsilon \{N, S1, S2\}$ and $j \epsilon \{0, 1\}$,

is a function of e_j. This means that the emission standard may be different for established firms and for new firms, being that the standard for new firms will be more restrictive than the one for stablished firms. Let θ be the total amount of pollutant generated by the firms when producing one unit of product, then $0 \leq ej \leq \theta$ (as the emission standard will be betIen 0 and the total unitary pollution of the industry), and $\theta - ej$ is the amount of abatement, which I assume to be unitary. I also assume all the firms are symmetrical regarding production costs, pollution emission levels and abatement costs.

As an initial assumption, I consider $a > c + \theta - e_0$, $a > c + \theta - e_1$, meaning that the South market is profitable.

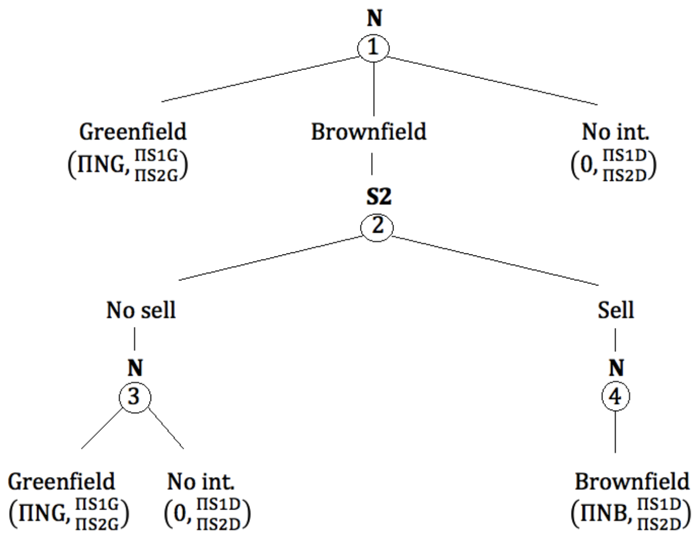
The order of the play is as follows:

1. Firm N chooses an internationalization strategy (No int, G, B). If the firm chooses "No int" the game ends here, if it chooses G, I jump to step 4.

2. Firm S2 decides whether it sells or not (Sell, no sell), in the case that N chooses to undertake Brownfield.

3. Firm N decides its internationalization strategy taken the South firm's decision.

4. Firms compete in quantities. If N acquires an existing firm, I will have two firms competing a la Cournot (N and S1), but three firms if N settles a new factory (N, S1 and S2).



5.3.1 The North firm enters as Greenfield investor

Firms maximize the following profit functions:

$$\Pi_{NG} = p_x x - (c + \theta - e_1)x - F_G$$
$$\Pi_{S1G} = p_y y_{S1} - (c + \theta - e_0)y_{S1} \quad (2)$$
$$\Pi_{S2G} = p_y y_{S2} - (c + \theta - e_0)y_{S2}$$

Where the subscript NG refers to the variable for the North firm, given that the North firm has decided to do Greenfield investment in the first stage. Similarly, $S1G$ and $S2G$ refer to the equilibrium variable from South firms when the North firm engages in Greenfield investment. F_G refers to the fixed cost of setting a new factory in the South country.

Via maximization, we obtain the following equilibrium profits [18]:

$$\Pi_{NG} = \frac{1}{2}\frac{(a(2\gamma-3) - 2\gamma(c+\theta-e_0) + 3(c+\theta-e_1))^2}{2(\gamma^2-3)^2} - 2F_G$$
$$\Pi_{S1G} = \Pi_{S2G} = \frac{(a(\gamma-2) - \gamma(c+\theta-e_1) + 2(c+\theta-e_0))^2}{4(\gamma^2-3)^2}$$

Profits will always be positive if the fixed cost is below a threshold, that is:

$$F < \frac{(a(2\gamma-3) - 2\gamma(c+\theta-e_0) + 3(c+\theta-e_1))^2}{4\left(\gamma^2-3\right)^2}$$

From now on, I will denote this threshold by τ^G, hence $\tau^G = \frac{(a(2\gamma-3)-2\gamma(c+\theta-e_0)+3(c+\theta-e_1))^2}{4(\gamma^2-3)^2}$.

5.3.2 The North firm enters as an acquirer

In this scenario, the North firm can produce both X and Y (as N is acquiring the South firm, now it owns the technology to produce product Y), to which I will refer as Brownfield type 1 (or $B1$) [19]. In order to acquire firm S2, the North firm must pay for it the amount that will make S2 indifferent between selling or not, plus a margin. This amount will be different depending on the next preferred alternative strategy for the North firm.

[18] see Appendix 2 for first order and non-negative conditions

[19] see appendix 4 for special case where N prodces only one variety

If the profits of investing in Greenfield are zero or negative, the preferred strategy will be not investing. If firm N does not invest, South firms will compete in a duopoly. In this case, the N firm will have to pay at least the duopoly benefit (Π_{S2D}) to the South firm in order to acquire it. If the profits of investing in Greenfield investment are positive, the alternative preferred strategy is Greenfield, as the profits of not investing are zero. In this case, the North firm will have to pay to the South firm at least the profit that the South firm would make if N chose to invest in Greenfield (Π_{S2G}), in order to acquire it. I will consider the three possible Brownfield modes of entry for this two acquaring cases (the North firm paying Π_{S2D} and Π_{S2G}) .

When $\Pi_{NG} > 0$ I study the case in which the benefits for the North firm under Greenfield investment are positive. This is true when the following condition holds:

$$F < \tau^G = \frac{(a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1))^2}{4\left(\gamma^2 - 3\right)^2}$$

In this case, the North firm's best option if no firm in the South wants to sell its factory, is engaging in Greenfield investment. Hence, the North firm will have to pay to the South firm at least its Greenfield profits in order to acquire it, and the fixed cost F_B will be equal to Π_{S2G} for the three next cases.

When the North firm produces both products X and Y, firms maximize the following profit functions [20]:

$$\Pi_{NB1} = p_x x + p_y y_N - (c + \theta - e_0)(x + y_N) - F_B \tag{3}$$

$$\Pi_{S1B1} = p_y y_{S1} - y_{S1}(c + \theta - e_0) \tag{4}$$

Where the subscript $NB1$ and $S1B1$ refer to the equilibrium variable for the respective firms given that the North firm has decided to undertake Brownfield investment in the first stage.

Via maximization, we obtain the following equilibrium profits [21]:

[20] For the special cases in which N produces a single product, see Appendix 4

[21] For first order and non-negative conditions see appendix 3

$$\Pi_{NB1} = \frac{1}{36(1+\gamma)}(13c^2 + 26ce_0 + 13e_0^2 + a^2(13-5\gamma) - 5c^2\gamma - 10ce_0\gamma - 5e_0^2\gamma + 2a(-13+5\gamma)(c+e_0-\theta)$$
$$+2(c+e_0)(-13+5\gamma)\theta + (13-5\gamma)\theta^2) - \frac{\text{Fb}(36+36\gamma)}{36(1+\gamma)}$$

$$\Pi_{S1B1} = \frac{1}{9}(a-c+e_0-\theta)^2$$

Finally, if I substitute F_B in Π_{NB1}, I obtain:

$$\Pi_{NB1} = \frac{1}{36}\left(\frac{9(\gamma-3)^2(a-c-\theta)^2}{(\gamma^2-3)^2} - \frac{2(\gamma-2)(a-c+e_0-\theta)(a+2(c-e_0+\theta))}{\gamma+1}\right.$$
$$+\frac{6(\gamma-5)(a(\gamma(13\gamma-10)-131)-6(\gamma+7)^2(c+\theta))(a-c+e_0-\theta)}{(\gamma-17)(\gamma+1)(7\gamma+25)}$$
$$\left.-\frac{3(a-c+e_0-\theta)(a(\gamma-3)-(\gamma+3)(c-e_0+\theta))}{\gamma+1}\right)$$

When $\Pi_{NG} \leq 0$ I study the case in which the benefits for the North firm under Greenfield investment are negative. This is true when the following condition holds:

$$F > \tau^G = \frac{(a(2\gamma-3) - 2\gamma(c+e_0-\theta) + 3(c+e_1-\theta))^2}{4\left(\gamma^2-3\right)^2}$$

In this case, the best option for the North firm if no firm in the South wants to sell its factory, is not internationalising its production. Hence, the North firm will have to pay to the South firm at least its Duopoly profits in order to acquire it, thus the fixed cost F_B will be equal to Π_{S2D} for the three next cases.

