The Reliability of the Bertrand Curse: An Experimental Investigation of Leniency Programs for Underground Work *

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Abstract

In this paper, the demand for underground work from all producers competing on the same output market is analyzed simultaneously. We first show that competition drastically undermines the individual benefits of tax evasion. At equilibrium, each firm nonetheless chooses evasion with a positive probability. Since this probability is strictly lower than one, this *Bertrand curse* could account for the fact that models focusing on individual incentives to evade overpredict evasion (often called the "tax evasion puzzle"). We thereafter assess whether denunciation could solve the Bertrand curse. Allowing firms to denunciate competitors' evasion in fact provides a credible threat against price cuts, hence fostering illegal work. As a result, reducing the cost of denunciation through leniency clauses appears as an highly counter-productive device against underground work. Empirical evidence from a laboratory experiment confirms those predictions.

Keywords: Underground work, Bertrand competition, Collusion, Laboratory experiment.

JEL code: K31, L44, C91.

1 Introduction

Underground activities are inherently illegal. They are then prohibited and, at least legally, punished in all economies over the world. There are however surprisingly few papers studying the behavior of firms inside this environnement. The aim of this paper is to assess the potential deterrence effect of allowing firms to denounce to authorities the illegal work of their competitors. This of course leads us to analyze the individual decision of evading taxes but also the implied dynamics on the output market.

In the context of the strong oligopoly competition (like Bertrand competition), the moonlighting demand gives a competitive advantage which should be fought by the competitors. However it is very

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difficult to obtain on behalf of the competitors that they denounce those that have a moonlighting demand: price competition coexists with a collusive silence.

Most of the literature addressing this matter have in fact focused on individual decisions in highlighting the costs saved by switching to the unofficial sector[1]. This includes not only saving taxes (Trandel & Snow, 1999) but also breaking away bureaucratic heaviness (Friedman, Johnson, Kaufmann & *al.*, 2000), compliance to the legal minimum wage (Rauch, 1991) and more generally the constraints imposed by work legislations (see Schneider & Enste (2000) for a survey). In the tradition of Becker's 1968 work on crime and punishment, those savings are to be balanced by the firm with the expected sanctions imposed by the repression policy.[2] Those sanctions seem to be empirically relevant in the individual decision to evade taxes. Almeida & Carneiro (2005) for instance estimate a -0.12 elasticity of illegal employment to law enforcement. Although behaviors are sensitive to the repression policy, the reason why firms evade so little remains puzzling. Indeed, as noted by Andreoni, Erard & Feinstein (1998), the expected sanctions are rather low as compared to the benefits listed above and the canonical model of tax evasion greatly overpredicts the amount of cheating.

We argue, here, that the demand for underground work highly departs from Becker's model. The reason is that not only one firm but even each firm competing on the market can rely on illegal work. Since hiring underground workers leads to a decrease in the marginal cost of production (thanks, e.g., to the amount of tax evaded), generalized evasion can be associated with more intense competition. As a result, the benefit of evading taxes depends upon the whole market equilibrium.

This feature is caught by assuming Bertrand competition on the output market. Since this model is known as describing a limit case of pure competition (see, e;g;, D'Aspremont, Dos Santos Ferreira & Gérard-Varet, 2003) this allows us to primarily focus on the demand for underground work, while incorporating the implied competitive behavior. Under this assumption, the Bertrand paradox predicts that all firms will choose marginal cost pricing. Given a decrease in marginal cost thanks to underground work, competition on the output market then tends to undermine the benefit of evasion. The question even arises as to whether competition constitutes a natural force against underground work. According to our first result, called the *Bertrand curse*, the answer is only partially affirmative. In spite of the expected profits being zero, we show that evasion is chosen with probability strictly between 0 and 1 in every equilibrium of the game. This has two consequences. First, competition does not imped underground work since the probability is strictly positive. Second, as the probability is strictly lower than one, evasion is chosen less often than what one would expect by inspecting individual decisions only.[3]

[1] "Underground" and "unofficial" both designates, here, the hidden production of legal products. See Gërxhani (2004) for a survey tracking the terms in the literature.

[2] This paper focuses on the demand side of the illegal work market. Cowell's work (1981 ; 1985 ; 1990) is the canonical reference regarding the supply side. It adds the allocation of hours between sectors to the traditional leisure/consumption trade-off. Lemieux, Fortin & Frechette (1994) provide estimations on Quebecian data of the various elasticities at stake in the decision.

[3] A recent contribution by Barth & Ognedal (2005) suggest a complementary justification to the tax puzzle, based on the assumption of correlated probability of detection inside a given firm. It is shown that demand is then the short side of the market for underground work, since firms internalize the increase in detection induced by each new underground

When the whole market equilibrium is considered, evasion is chosen although it leaves the individual expected profits unchanged (i.e. equal to zero). The mechanism underlying the result is rather simple. It stems from the fact that firms cannot "collude" on marginal cost (by maintaining legal hiring) just for the same reason as they cannot collude on price, *i.e.* competition. In a sense, the market lacks one instrument for implementing a zero-profit legal equilibrium rather than the illegal one embedded in the Bertrand curse. Whether denunciation can play such a role is thereafter studied.

Starting with the analysis of self-reporting (Kaplow & Shavell, 1994), a growing body of literature is devoted to the effectiveness of denunciation in deterring criminal behavior .[4] It proves to be a particularly thrifty disciplining device since the cost of detection is born by criminals themselves. Due to leniency clauses being effective in actual anti-trust legislation of both the US and the EU, the analysis have been extensively applied to cartel deterrence[5]. The main result is that the impact of leniency clauses is highly dependent on whether a reward or a reduction in fine is granted to the denunciating firm. Programs that reward denunciation, called "bonus" leniency, are recognized to be well suited to fight collusion (Aubert, Kovacic & Rey, 2005, Brisset & Thomas, 2004). Ambiguous effects however arise in the case of a "moderate" leniency program, designed as a fine discount. The reason is that leniency allows firms to punish more severely the deviators. Denunciation is therefore used as a threat against deviation, hence helping collusion.[6] To our knowledge, Buccirossi & Spagnolo (2005) is the only attempt to apply those results to more general issues. Illegal activities that require the participation of more than one party are shown to be supported too, rather than deterred, by moderate leniency clauses.

Our model partly shares those features. We show that denunciation does not help avoiding the Bertrand curse. Because of its very nature of providing a threat against cheating, denunciation in fact preserves the benefit of evasion. The intuition behind the result is best understood by describing the strategy supporting this collusive evasion. According to the *collusive silence* strategy, each firm does choose evasion. A collusive price is moreover sustained by denouncing every firm choosing a price below the collusive one, and keeping silent otherwise. This way, the equilibrium strategy is supported by two collusion variables: not only the price but also the reporting of evasion to authorities. Beyond the traditional price cutting in case of deviation, the both collusive dimensions are supported by the punishment offered by denunciation.

An experiment is designed for evaluating the empirical relevance of those results. This is at least claimed by the current discrepancy between theory and the facts. Indeed, the only empirical work we are aware of, by Apesteguia, Dufwenberg & Selten (2005), provides mitigate support to the effect of leniency on collusion expected by the theory. The authors study collusion behavior in a one-shot

hiring. A distinct area of research is to explain the puzzle by behavioral assumptions such as social stigma or moral cost. See, e.g., Ratto, Thomas & Ulph (2005) for a theoretical analysis, and the experimental investigations of Fortin, Lacroix & Villeval (2004) and Güth, Levati & Saugruber (2005).

[4]This includes, among others, the works by Innes (1999a ; 1999b ; 2000 ; 2001) and Feess & Heesen (2002).

[5]Papers devoted to comparisons of the two implementations includes Feess & Walzl (2003), Motchenkova & Kort (2004) and Motchenkova & Laan (2005)

[6]The seminal model highlighting the conflicting effects of leniency on collusion is Motta & Polo (2003). See, e.g., Spagnolo (2004) for a comparative review of the theoretical literature on the subject.