When the North firm produces both products, firms maximize the following profit functions [22]:

$$\Pi_{NB1} = p_x x + p_y y_N - (x+y_N)(c-e_0+\theta) - F_B$$

$$\Pi_{S1B1} = p_y y_{S1} - (c-e_0+\theta)y_{S1} \tag{5}$$

Where the subscript $NB1, S1B1$ and $S2B1$ means the equilibrium variable for the respective firms given that the North firm has decided to undertake Brownfield investment in the first stage, and $S2D$ refers to the duopoly profits of the firm S2.

[22] For the special cases in which N produces a single product, see Appendix 6

Via maximization I obtain the following profits [23]:

$$\Pi_{NB1} = \frac{1}{36(1+\gamma)}(13c^2 + 26ce_0 + 13e_0^2 + a^2(13-5\gamma) - 5c^2\gamma - 10ce_0\gamma - 5e_0^2\gamma + 2a(5\gamma-13)(c+e_0-\theta)$$
$$+2(c+e_0)(-13+5\gamma)\theta + (13-5\gamma)\theta^2) - \frac{F_B(36+36\gamma)}{36(1+\gamma)}$$

$$\Pi_{S1B1} = \frac{1}{9}(a-c+e_0-\theta)^2$$

Finally, if I substitute F_B in Π_{NB1}, I obtain:

$$\Pi_{NB1} = \frac{(1-\gamma)(a-c+e_0-\theta)^2}{4(\gamma+1)}$$

5.3.3 Analysis

Now I are interested on looking at the Nash equilibriums of this first game. I will distinguish between 3 cases that will lead to different Nash equilibria:

- Case one $\Pi_{NG} > \Pi_{NB1} > 0$ .This is true when $F_G < \tau^B$.
- Case two $\Pi_{NB1} > \Pi_{NG} > 0$. This is true when $\tau^B < F_G < \tau^G$.
- Case three $\Pi_{NB1} > 0 > \Pi_{NG}$. This is true when $F > \tau^G$.

I can now select the subgame perfect Nash equilibria. These are the solutions for our game. As before, I will obtain different solutions depending on the value of the parameters.

Proposition 1:

i) If $\Pi_{NG} > \Pi_{NB1} > 0$*, then the SPNE is ((G, G, B1), sell).*
ii) If $\Pi_{NB1} > \Pi_{NG} > 0$*, then the SPNE is ((B, G, B1), sell).*
iii) If $\Pi_{NB1} > 0 > \Pi_{NG}$*, then the SPNE is ((B, No int, B1), sell).*

[23] for first order and non-negative conditions see Appendix 5

The way to interpret the Nash equilibrium is the following: the first three strategies inside the parenthesis refer to the North's decision in the nodes 1, 3 and 4. The remaining strategy is the South firm's decision in the node 2.

i) When the fixed cost of setting a new factory is lower than a threshold τ^B, the benefit from investing in Greenfield is higher than the benefit from investing in Brownfield, both being positive. In this scenario, the North firm will choose Greenfield over Brownfield, Brownfield type 1 if the South firm sells its factory (that is producing both products X and Y), and Greenfield if it does not. The South firm will choose to sell its factory.
ii) On the contrary, when the fixed cost is higher than τ^B (but smaller than τ^G), the benefit from acquiring an existing firm is higher than the benefit from Greenfield, both being positive, the North firm will choose Brownfield over Greenfield, Brownfield type 1 if the South firm sells its factory, and Greenfield if it does not. The South firm will choose to sell its factory.
iii) When the cost of setting a factory is higher than a threshold $F > \tau^G$, the North firm's profit from investing in Greenfield is negative. Hence the North firm will choose Brownfield over Greenfield, Brownfield type 1 if the South firm sells its factory, and not internationalizing if it does not. The South firm will choose to sell its factory.

Note that the firm S2 will always sell, since the North firm has no incentive to offer a quantity that will not be accepted.

The threshold τ^B will also depend on the value of the parameters of the model, meaning that the parameters can influence this threshold. I will say that an increase in a parameter encourages Greenfield (or discourages Brownfield), when this parameter has a positive impact in the threshold. If the threshold is bigger, then Greenfield will be better than Brownfield for more possible values of the fixed cost F. On the contrary, I will say that a parameter discourages Greenfield (or encourages Brownfield) when it has a negative impact on the threshold. If the threshold is smaller, then Greenfield will be better than Brownfield for less possible values of the fixed cost F. Note that, even if a parameter encourages or discourages either of the strategies, the final result will always depend on the real value of the fixed cost. The change of the parameters will only make one of the strategies more likely to be profitable over the other one.

The market size a will generally have a bigger impact on the Brownfield benefit, when the firm investing in Brownfield is producing two products, hence participating in two markets. But the market size will encourage Greenfield over Brownfield when the market is relatively small and the products are not perfectly differentiated: $\gamma > 0$ and $a < \tau^a$.

The impact of the old emission standard e_0 will depend on the product substitutability and the market size. e_0 will encourage Greenfield if $\gamma > \tau^{e_0\gamma}$ and $a < \tau^{ae_0}$. Hence, when the products are not perfectly differentiated, the benefit from engaging in Brownfield and producing the two products decreases.

An increase in the new emission standard e_1 will only encourage Greenfield investment when the market size is relatively big $a > \tau^{e_1 a}$.

An increase in the product substitutability will affect negatively the profits for both strategies, but an increase on it will always encourage Greenfield investment over Brownfield since the benefit of producing two products decreases when they are similar.

An increase in θ will affect negatively the profits for both strategies via an increase in the costs, but it also decreases the cost of acquiring firm S2. It will incentivise Greenfield under two scenarios, where the decrease in the profits of Brownfield will be higher than the decrease in the price of S2:

(1) $\gamma = 0$. When the products are differentiated, an increase in the pollution of the industry will encourage Greenfield over Brownfield.

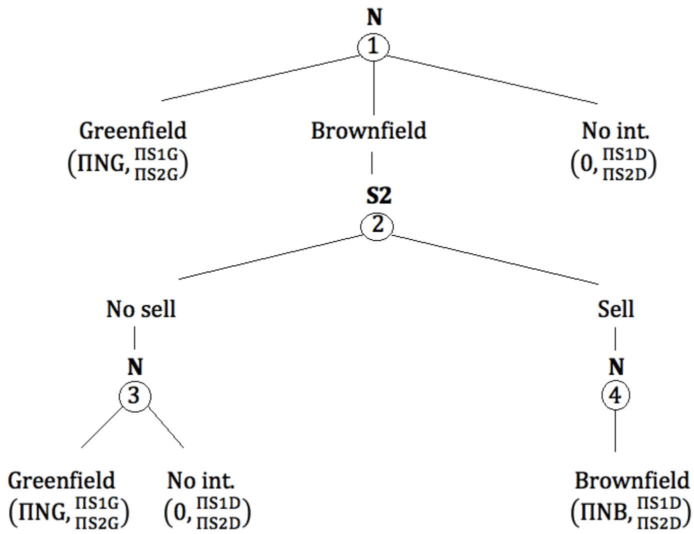
(2) $\gamma > 0$ and $a < \tau^a$. When the products are substitutes to any degree and the market is relatively small, an increase in the pollution of the industry will encourage Greenfield over Brownfield.

5.4 Emission standard is endogenous

Now I want to examine the internationalization game when the emission standard is endogenous. This means that the South Country's government will anticipate the North firm's decision, hence setting a pollution standard that maximizes the welfare in the South country. I will have two cases: when the South government anticipates that the North firm will engage in Greenfield investment, and when it anticipates it will engage in Brownfield. From this two cases I will obtain three pollution allotments: two for the Greenfield case (one for the settled firms and one new firms), and one for the Brownfield case.