Bertrand competition experiment. Communication between players and leniency clauses are introduced thanks to experimental treatments. Surprisingly, leniency clauses appear to be rather effective in deterring collusion, decreasing both the number of collusive agreements and the average equilibrium price. Bonus-type leniency are moreover associated to an increase in the number of collusive agreements, hence contradicting the theoretical consensus summarized above. The design of the experiment is aimed at reproducing as carefully as possible the assumptions of the model. We therefore implement a repeated Bertrand competition game with endogenous marginal cost. Denunciation and leniency clauses are introduced through successive treatments. Thanks to the experimental methodology, the whole theoretical variables are observed by the econometricians. The econometric model moreover disentangles the implementation of collusive evasion and the coordination process underlying the selection of a particular collusive price. In accordance with thee model, denunciation is shown to facilitate collusive evasion, whereas letting the collusive price selection unexplained. Absent denunciation, we find strong evidence of a Bertrand curse in the data: the experimental firms choose evasion with a probability close to (but lower than) one although expected profits are almost zero.

The theoretical model is presented in Section 2. Experimental evidence is thereafter provided (Section 3). The Last section concludes.

2 Demand for underground work: Theoretical analysis

We consider an industry where n symmetric firms compete in price. The production is delegated to an agent, the effort of who, denoted by e, translates into output through the production function: $q = f(e)$. The effort associated with a particular level of production is denoted by $e(q) = f^{-1}(q)$. Denoting W the piece-rate of the - perfectly observed - effort, the cost function is: $C(q) = e(q)\ W$.

For simplicity, consider the linear production case $q = e$, so that: $C(q) = q\ W$ and marginal cost is constant at $C_m = W$, as Bertrand competition requires.[7]. Assuming homogeneous workers, the effort provided for given technology at equilibrium wage is therefore constant at e_0.

The well-known Bertrand paradox states that, whatever n is, the non-cooperative equilibrium of the game is the competitive price/quantities pair: $(p^c, Q^c/n)$ such that $\Pi_c = 0$, where $Q^c = D(p^c)$ is the market demand at price p^c. We focus here on the dynamic version of the game: at each period, the market can randomly vanish with constant probability γ. In this case, collusive pricing can be sustained if the industry is such that the cost of punishing deviants is at least compensated by the benefit of collusion. Consider the particular case of punishment by a trigger strategy. It is the severest implementable punishment since it consists in cooperating until competitors deviates, then staying at competitive prices forever (see, e.g. Rey, 2003). For every positive profit Π_m, trigger strategies are able to support collusive pricing if :

$$\sum_{t=0}^{\infty}(1-\gamma)^t.\frac{\Pi_m}{n} \geq \Pi_m + \sum_{t=1}^{\infty}(1-\gamma)^t \Pi_c \tag{1}$$

[7]See, e.g., D'Aspremont, Dos Santos Ferreira, & Gérard-Varet (2003)

Tacit collusion is thus sustainable for low enough destruction probabilities such that: $\gamma \leq \dfrac{1}{n} \equiv \gamma_c$. When this condition is fulfilled, firms obtain positive profits despite competition.

In our setting, the benefit of evasion is another potential source of positive profits. Underground work is modeled as an endogenous reduction in marginal cost, stemming from evading taxes. Let τ denote the tax rate and w the equilibrium wage an agent earns in compensation for e. The marginal cost of a legal work contract is hence $W = (1+\tau)\ w$ whereas the effort under an illegal contract costs $W = w$ per unit. The counterpart of this reduction in cost is the sanction incured in case of detection. Suppose that illegal contracts are detected with the exogenous probability α and punished by a fine F and the reimbursement of evaded taxes. For a given level of sells, q, the latter obviously amounts to $\tau\ w\ q$. At the competitive equilibrium, the one period profit of illegality is then:

$$\Pi_F \quad = \quad (1-\alpha)\tau\ w\ \frac{Q^c}{n} - \alpha\ F = \pi_F - \alpha\ F \tag{2}$$

where $\pi_F = (1-\alpha)\tau\ w\ \dfrac{Q^c}{n}$ denotes the one-shot gross benefit of evasion.