The order of the play is as follows:

1. Firm N chooses an internationalization strategy (No int, B, G).
2. Given firms' decisions, governments set their welfare-maximizing emission standards.
3. Firm S2 decides whether it sells or not (Sell, no sell), in the case that N chooses to undertake Brownfield.
4. Firm N decides how many products it should produce if it undertakes Brownfield (B1, B2, B3).
5. Firms compete in quantities. If N acquires an existing firm, I will have two firms competing a la Cournot, but three firms if N settles a new factory.



I will analyze its decision under Greenfield and Brownfield type 1, as I shoId that this type of investment leads to the highest profits of the three options under any possible condition.

5.4.1 When the North firm enters as Greenfield investor

Firms maximize the following profit functions:

$$\Pi_{NG} = p_x x - (c + \theta - e_1)x - F_G$$

$$\Pi_{S1G} = p_y y_{S1} - (c + \theta - e_0)y_{S1} \tag{6}$$

$$\Pi_{S2G} = p_y y_{S2} - (c + \theta - e_0) y_{S2}$$

Where the subscript NG means the equilibrium variable for the North firm given that the North firm has decided to undertake Greenfield investment in the first stage. Similarly, $S1G$ and $S2G$ refer to the equilibrium variable for South firms when N firm engages in Greenfield investment. F_G refers to the fixed cost of setting a new factory in the South country.

Via maximization, we obtain the following equilibrium profits [24]:

$$\Pi_{NG} = \frac{1}{2} \frac{(a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1))^2}{2(\gamma^2 - 3)^2} - 2F_G$$

$$\Pi_{S1G} = \Pi_{S2G} = \frac{(a(\gamma - 2) - \gamma(c + \theta - e_1) + 2(c + \theta - e_0))^2}{4(\gamma^2 - 3)^2}$$

Now, the government maximizes the global welfare in the South country:

$$W_G = CS_Y + CS_X + \Pi_{S1G} + \Pi_{S2G} - e_0 Y - e_1 X$$

Where CS_X and CS_Y are the consumer surplus obtained from the consumption of both goods, and $e_0 Y + e_1 X$ is the pollution derivate from the production process of both goods. If I assume that every unit of pollution leads to a unit cost on society, then $e_0 Y + e_1 X$ is the total social cost of polluting.

Via maximization I obtain the following equilibrium values for the pollution permissions [25]:

$$e_0 = \frac{(\gamma - 3)(a - c - \theta)}{2(\gamma^2 - 3)}, \qquad e_1 = \frac{(1 - \gamma)(a - c - \theta)}{\gamma^2 - 3}$$

Substituting, I obtain the following profits:

$$\Pi_{NG} = \frac{1}{(\gamma^2 - 3)^2} (a^2(\gamma - 1)^2 + c^2(\gamma - 1)^2(+\gamma^2 - 3)^2 + 2c(\gamma - 1)^2\theta + (\gamma - 1)^2\theta^2 - 2a(\gamma - 1)^2(c + \theta)) - F_G$$

$$\Pi_{S1G} = \Pi_{S2G} = \frac{(\gamma - 3)^2(c + \theta - a)^2}{4(\gamma^2 - 3)^2}$$

[24] For first order and non-negative conditions, see Appendix 7

[25] See Appendix 7

The North firm will invest in Greenfield investment under an endogenous emission standard when the fixed cost is below a threshold, that is:

$$F < \frac{(\gamma - 1)^2(c + \theta - a)^2}{(\gamma^2 - 3)^2}$$

Comparing both emission standards, I find that $e_0 - e_1 = \frac{(3\gamma-5)(a-c-\theta)}{2(\gamma^2-3)}$, thus e_1 will be lower than e_0 only when $\theta > a - c$, that is when the industry is so polluting that the social cost outweighs the market profitability. In this case, the old standard could be more strict than the new one. This is a extreme case that would need to be considered separately, but will not be covered in this paper.

For a market where $a > c + \theta$, which means that the market is profitable enough to cover both the costs of the firms and the social pollution cost, the standard for newly set firms will be more strict than the old standard. This leads us to the next proposition:

Proposition 2:

When the environmental regulation is settled endogenously, the regulation for newly settled firms e_1 will always be more strict than the regulation for the already settled firms e_0.

When setting a pollution standard, the government faces a tradeoff: a high emission standard (lax policy) yields a higher cost on society, but allows for a greater production, which benefits both the consumer and producer surplus. On the other hand, a loIr emission standard (strict policy), minimizes the cost on society but reduces the producer and consumer surplus due to the decrease in the quantity produced.

When the industry is not excessively polluting, the environmental policy is more strict for newly settled firm than for the other firms. This means that, for the newly settled firms, their contribution to the pollution is more harmful than for the settled firms relative to their contribution to the consumer surplus. This is due to the fact that, even tough they contribute to the consumer surplus by selling their product, because it is a foreign firm, its profits are not a part of the social welfare of the South country. This is in line with the assumptions of the emission standard for new firms being more strict than the one for the already settled national firms, which is one of my main assumptions in the first part of this paper.

Furthermore, if I analyse the impact of the pollution level of the industry, I see that this has a positive impact in both e_0 and e_1, meaning that the more pollutant the industry is, the more strict the environmental regulation will be for both old and newly settled firms. I also see that the market size has a positive impact in the emission standard, which is in line with the results by Dong et al. (2012), that show how small markets can lead to more stringent emission standards.

This simple model supports the idea that, even though the emission standards could get more strict over time due to international pressure, it is also a strategic decision for the recipient country. In this simple model I do not account for the creation of new national firms that would be harmed by a tighter permission, but if I take that the increasing globalization leads to an increased international trade, a bigger number of international firms subject to a more strict standard will compensate for the loss of welfare of the newly created national firms.

5.4.2 When the North firm enters as an acquirer

When $\Pi_{NG} > 0$ In this scenario, the best option for the North firm if no firm in the South wants to sell its factory, is engaging in Greenfield investment. Thus, the North firm will always have to pay to the South firm at least its Greenfield profits in order to acquire it, so the fixed cost F_B will be equal to Π_{S2G} for the three next cases.

When the North firm produces X and Y, then profits are:

$$\Pi_{NB1} = p_x x + p_y y_N - (c - e_0 + \theta)(x + y_N) - F_B$$

$$\Pi_{S1B1} = p_y y_{S1} - y_{S1}(c - e_0 + \theta) \tag{7}$$

Where the subscript $NB1, S1B1$ and $S2B1$ means the equilibrium variable for the respective firms given that the North firm has decided to undertake Brownfield investment in the first stage.
Via maximization, I obtain the following profits [26]:

$$\Pi_{NB1} = \frac{(1-\gamma)(a-c-e+\theta)^2}{4(1+\gamma)}, \quad \Pi_{S1B1} = \frac{1}{9}(a-c-e+\theta)^2$$

[26] For first order and non-negative conditions, see Appendix 8.

Now, the government maximizes the global Ilfare in the South country:

$$W_B = CS_Y + CS_X + \Pi_{S1G} + \Pi_{S2G} - e_0(X + Y)$$

In this case the old regulation will be the same for the two firms, hence the unitary level of pollution derived from the production of the two goods will be the same.

Through maximization, I obtain the following pollution permission and profits [27]:

$$e_0 = \frac{3(1-\gamma)(a-c-\theta)}{\gamma - 17}$$

$$\Pi_{NB1} = \frac{1}{9(\gamma-17)^2(\gamma-1)}(a^2(7+\gamma)^2(5\gamma-13) + c^2(7+\gamma)^2(5\gamma-13) + 2c(7+\gamma)^2(5\gamma-13)\theta$$
$$+(7+\gamma)^2(5\gamma-13)\theta^2 - 2a(7+\gamma)^2(-13+5\gamma)(c+\theta)) - Fb$$

$$\Pi_{S1B1} = \frac{1}{9}(a - c + e_0 - \theta)^2$$

If I substitute $Fb = \Pi_{S2G} = \frac{(\gamma-3)^2(c+\theta-a)^2}{4(\gamma^2-3)^2}$, I obtain:

$$\Pi_{NB1} = -\frac{((477+\gamma(7317+\gamma(3498+\gamma(2826+\gamma(-4267+\gamma(141+4\gamma(57+5\gamma)))))))(-a+c+\theta)^2)}{(36(-17+\gamma)^2(1+\gamma)(-3+\gamma^2)^2)}$$

Which is negative, meaning that the fixed cost that the North firm has to pay to firm S2 in order to acquire it, is too high when I account for the endogenous environmental regulation. This means that this internationalisation strategy is not profitable, and the North firm will not engage in it.

When $\Pi_{NG} \leq 0$ Now I study the case in which Greenfield benefit is negative. This will happen when the emission standard is so high that it offsets the benefit from exploiting the South market, that is when $a \leq c + \theta - e_1$.

In this case, the best option for the North firm if no firm in the South wants to sell its factory, is not internationalising its production. Thus the North firm will always have to pay to the South firm at least its Duopoly profits in order to acquire it, so the fixed cost F_B will be equal to Π_{S2D} for the three next cases.

[27] See Appendix 8.

When the North firm produces both products, then profits are [28]:

$$\Pi_{NB1} = p_x x + p_y y_N - (x + y_N)(c - e_0 + \theta) - F_B$$

$$\Pi_{S1B1} = p_y y_{S1} - (c - e_0 + \theta) y_{S1} x \tag{8}$$

$$\Pi_{S2B1} = \Pi_{S2D}$$

Where the subscript $NB1, S1B1$ and $S2B1$ means the equilibrium variable for the respective firms given that the North firm has decided to undertake Brownfield investment in the first stage, and $S2D$ refers to the duopoly profits of the firm S2.

Via maximisation I obtain the following profits:

Then, the equilibrium profits are:

$$\Pi_{NB1} = \frac{1}{36(1+\gamma)}(13c^2 + 26ce + 13e^2 + a^2(13 - 5\gamma) - 5c^2\gamma - 10ce\gamma - 5e^2\gamma + 2a(-13 + 5\gamma)(c + e - \theta)$$
$$+2(c + e)(-13 + 5\gamma)\theta + (13 - 5\gamma)\theta^2) - Fb\frac{(36 + 36\gamma)}{36(1+\gamma)}$$

$$\Pi_{S1B1} = \frac{1}{9}(a - c + e_0 - \theta)^2$$

Now, the government maximizes the global welfare in the South country:

$$W_B = CS_Y + CS_X + \Pi_{S1G} + \Pi_{S2G} - e_0(X + Y)$$

Since the welfare function is not concave, the maximum value for the welfare will be either the maximum or the minimum pollution standard, being $e_0 = 0$ or $e_0 = \theta$ respectively.
I obtain the welfare values for both, which are $W_B(e_0 = 0) = \frac{(41+23\gamma)(a-c+\theta)^2}{72(1+\gamma)}$ and $W_B(e_0 = \theta) = \frac{(a-c)((a-c)(41+23\gamma)-12(7+\gamma)\theta)}{72(1+\gamma)}$. Now I proceed to compare both values:

$$W_B(e_0 = 0) - W_B(e_0 = \theta) = \frac{\theta(2(a - c)(83 + 29\gamma) + (41 + 23\gamma)\theta)}{72(1+\gamma)}$$

[28]For first order and non-negative conditions, refer to Appendix 9

Which is always positive. Thus, under this condition, the emission standard will be the more possibly stringent, which is an allowance of 0 units of pollution for all the producing firms.
Comparing the emission standards under Greenfield and Brownfield strategies I observe that, when the North firm engages in Greenfield investment, the pollution allowance is positive. This is becasue the increase in the consumer surplus offsets the increase in pollution. But when the North firm engages in Browfield investment, one of the firm's profits stops contributing to the global welfare, thus the increase in pollution is not compensated by the increase in the consumer surplus anymore.

5.5 Conclusions

Despite a large increase in the empirical literature that investigates the link between environmental policy and FDI the results remain inconclusive. This article studies the interrelationship between FDI and environmental policy using a North-South model that may go some way to explain this lack of robust evidence. The policy instrument considered in the model is a conventional CAC one emission standard regulation and does not generate any fiscal revenues for the government. Thus it induces no incentive distortion on the regulators' environmental policy decisions. Firms compete a la Cournot subject to the country's domestic environmental standard. Pollution is non-transboundary and emissions are only accompanied by production.

An important finding of this article is that a tightening of the current environmental regulation does not necessarily reduce the profitability of foreign firms and the probability of choosing FDI as the preferred mode of entry, but incentivize the Brownfield investment over the Greenfield investment when the market is big enough and the products are not differentiated. This can explain the mixed results about the relationship between FDI and environmental regulation in the literature hitherto. Our model provides a theoretical framework that can explain how different stringencies would not have a directly positive or negative impact in the FDI patterns, but rather change the composition in the industry by attracting dirtier or cleaner production processes, depending on parameters as the market size and product substitutability.

We also provide some evidence for a theoretical explanation of the grandfathering policies, showing that it is a strategic decision to implement a higher allowance for the domestic settled firms and a lower allowance for the newly settled firms, thus giving consistency to our model's initial assumptions.

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5.7 Appendix 1

For the three cases considered under exogenous pollution standards, I obtain the following Nash eqilibria:

i) If $\Pi_{NG} > \Pi_{NB1} > 0$ (that will hold when F_G is loIr than a threshold τ), then I obtain 22 Nash equilibria:
((G, B1, G), sell), ((G, B1, no), sell), ((G, B2, G), sell), ((G, B2, no), sell), ((G, B3, G), sell), ((G, B3, no), sell), ((G, B1, G), sell), ((G, B1, no), sell), ((G, B2, G), sell), ((G, B2, no), sell), ((G, B3, G), sell), ((G, B3, no), sell), ((G, B1, G), no sell), ((G, B1, no), no sell), ((G, B2, G), no sell), ((G, B2, no), no sell), ((G, B3, G), no sell), ((G, B3, no), no sell), ((G, B1, G), no sell), ((G, B1, no), no sell), ((G, B2, G), no sell), ((G, B2, no), no sell), ((G, B3, G), no sell), ((G, B3, no), no sell).
ii) If $\Pi_{B1} > \Pi_{NG} > 0$ (that will hold when F_G is higher than a threshold τ), I obtain 12 Nash equilibria:
((G, B1, G), no sell), ((G, B1, no), no sell), ((G, B2, G), no sell), ((G, B2, no), no sell), ((G, B3, G), no sell), ((G, B3, no), no sell), ((G, B1, G), no sell), ((G, B1, no), no sell), ((G, B2, G), no sell), ((G, B2, no), no sell), ((G, B3, G), no sell), ((G, B3, no), no sell), ((B, B1, G), sell).
iii) If $\Pi_{NB1} > 0 > \Pi_{NG} > 0$ (that will hold under the condition $F > \frac{(a(2\gamma-3)-2\gamma(c+e_0-\theta)+3(c+e_1-\theta))^2}{4(\gamma^2-3)^2}$), I obtain two NE, that are:
((B, B1, G), sell) and ((B, B1, No int), sell).

The way to interpret the Nash equilibrium is the following: the first three strategies inside the parenthesis refer to the North's decision in the nodes 1, 3 and 4. The remaining strategy is the South 1 decision in the node 2.