If tacit collusion is sustainable, evasion increases the positive profit Π_m in (1). In this case, underground work is trivially attractive, through tacit collusion. We rule out this case by restricting ourselves to collusion-proof markets, where $\gamma \geq \gamma_c$. Under collusion proofness, competitive pricing is the only legal (i.e. involving legal work) equilibrium. Null profits hence constitutes the benefit of legal work for a firm. As a result, a risk-neutral firm has incentives to evade taxes if the profit from evasion is positive, i.e.: $\pi_F \geq \alpha.F$. Studying the demand for underground work requires this condition to be fulfilled.

Assumption 1 *We restrict attention to markets and deterrence policies such that :*

1. *There is no legal collusion:* $\gamma > \dfrac{1}{n}$*;*
2. *Evasion is profit improving at competitive equilibrium:* $(1-\alpha)\tau\ w\ \dfrac{Q^c}{n} - \alpha.F > 0$.

Under Assumption (1.1), competition traditionally leads to null profits. In our case, as stated in Assumption (1.2), firms can however reduce marginal cost by evading taxes. The extent to which this reduction gives rise to positive profits depends upon the dynamic of the market when all competitors choose evasion.

2.1 The Bertrand curse

From Assumption (1.2) every firm strictly prefers evasion to legal cost at competitive equilibrium price. Given evasion, the dynamic of competition can lead to one of the two following states. First, evasion can give rise to positive profits if firms can sustain prices above marginal cost. For this reason, this state is called *collusive evasion*. The only alternative is a new price war being opened.

In this second case, the lower marginal cost is used by the firms to increase their market shares. This price war scenario leads to a state where profits conditional on evasion are zero, called *illegal competitive equilibrium*.

Proof See Appendix, Section A.1. ∎

By way of definition, collusive evasion give rise to positive profits. This state is therefore strictly preferred by the firms to the illegal competitive equilibrium. This strategy is sustainable if the intertemporal benefit from market sharing at competitive prices exceeds deviation one-shot profits. Deviation consists in posting a price infinitesimally lower than the competitive one: $p^c - \epsilon$. In this case the deviating firm realizes a profit asymptotically equal to $n\pi_F - \alpha\ F$ while the $n-1$ others experience negative profits equal to $-\alpha\ F$. As before, the hardest punishment to this deviation is return to the illegal competitive equilibrium, where expected profits are equal to zero. Collusive evasion is thus an equilibrium if :

$$\gamma \leq \frac{\pi_F - \alpha\ F}{n\ \pi_F - \alpha\ F} \tag{3}$$

When this condition is fulfilled, a market that seems competitive thus hides tax evasion. This equilibrium, however, cannot be sustained on a non collusive market. The illegal competitive equilibrium therefore remains as the only equilibrium on a tacit collusion-proof market.

Proposition 1 ***(Bertrand curse)*** *Under Assumption 1, firms choose evasion with positive probability and expected profits are zero at equilibrium.*

Proof The proposition results from the fact that tacit collusion proofness makes collusive evasion unstainable: $\gamma \geq \gamma_c \Leftrightarrow \gamma \geq \frac{\pi_F - \alpha.F}{n.\pi_F - \alpha.F}$ This stems from simple manipulations of the following comparison: $\frac{1}{n} \geq \frac{\pi_F - \alpha.F}{n.\pi_F - \alpha.F}$. In fact, this condition reduces to: $\frac{\alpha.F.(n-1)}{n} \geq 0$. For every non monopolistic industry ($n \geq 2$), tacit collusion proofness thus implies collusive evasion proofness. ∎

This result seems quite intuitive from the definition of tacit-collusion proofness. In fact, γ being above γ_c implies that the industry cannot sustain *every* positive profit. Proposition 1 simply confirms that it is still the case even when positive profits stems from tax evasion.