5.8 Appendix 2

When the environmental standard is exogenous and the North firm enters as Greenfield investor, firms maximize the following profit functions:

$$\Pi_{NG} = p_x x - (c + \theta - e_1)x - F_G$$

$$\Pi_{S1G} = p_y y_{S1} - (c + \theta - e_0)y_{S1} \tag{9}$$

$$\Pi_{S2G} = p_y y_{S2} - (c + \theta - e_0)y_{S2}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NG}}{dx} = a - c + e1\_2x - (y_{S1} + y_{S2})\gamma - \theta = 0$$

$$\frac{d\Pi_{S1G}}{dy_{S1}} = a - c + e_0 - 2y_{S1} - y_{S2} - x\gamma - \theta = 0$$

$$\frac{d\Pi_{S2G}}{dy_{S2}} = a - c + e_0 - y_{S1} - 2y_{S2} - x\gamma - \theta = 0$$

The equilibrium quantities to this game are:

$$x = \frac{a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1)}{2\gamma^2 - 3} \tag{10}$$

$$y_{S1} = y_{S2} = \frac{a(\gamma - 2) + 2(c + \theta - e_0) - \gamma(c + \theta - e_1)}{2(\gamma^2 - 3)} \tag{11}$$

If I substitute (10) and (11) in (9), the equilibrium profits are:

$$\Pi_{NG} = \frac{1}{2}\frac{(a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1))^2}{2(\gamma^2 - 3)^2} - 2F_G$$

$$\Pi_{S1G} = \Pi_{S2G} = \frac{(a(\gamma - 2) - \gamma(c + \theta - e_1) + 2(c + \theta - e_0))^2}{4(\gamma^2 - 3)^2}$$

To give consistency to the model, the condition of positive equilibrium quantities has to be included: x will always be positive if $e_1 < \frac{a-c-\theta}{6\gamma-9} - \frac{2e_0\gamma}{3}$ holds.

Profits will always be positive if the fixed cost is below a threshold, that is:

$$F < \frac{(a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1))^2}{4\left(\gamma^2 - 3\right)^2}$$

From now on, I will denote this threshold by τ^G, hence $\tau^G = \frac{(a(2\gamma-3)-2\gamma(c+\theta-e_0)+3(c+\theta-e_1))^2}{4(\gamma^2-3)^2}$.

5.9 Appendix 3

When the environmental standard is exogenous, the North firm enters as an acquirer and $\Pi_{NG} > 0$, firms maximize the following profit functions :

$$\Pi_{NB1} = p_x x + p_y y_N - (c + \theta - e_0)(x + y_N) - F_B \tag{12}$$

$$\Pi_{S1B1} = p_y y_{S1} - y_{S1}(c + \theta - e_0) \tag{13}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB1}}{dx} = a - c - e_0 - 2x - (2y_N + y_{S1})\gamma + \theta = 0$$

$$\frac{d\Pi_{NB1}}{dy_N} = a - c - e_0 - 2y_N - y_{S1} - 2x\gamma + \theta = 0$$

$$\frac{d\Pi_{S1B1}}{dy_{S1}} = a - c - e_0 - y_N - 2\mathrm{y}_{S1} - x\gamma + \theta = 0$$

Then, the equilibrium quantities are:

$$y_N = \frac{1}{3}(a - c - e_0 - \theta), \quad x = \frac{a - c + e_0 - \theta}{2\gamma + 2}, \quad y_{S1} = \frac{(2 - \gamma)(a - c + e_0 - \theta)}{6(\gamma + 1)} \tag{14}$$

If I substitute (14) in (12) and (12), the equilibrium profits are:

$$\Pi_{NB1} = \frac{1}{36(1+\gamma)}(13c^2 + 26ce_0 + 13e_0^2 + a^2(13 - 5\gamma) - 5c^2\gamma - 10ce_0\gamma - 5e_0^2\gamma + 2a(-13 + 5\gamma)(c + e_0 - \theta)$$
$$+2(c + e_0)(-13 + 5\gamma)\theta + (13 - 5\gamma)\theta^2) - \frac{\mathrm{Fb}(36 + 36\gamma)}{36(1+\gamma)}$$

$$\Pi_{S1B1} = \frac{1}{9}(a - c + e_0 - \theta)^2$$

Π_{NB1} will be positive if $F_B < \frac{(13-5\gamma)(a-c+e_0-\theta)^2}{36(1+\gamma)}$. As mentioned before, $F_B = \Pi_{S2G}$ in this section.

Substituting: $\frac{(a(\gamma-2)-\gamma(c+\theta-e_1)+2(c+\theta-e_0))^2}{4(\gamma^2-3)^2} < \frac{(13-5\gamma)(a-c+e_0-\theta)^2}{36(1+\gamma)}$.
Because $\frac{(a(\gamma-2)-\gamma(c+\theta-e_1)+2(c+\theta-e_0))^2}{4(\gamma^2-3)^2} - \frac{(13-5\gamma)(a-c+e_0-\theta)^2}{36(1+\gamma)} < 0$, Π_{NB1} will always be positive.

Finally, if I substitute F_B in Π_{NB1}, I obtain:

$$\Pi_{NB1} = \frac{1}{36}(\frac{9(\gamma-3)^2(a-c-\theta)^2}{(\gamma^2-3)^2} - \frac{2(\gamma-2)(a-c+e_0-\theta)(a+2(c-e_0+\theta))}{\gamma+1}$$
$$+\frac{6(\gamma-5)(a(\gamma(13\gamma-10)-131)-6(\gamma+7)^2(c+\theta))(a-c+e_0-\theta)}{(\gamma-17)(\gamma+1)(7\gamma+25)}$$
$$-\frac{3(a-c+e_0-\theta)(a(\gamma-3)-(\gamma+3)(c-e_0+\theta))}{\gamma+1})$$

5.10 Appendix 4

When the environmental standard is exogenous, N enters as an investor, and $\Pi_{NG} \geq 0$.

Here I consider the special cases where N enters the South country as an investor, and produces only one product (either X or Y). Then, I will compare the profits to the main case (producing both). For simplicity, I will denote the main case as Brownfield type 1, producing Y as Brownfield 2, and producing X as Brownfield 3.

i) When the North firm only produces its own product X, firms maximize the following profit functions:

$$\Pi_{NB2} = p_x x - x(c-e_0+\theta) - F_B$$
$$\Pi_{S1B2} = p_y y_{S1} - (c-e_0+\theta)y_{S1} \tag{15}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB2}}{dx} = a-c-e_0-2x-y\gamma+\theta = 0$$
$$\frac{d\Pi_{S1B2}}{dy_{S1}} = a-c-e_0-2y-x\gamma+\theta = 0$$

Then, the equilibrium quantities are:

$$x = y_{S1} = \frac{a-c+e_0-\theta}{\gamma+2} \tag{16}$$

Substituting (16) in (15) I obtain the following profits:

$$\Pi_{NB2} = \frac{(2+\gamma)^2 + (a-c+e_0-\theta)^2}{(2+\gamma)^2 - F_B}, \qquad \Pi_{S1B2} = \frac{(a-c+e_0-\theta)^2}{(2+\gamma)^2}$$

Π_{NB2} will be positive when the fixed cost is lower than a threshold, which is $F_B < \frac{(a-c+e-\theta)^2}{(2+\gamma)^2}$. As mentioned before, $F_B = \Pi_{S2G}$ in this section.

Substituting: $\frac{(a(\gamma-2)-\gamma(c+\theta-e_1)+2(c+\theta-e_0))^2}{4(\gamma^2-3)^2} < \frac{(a-c+e_0-\theta)^2}{(2+\gamma)^2}$

Because $\frac{(a(\gamma-2)-\gamma(c+\theta-e_1)+2(c+\theta-e_0))^2}{4(\gamma^2-3)^2} - \frac{(a-c+e_0-\theta)^2}{(2+\gamma)^2} < 0$, Π_{NB2} will always be positive.