To summary, competition makes firms choosing evasion, but the new price war cancels out evasion profits. Firms are therefore indifferent between the two (legal or illegal) competitive equilibriums. The legal competitive equilibrium is however unstainable, due to the profitability of evasion at legal competitive price. The next section evaluates how this "curse" is broken by allowing firms to denounce competitors' illegal work.

2.2 Denunciation: collusive evasion through collusive silence

Beyond the exogenous monitoring exerted by authorities, this section introduces endogenous monitoring through denunciation. Suppose that each firm perfectly observes the behavior of competitors. Formally, each firm i receives a vector of signals $I_i = \left\{ I_i^j : j \neq i, j = 1, ..., n \right\}$ where $I_i^j = 1\ \forall i$ if firm j evades, 0 otherwise. A denunciation strategy is then a mapping from I_i to $\{0, 1\}$ indicating whether firm i will reveal (1) or not (0) that j evaded both in case he did and in case he in did not. To summarize, a strategy for a firm i at each period t in our framework consists in a triplet $\{p_{i,t}; W_{i,t}; D_{i,t}(I_{i,t})\}$ respectively denoting the pricing strategy, the legality of the wage and the vector of denunciations of illegal behaviors $(D_i(I_i) = \left\{D_i^j(I_i) : j \neq i, j = 1, ..., n\right\}, D_i^j(I_i) = \{0, 1\})$.[8]

We suppose here that denunciation is used by authorities for punishing underground work. As a result, a denunciated firm (*i.e.* every firm i such that $\sum_{j \neq i} D_j^i(1) > 0$) incurs the sanctions with certainty, namely the fine F and the reimbursement of evaded taxes. We moreover assume that the marginal cost chosen by a denounciator (*i.e.* every firm i such that $\sum_{j \neq i} D_i^j(1) > 0$) is perfectly revealed to authorities. We denote by F' the - possibly reduced - fine imposed on an evader that denunciated other(s).[9]

2.2.1 Collusive silence

Regarding collusive evasion, the only change in the model is that evasion can now be revealed to authorities. Of course, collusive evasion cannot be an equilibrium if evasion is denounced. We call *collusive silence* the strategy according to which a firm evades while keeping silent about other's evasion at legal competitive price, and denounce evasion otherwise.

Definition 1 *We call* Collusive Silence *the state were firm i's reply to firm j* $\forall i, j \neq i, t$ *is:*

$$p_{i,t}^* = p^c; W_{i,t}^* = w; D_{i,t}^{j*}(0) = 0; D_{i,t}^{j*}(1) = \begin{cases} 0 & \text{if } p_{j,t} = p^c \\ 1 & \text{if } p_{j,t} < p^c \end{cases}$$

Consider a small deviation from this state. Denunciation may now provide a credible threat against deviants. In fact, the threat to denounce the deviating firm in order to implement collusive evasion in subsequent periods is credible if: $-F' + \sum_{t=1}^{\infty}(1-\gamma)^t \Pi_F \geq 0$:[10]

$$\gamma \leq \frac{\Pi_F}{F' + \Pi_F} \equiv \gamma_F \tag{4}$$

By way of definition, the strategy: $D^*(1) = 1$ is a best reply to deviation as soon as it implements approbation in subsequent periods: evaders are therefore denounced as soon as they try to deviate from legal competitive pricing. As a result, it is a best reply to evade while staying at the competitive equilibrium since denunciated deviation gives rise to negative profits (equals to $-F$) whereas collusive silence is associated to positive profits under Assumption (1.2). Collusive silence is hence a Nash equilibrium when (4) is fulfilled.

[8]In the preceding section, things were kept simple by ignoring the signal I_i. However note that information is assumed to be received *after* the decision on price. In terms of the current setting, the model presented in Section 2.1 hence corresponds to the case where denunciation is neutral, in the sense that authorities do not base detection on reported violations. Without loss of generality, this case can be formalized as $D_i^j(I_i^j)$ being constrained to 0 for every $I_i^j \in \{0; 1\}$. Proposition 1 is hence the theoretical prediction for the benchmark case of neutral denunciation.