Finally, if I substitute F_B in Π_{NB2}, I obtain:

$$\Pi_{NB2} = \frac{(a(2-\gamma) - 2(c+e_0-\theta) + \gamma(c+e_1-\theta))^2}{4(\gamma^2-3)^2}$$
$$+ \frac{(c+e_0-\theta)(-a+c+e_0-\theta)}{2+\gamma} + \frac{(a+(1+\gamma)(c+e_0-\theta))(a-c-e_0+\theta)}{(2+\gamma)^2}$$

ii) When the North firm produces only the South firm's product Y, firms maximize the following profit functions:

$$\Pi_{NB3} = p_y y_N - y_N(c - e_0 + \theta) - F_B$$

$$\Pi_{S1B3} = p_y y_{S1} - y_{S1}(c - e_0 + \theta) \tag{17}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB3}}{dy_N} = a - c - e_0 - y_{S1} - 2y_N + \theta = 0$$

$$\frac{d\Pi_{S1B3}}{dy_{S1}} = a - c - e_0 - 2y_{S1} - y_N + \theta = 0$$

Then, the equilibrium quantities and profits are:

$$y_{S1} = y_{S2} = \frac{1}{3}(a - c + e_0 - \theta) \tag{18}$$

Substituting (18) in (17) I obtain the following profits:

$$\Pi_{NB3} = \frac{1}{9}(a-c+e_0-\theta)^2 - F_B, \qquad \Pi_{S1B3} = \frac{1}{9}(a-c+e_0-\theta)^2$$

Π_{NB3} will be positive when the fixed cost is lower than a threshold, which is $F_B < \frac{1}{9}(a-c+e-\theta)^2$. As mentioned before, $F_B = \Pi_{S2G}$ in this section.

Substituting: $\frac{(a(\gamma-2)-\gamma(c+\theta-e_1)+2(c+\theta-e_0))^2}{4(\gamma^2-3)^2} < \frac{1}{9}(a-c+e_0-\theta)^2$
Because $\frac{(a(\gamma-2)-\gamma(c+\theta-e_1)+2(c+\theta-e_0))^2}{4(\gamma^2-3)^2} - \frac{1}{9}(a-c+e_0-\theta)^2 < 0$, Π_{NB2} will always be positive.

Finally, if I substitute F_B in Π_{NB2}, I obtain:

$$\Pi_{NB3} = \frac{1}{12}(\frac{3(a(2-\gamma)-2(c+e_0-\theta)+\gamma(c+e_1-\theta))^2}{(\gamma^2-3)^2} + 4(c+e_0-\theta)(+c+e_0-\theta-a) + \frac{4}{3}(a+2(c+e_0-\theta))(a-c-e_0+\theta))$$

Now I proceed to compare the benefits under the three possible Brownfield modes of entry.

- Brownfield 1 VS Brownfield 2: $\Pi_{NB1} - \Pi_{NB2} = \frac{(1-\gamma)(16+\gamma(12+5\gamma))(a-c+e_0-\theta)^2}{36(1+\gamma)(2+\gamma)^2}$ which is positive.
- Brownfield 1 VS Brownfield 3: $\Pi_{NB1} - \Pi_{NB3} = \frac{(1-\gamma)(a-c+e_0-\theta)^2}{4(1+\gamma)}$ which is positive.

- Brownfield 2 VS Brownfield 3: $\Pi_{NB2} - \Pi_{NB3} = \frac{(1-\gamma)(5+\gamma)(a-c+e_0-\theta)^2}{9(2+\gamma)^2}$ which is positive.

Thus, meaning that $\Pi_{NB1} > \Pi_{NB2} > \Pi_{NB3}$.

5.11 Appendix 5

When the environmental standard is exogenous, N enters as an investor and $\Pi_{NG} \leq 0$, firms maximize the following profit functions:

$$\Pi_{NB1} = p_x x + p_y y_N - (x + y_N)(c - e_0 + \theta) - F_B$$

$$\Pi_{S1B1} = p_y y_{S1} - (c - e_0 + \theta) y_{S1} \tag{19}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB1}}{dx} = a - c - e_0 - 2x - (2y_N + y_{S1})\gamma + \theta = 0$$

$$\frac{d\Pi_{NB1}}{dy_N} = a - c - e_0 - 2y_N - y_{S1} - 2x\gamma + \theta = 0$$

$$\frac{d\Pi_{S1B1}}{dy_{S1}} = a - c - e_0 - y_N - 2y_{S1} - x\gamma + \theta = 0$$

Then, the equilibrium quantities are:

$$x = \frac{a - c + e_0 - \theta}{2\gamma + 2}, \quad y_{S1} = \frac{1}{3}(a - c + e_0 - \theta), \quad y_{S2} = \frac{(2-\gamma)(a - c + e_0 - \theta)}{6(\gamma+1)} \tag{20}$$

If I substitute (20) in (19) I obtain the following profits:

$$\Pi_{NB1} = \frac{1}{36(1+\gamma)}(13c^2 + 26ce_0 + 13e_0^2 + a^2(13-5\gamma) - 5c^2\gamma - 10ce_0\gamma - 5e_0^2\gamma + 2a(5\gamma - 13)(c + e_0 - \theta)$$
$$+2(c+e_0)(-13+5\gamma)\theta + (13-5\gamma)\theta^2) - \frac{F_B(36+36\gamma)}{36(1+\gamma)}$$

$$\Pi_{S1B1} = \frac{1}{9}(a - c + e_0 - \theta)^2$$

Π_{NB1} will be positive if $F_B < \frac{(13-5\gamma)(a-c+e_0-\theta)^2}{36(1+\gamma)}$. As mentioned before, $F_B = \Pi_{S2D}$ in this section.

Substituting: $\frac{1}{9}(a - c + e_0 - \theta)^2 < \frac{(13-5\gamma)(a-c+e_0-\theta)^2}{36(1+\gamma)}$.
Because $\frac{1}{9}(a - c + e_0 - \theta)^2 - \frac{(13-5\gamma)(a-c+e_0-\theta)^2}{36(1+\gamma)} < 0$, Π_{NB1} will always be positive.

Finally, if I substitute F_B in Π_{NB1}, I obtain:

$$\Pi_{NB1} = \frac{(1-\gamma)(a - c + e_0 - \theta)^2}{4(\gamma+1)}$$

5.12 Appendix 6

When the environmental standard is exogenous, N enters as an investor, and $\Pi_{NG} \leq 0$.

Here I consider the special cases where N enters the South country as an investor, and produces only one product (either X or Y). Then, I will compare the profits to the main case (producing both).
For simplicity, I will denote the main case as Brownfield type 1, producing Y as Brownfield 2, and producing X as Brownfield 3.

i) When the North firm only produces its own product, firms maximize the following profit functions:

$$\Pi_{NB2} = p_x x - (c + \theta - e_0)x - F_B$$

$$\Pi_{S1B2} = p_y y_{S1} - (c + \theta - e_0)y_{S1} \tag{21}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB2}}{dx} = a - c + e_0 - 2x - y_{S1}\gamma - \theta = 0$$

$$\frac{d\Pi_{S1B2}}{dy_{S1}} = a - c + e_0 - 2y_{S1} - x\gamma - \theta = 0$$

Then, the equilibrium quantities are:

$$x = y_{S1} = \frac{a - c + e_0 - \theta}{2 + \gamma} \tag{22}$$

If I substitute (22) in (21) I obtain the following profits:

$$\Pi_{NB2} = \frac{(2+\gamma)^2 + (a - c + e_0 - \theta)^2}{(2+\gamma)^2 - F_B}, \qquad \Pi_{S1B2} = \frac{(a - c + e_0 - \theta)^2}{(2+\gamma)^2}$$

Π_{NB2} will be positive when the fixed cost is lower than a threshold, which is Fb $< \frac{(a-c+e-\theta)^2}{(2+\gamma)^2}$. As mentioned before, $F_B = \Pi_{S2D}$ in this section.

Substituting: $\frac{1}{9}(a - c + e_0 - \theta)^2 < \frac{(a-c+e_0-\theta)^2}{(2+\gamma)^2}$

Because $\frac{1}{9}(a - c + e_0 - \theta)^2 - \frac{(a-c+e_0-\theta)^2}{(2+\gamma)^2} < 0$, Π_{NB2} will always be positive.