[9]One can think to a more general model, where a denounciator is detected with probability $\phi < 1$, the cost of denunciation becoming $\phi F' < F'$. As regard to comparative statics of the model (Table 1 below), this would complicate the analysis without changing the main mechanisms.

[10]In the remaining, we consider the competitive price, p^c, as an upper bound for the pricing strategy. This simplification allows to focus attention on collusive silence alone. However note that every price is sustainable as soon as positive profits are obtained at equilibrium. One can thus add every positive profit stemming from collusion in price, $\Pi_m(Q_m/n)$, to the profit of tax evasion, $\Pi_F(Q_m/n)$, in what follows. This would complicate the analysis of collusive evasion without changing qualitative results.

Table 1: Comparative statics of collusive evasion sustainability

	Exemption ($F' > 0$)							**Leniency**	**Bonus** ($F' < 0$)						
	Sign	τ	w	Q^c	α	F	n	(F')	Sign	τ	w	Q^c	α	F	n
R	$+/-$[a]	$+$	$+$	$+$	$-$	$-$	$+/-$[b]	$-$	$+$	$+$	$+$	$+$	$+/-$[c]	$-$	$+$
γ_F	< 1	$+$	$+$	$+$	$-$	$-$	$-$	$-$	> 1	$-$	$-$	$-$	$-$	$+$	$+$

[a] Positive if: $(n-1)\Pi_F > F'$ [b] Positive if: $\frac{F'}{F} < \frac{1}{\alpha(n-1)^2}$ [c] Positive if: $F' > n(n-1)\alpha$

Proposition 2 *The denunciation pattern described by the collusive silence strategy is a credible threat under (4). Under this condition, collusive silence is the Nash equilibrium of the market.*

Proposition 2 states that collusive evasion can be an equilibrium thanks to denunciation, through collusive silence.

2.2.2 Collusive silence on tacit collusion-proof markets

Now turn to market characteristics that supports collusive silence under Assumption (1.1). It is the case that competitive pricing hides tax evasion if: $\frac{1}{n} \leq \gamma \leq \gamma_F$. As a consequence, there is a room for collusive silence at competitive equilibrium if: $\frac{1}{n} \leq \gamma_F \Leftrightarrow \frac{1}{\gamma_F} \leq n$. Using the definition in (4), this condition translates into market characteristics as :

$$\tau\ w\ Q^c - \frac{nF' + \alpha\ n(n-1)F}{(1-\alpha)(n-1)} \equiv R \geq 0 \tag{5}$$

Using simple manipulations, it can easily be shown that R is positive if: $(n-1)\Pi_F > F'$. Remember that Π_F is the one-shot net profit of evasion for one firm. The r.h.s. is hence the benefit of collusive silence for the whole firms except for the deviant. On a tacit collusion-proof market, collusive silence can therefore occur if the benefit of collusion for the whole market overcomes the cost bear by the denunciator. Denunciation hence provides a credible threats that allows firms to sustain collusive evasion thanks to collusive silence strategy.

Proposition 3 *When denunciation is a credible threat ($\gamma \leq \gamma_F$), collusive silence is an equilibrium of every tacit collusion-proof market such that $(n-1)\Pi_F > F'$.*

As highlighted in Proposition 3, deterrence policies and market characteristics influence the ability of firms to collude on illegal work through two channels. On the one hand, competitive markets are more and more likely to hide collusive silence regarding illegal work as R increases. On the other hand, denunciation is a less and less costly threat as γ_F increases since future profits it implements increases. As a result, collusive silence is easier to implement.

2.2.3 Comparative statics

Simple first order derivatives leads to the results summarized in Table 1. [*Section to be completed*]

To sum up, collusive evasion is trivially sustainable when the market can sustain tacit collusion. Ruling out this possibility, we first studied the equilibrium of the market under neutral denunciation. In this case, the Bertrand curse occurs on every market that cannot sustain tacit collusion: evasion is chosen, but competition drops the benefit of illegality. In this setting, denunciation may provide a credible threat against price reductions. Collusive silence then sustain collusive evasion. This model is implemented through a laboratory experiment, a setting that allows to observe precisely how firms react to variations in the parameters we focused on.