Finally, if I substitute F_B in Π_{NB2}, I obtain:

$$\Pi_{NB2} = \frac{(c(5+\gamma) - a(5+\gamma) + (\gamma - 1)(e_0 - \theta))(c + a(\gamma - 1) - c\gamma - (5+\gamma)(e_0 - \theta))}{9(2+\gamma)^2}$$

ii) When the North firm produces only the South firm's product, firms maximize the following profit functions:

$$\Pi_{NB3} = p_y y_{S2} - y_{S2}(c - e_0 + \theta) - F_B$$

$$\Pi_{S1B3} = p_y y_{S1} - y_{S1}(c - e_0 + \theta) \tag{23}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB3}}{dy_N} = a - c - e_0 - y_{S1} - 2y_N + \theta = 0$$

$$\frac{d\Pi_{S1B3}}{dy_{S1}} = a - c - e_0 - 2y_{S1} - y_N + \theta = 0$$

Then, the equilibrium quantities are:

$$y_N = y_{S1} = \frac{1}{3}(a - c - e_0 + \theta) \tag{24}$$

If I substitute (24) in (23) I obtain the following profits:

$$\Pi_{NB3} = \frac{1}{9}(a - c + e_0 - \theta)^2 - F_B, \qquad \Pi_{S1B3} = \frac{1}{9}(a - c + e_0 - \theta)^2$$

Π_{NB3} will be positive when the fixed cost is loIr than a threshold, which is $F_B < \frac{1}{9}(a - c + e - \theta)^2$. As mentioned before, $F_B = \Pi_{S2G}$ in this section.

Substituting: $19(a - c + e_0 - \theta)^2 < \frac{1}{9}(a - c + e_0 - \theta)^2$

Because $\frac{1}{9}(a - c + e - \theta)^2 - \frac{1}{9}(a - c + e - \theta)^2 = 0$, Π_{NB2} will be equal to 0, thus the North firm will be indifferent between engaging in Brownfield type 3 and not internationalising.

Finally, if I substitute F_B in Π_{NB3}, I obtain:

$$\Pi_{NB3} = 0$$

Now I proceed to compare the three modes of Brownfield entry:

- Brownfield 1 VS Brownfield 2: $\Pi_{NB1} - \Pi_{NB2} = \frac{(1-\gamma)(\gamma(5\gamma+12)+16)(a-c+e_0-\theta)^2}{36(\gamma+1)(\gamma+2)^2}$, which is positive, meaning that Brownfield type 1 leads to higher profits.
- Brownfield 3 VS Brownfield 3: $\Pi_{NB2} - \Pi_{NB3} = \frac{(1-\gamma)(\gamma+5)(a-c+e_0-\theta)^2}{9(\gamma+2)^2}$ which is positive, meaning that Brownfield type 2 leads to higher profits.
- Brownfield 1 VS Brownfield 3: $\Pi_{NB1} - \Pi_{NB3} = \frac{(1-\gamma)(a-c+e_0-\theta)^2}{4(\gamma+1)}$ which is positive, meaning that

Brownfield type 1 leads to higher profits.

Thus, meaning that $\Pi_{NB1} > \Pi_{NB2} > \Pi_{NB3}$. It is always more profitable for the North firm to engage in Brownfield type 1 for any given condition.

5.13 Appendix 7

When the environmental standard is endogenous and the North firm enters as Greenfield investor, firms maximize the following profit functions:

$$\Pi_{NG} = p_x x - (c + \theta - e_1)x - F_G$$

$$\Pi_{S1G} = p_y y_{S1} - (c + \theta - e_0) y_{S1} \tag{25}$$

$$\Pi_{S2G} = p_y y_{S2} - (c + \theta - e_0) y_{S2}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NG}}{dx} = a - c - e_1 - 2x - (y_{S1} + y_{S2})\gamma + \theta = 0$$

$$\frac{d\Pi_{S1G}}{dy_{S1}} = a - c - e_0 - 2y_{S1} - y_{S2} - x\gamma + \theta = 0$$

$$\frac{d\Pi_{S2G}}{dy_{S2}} = a - c - e_0 - y_{S1} - 2y_{S2} - x\gamma + \theta = 0$$

The equilibrium quantities to this game are:

$$x = \frac{a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1)}{2\gamma^2 - 3} \tag{26}$$

$$y_{S1} = y_{S2} = \frac{a(\gamma - 2) + 2(c + \theta - e_0) - \gamma(c + \theta - e_1)}{2(\gamma^2 - 3)}$$

If I substitute (26) in (25), the equilibrium profits are:

$$\Pi_{NG} = \frac{1}{2}\frac{(a(2\gamma - 3) - 2\gamma(c + \theta - e_0) + 3(c + \theta - e_1))^2}{2(\gamma^2 - 3)^2} - 2F_G$$

$$\Pi_{S1G} = \Pi_{S2G} = \frac{(a(\gamma - 2) - \gamma(c + \theta - e_1) + 2(c + \theta - e_0))^2}{4(\gamma^2 - 3)^2}$$

Now, the government maximizes the global welfare in the South country:

$$W_G = CS_Y + CS_X + \Pi_{S1G} + \Pi_{S2G} - e_0 Y - e_1 X$$

Where CS_X and CS_Y are the consumer surplus obtained from the consumption of both goods, and $e_0 Y + e_1 X$ is the pollution derivate from the production process of both goods. If I assume that every unit of pollution leads to a unit cost on society, then $e_0 Y + e_1 X$ is the total social cost of polluting.
I first check that the welfare function is concave in the pollutions standards. For this, I compute the second derivatives respect to e_0 and e_1. $\frac{d^2 W_G}{e_0^2} = \frac{\gamma^2 - 4}{(\gamma^2-3)^2}$, and $\frac{d^2 W_G}{e_1^2} = \frac{8\gamma^2-27}{4(\gamma^2-3)^2}$. With both values being negative, I can confirm that the welfare function of the South country is concave in the pollution standards, thus the South country will set them so as to maximize its welfare.

Through maximization, I obtain the following first order conditions:

$$\frac{dW_G}{de_0} = \frac{a\left(4+\gamma-2\gamma^2\right) - 4(c+2e_0+\theta) - \gamma(c - 2c\gamma + e_1(2\gamma^2-7) + \theta - 2\gamma(e_0+\theta))}{2\left(-3+\gamma^2\right)^2} = 0$$

$$\frac{dW_G}{de_1} = \frac{a(-9+2\gamma(1+\gamma)) + 9(c - 3e_1 + \theta) - 2\gamma(-7e_0 + c(1+\gamma) + \theta + \gamma(-4e_1 + 2e\gamma + \theta))}{4\left(-3+\gamma^2\right)^2} = 0$$

The equilibrium values for the pollution permissions are:

$$e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, \qquad e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$$

Substituting, I obtain the following quantities and profits:

$$x = \frac{(a-c)(\gamma-2) + (\gamma-1)\theta}{(\gamma^2-3)}, \qquad y_{S1} = y_{S2} = \frac{(a-c)(\gamma-1) + (\gamma-3)\theta}{2(\gamma^2-3)}$$

$$\Pi_{NG} = \frac{1}{(\gamma^2-3)^2}(a^2(\gamma-1)^2 + c^2(\gamma-1)^2(+\gamma^2-3)^2 + 2c(\gamma-1)^2\theta + (\gamma-1)^2\theta^2 - 2a(\gamma-1)^2(c+\theta)) - F_G$$

$$\Pi_{S1G} = \Pi_{S2G} = \frac{(\gamma-3)^2(c+\theta-a)^2}{4(\gamma^2-3)^2}$$

The North firm will invest in Greenfield investment under an endogenous emission standard when the fixed cost is below a threshold, that is:

$$F < \frac{(\gamma-1)^2(c+\theta-a)^2}{(\gamma^2-3)^2}$$

5.14 Appendix 8

When the environmental standard is endogenous, N enters as an acquirer and $\Pi_{NG} > 0$, firms maximize the following profits:

$$\Pi_{NB1} = p_x x + p_y y_N - (c - e_0 + \theta)(x + y_N) - F_B$$

$$\Pi_{S1B1} = p_y y_{S1} - y_{S1}(c - e_0 + \theta) \tag{27}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB1}}{dx} = a - c - e_0 - 2x - (2y_N + y_{S1})\gamma + \theta = 0$$

$$\frac{d\Pi_{NB1}}{dy_N} = a - c - e_0 - 2y_N - y_{S1} - 2x\gamma + \theta = 0$$

$$\frac{d\Pi_{S1B1}}{dy_{S1}} = a - c - e_0 - y_N - 2\mathrm{y}_{S1} - x\gamma + \theta = 0$$

Then, the equilibrium quantities and profits are:

$$y_N = \frac{1}{3}(a - c - e_0 - \theta), \quad x = \frac{a - c + e_0 - \theta}{2\gamma + 2}, \quad y_{S1} = \frac{(2-\gamma)(a - c + e_0 - \theta)}{6(\gamma+1)} \tag{28}$$

Substituting (28) in (27) I obtain:

$$\Pi_{NB1} = \frac{(1-\gamma)(a - c - e + \theta)^2}{4(1+\gamma)}, \quad \Pi_{S1B1} = \frac{1}{9}(a - c - e + \theta)^2$$

Now, the government maximizes the global welfare in the South country:

$$W_B = CS_Y + CS_X + \Pi_{S1G} + \Pi_{S2G} - e_0(X + Y)$$

In this case the old regulation will be the same for the two firms, hence the unitary level of pollution derived from the production of the two goods will be the same. I first check that the welfare function is concave in the pollution standard. I compute the second derivative respect to e_0. $\frac{d^2W_G}{e_0^2} = \frac{\gamma-17}{12(1+\gamma)}$. Since this value is negative, I can confirm that the welfare function of the South country is concave in the pollution standard, thus the South country will set it so as to maximize its Ilfare.

Through maximization, I obtain the following first order conditions and value for the pollution permission:

$$\frac{dW_B}{de_0} = \frac{e_0(\gamma-17)+3a(\gamma-1)-3c(\gamma-1)-3(\gamma-1)\theta}{12(\gamma+1)} = 0$$

$$e_0 = \frac{3(1-\gamma)(a-c-\theta)}{\gamma-17}$$

Substituting I obtain the following quantities and profits:

$$x = \frac{(\gamma-7)(a-c-\theta)}{(\gamma-17)(1+\gamma)}, \quad y_N = \frac{(\gamma-2)(7+\gamma)(a-c-\theta)}{3(\gamma-17)(1+\gamma)}, \quad y_S = \frac{2(\gamma-7)(a-c-\theta)}{3(\gamma-17)}$$

$$\Pi_{NB1} = \frac{1}{9(\gamma-17)^2(\gamma-1)}(a^2(7+\gamma)^2(5\gamma-13)+c^2(7+\gamma)^2(5\gamma-13)+2c(7+\gamma)^2(5\gamma-13)\theta$$
$$+(7+\gamma)^2(5\gamma-13)\theta^2-2a(7+\gamma)^2(-13+5\gamma)(c+\theta))-Fb$$

$$\Pi_{S1B1} = \frac{1}{9}(a-c+e_0-\theta)^2$$

If I substitute $Fb = \Pi_{S2G} = \frac{(\gamma-3)^2(c+\theta-a)^2}{4(\gamma^2-3)^2}$, I obtain:

$$\Pi_{NB1} = -\frac{((477+\gamma(7317+\gamma(3498+\gamma(2826+\gamma(-4267+\gamma(141+4\gamma(57+5\gamma)))))))(-a+c+\theta)^2)}{(36(-17+\gamma)^2(1+\gamma)(-3+\gamma^2)^2)}$$

5.15 Appendix 9

When the emission standard is endogenous, N enters as an acquirer and $\Pi_{NG} \leq 0$, firms maximize the following profits:

$$\Pi_{NB1} = p_x x + p_y y_N - (x+y_N)(c-e_0+\theta) - F_B$$

$$\Pi_{S1B1} = p_y y_{S1} - (c-e_0+\theta)y_{S1} \tag{29}$$

$$\Pi_{S2B1} = \Pi_{S2D}$$

From maximizing the profit functions I obtain the following first order conditions:

$$\frac{d\Pi_{NB1}}{dx} = a - c - e_0 - 2x - (2y_N + y_{S1})\gamma + \theta = 0$$

$$\frac{d\Pi_{NB1}}{dy_N} = a - c - e_0 - 2y_N - y_{S1} - 2x\gamma + \theta = 0$$

$$\frac{d\Pi_{S1B1}}{dy_{S1}} = a - c - e_0 - y_N - 2\mathrm{y}_{S1} - x\gamma + \theta = 0$$

Then, the equilibrium quantities and profits are:

$$x = \frac{a - c + e_0 - \theta}{2\gamma + 2}, \quad y_{S1} = \frac{1}{3}(a - c + e_0 - \theta), \quad y_{S2} = \frac{(2-\gamma)(a - c + e_0 - \theta)}{6(\gamma + 1)}$$

$$\Pi_{NB1} = \frac{1}{36(1+\gamma)}(13c^2 + 26ce + 13e^2 + a^2(13 - 5\gamma) - 5c^2\gamma - 10ce\gamma - 5e^2\gamma + 2a(-13 + 5\gamma)(c + e - \theta)$$
$$+2(c+e)(-13+5\gamma)\theta + (13 - 5\gamma)\theta^2) - Fb\frac{(36 + 36\gamma)}{36(1+\gamma)}$$

$$\Pi_{S1B1} = \frac{1}{9}(a - c + e_0 - \theta)^2$$

Now, the government maximizes the global welfare in the South country:

$$W_B = CS_Y + CS_X + \Pi_{S1G} + \Pi_{S2G} - e_0(X + Y)$$

I first check that the welfare function is concave in the pollution standard. I compute the second derivative respect to e_0. $\frac{d^2 W_G}{e_0^2} = \frac{(\gamma+1)+95}{36(1+\gamma)}$. This value is positive, so this function is not concave. Thus, the maximum value for the welfare will be either the maximum or the minimum pollution standard, being $e_0 = 0$ or $e_0 = \theta$ respectively. I obtain the welfare values for both, and I get $W_B(e_0 = 0) = \frac{(41+23\gamma)(a-c+\theta)^2}{72(1+\gamma)}$ and $W_B(e_0 = \theta) = \frac{(a-c)((a-c)(41+23\gamma)-12(7+\gamma)\theta)}{72(1+\gamma)}$. Now I proceed to compare both values:

$$W_B(e_0 = 0) - W_B(e_0 = \theta) = \frac{\theta(2(a-c)(83 + 29\gamma) + (41 + 23\gamma)\theta)}{72(1+\gamma)}$$

5.16 Appendix 10

For the three cases considered under endogenous pollution standards, I obtain the following Nash eqilibria:

i) If $\Pi_{NG} > \Pi_{NB1} > 0$ (that will hold when $F < \frac{(\gamma-1)^2(c+\theta-a)^2}{(\gamma^2-3)^2}$), then I obtain 22 Nash equilibria: ((G, B1, G), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),sell), ((G, B1, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B2, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B2, no), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),sell), ((G, B3, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B3, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B1, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B1, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B2, G), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),sell), ((G, B2, no), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),sell), ((G, B3, G), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),sell), ((G, B3, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), sell), ((G, B1, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B1, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B2, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B2, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B3, G), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),no sell), ((G, B3, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B1, G), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),no sell), ((G, B1, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B2, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B2, no),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B3, G),($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$), no sell), ((G, B3, no), ($e_0 = \frac{(\gamma-3)(a-c-\theta)}{2(\gamma^2-3)}, e_1 = \frac{(1-\gamma)(a-c-\theta)}{\gamma^2-3}$),no sell).

ii) If $\Pi_{NB1} > 0 > \Pi_{NG} > 0$ (that will hold when $F > \frac{(\gamma-1)^2(c+\theta-a)^2}{(\gamma^2-3)^2}$,), I obtain two NE, that are: ((B, B1, G), ($e_0 = 0$), sell) and ((B, B1, No int), ($e_0 = 0$),sell).

The way to interpret the Nash equilibrium is sue following: the first three strategies inside the parenthesis refer to the North?s decision in the nodes 1, 3 and 4. The second strategy is the Government's decision on the environmental standard. The remaining strategy is the South 1 decision in the node 2.

Note that there is no possible scenario where $\Pi_{B1} > \Pi_{NG} > 0$.