3 Experimental evidence

We first describe our empirical strategy: the design of the experiment and the way data are analyzed. We then describe the patterns observed on experimental markets.

3.1 Experimental design

At the beginning of the experiment, participants are grouped to form markets. The participants involved in the experiments are assigned the role of a firm. The size of the market is fixed for the whole experiment, and announced to each firm before the experiment starts.

The basic Bertrand competition game is implemented through the two following stages. At the beginning of a period, each participant is asked to privately decide: first on marginal cost, W, by choosing between legal and illegal wage and, then, on the price posted. Once all prices have been posted, the number of active firms for the period, n, gathers all those firms that posted the lowest price, hence being the market price for the period.

The demand for the homogeneous product offered is assumed linear: $Q = d - lp$, where p is the market price. This demand function is summarized to the participants by way of a table, an example of which is reproduced in Appendix, Table A. The cells provide the quantity demanded at price in line to each of the active firm, when the number of active firms is the one indicated in column. The gross profit earned by each active firm is then calculated as : $Q/n.(p - W)$, whereas this gross profit is set to 0 for every non-active firm.

Each firm that indulges in evasion incurs detection. To this matter, a random draw is performed before the period ends for each firm that chose the illegal wage. With probability α, the evader is detected: the gross profit is canceled out and the net profit for the period is therefore negative, equal to the fine: $-F$. Participants are informed about this net profit at the end of the period.

For insuring coherency with the theoretical analysis, we implement repeated competition through a random survival of the market: at the end of each period the market can vanish with probability γ. With probability $1 - \gamma$, all the firms hence play a new period, identical to the one just played. Whether a new period will be played or not is announced to firms at the end of the period.

This setting forms the basis of our experiment. Collusive silence implementation is studied through slight adjustments to the game, aimed at introducing denunciation.

3.1.1 Treatments

The treatments duplicates our theoretical approach. A BENCHMARK is first settled, in which denunciation is ruled out. As assumed in the model, we however provide perfect information to each firm on competitors' behavior. For this purpose, the whole list of decisions is displayed, once made, on a separate window. This contains one row per firm, consisting in the cost chosen and next the price posted by the firm. Their own decisions are grey tint on the screen of each participant. Reputation issues are ruled out by reshuffling from period to period the order of appearance in the list. Participants had to close the window before continuing in order to insure they – at least – had a look at it.

This first treatment provides observations on collusion and evasion behavior when no credible threat can be used to implement the collusive silence. Our second treatment, hence called DENUNCIATION, introduces such a mechanism. If a participant has chosen to evade, the list of decisions displayed is augmented with a check box in front of the price and cost he has chosen. Participants can then decide to denounce (check the box) as much evaders as they want to, including 0. In case a firm denounces at least one competitor, the gross profit for the period is canceled out and the net profit for the period is negative, equal to $-F$. Similarly, the net profit of a denounced (one time or more) evader earns net profits equal to $-F$ for the period.

Last, we check for the sensitivity of the collusive silence equilibrium to the fine imposed on denunciation in a so-called LENIENCY treatment. This treatment implements a reduced fine ($F' < F$) for the denounciators.[11]

Beyond those variants of the game, we also perform variations in the size of the markets ranging from 3 to 6. The destruction probability is however kept constant. Depending on their size, the markets we observe therefore exhibit different abilities to sustain tacit collusion as well as collusive silence. In fact, whereas all markets sizes should be able to sustain the collusive silence equilibrium, none of them but 3-firms markets should succeed in tacit collusion.

3.1.2 Experimental procedure

The three treatments are played successively by the same subjects, BENCHMARK first, then DENUNCIATION and, lastly, LENIENCY. The markets (i.e. groups) were hold fixed for the whole experiment. The instructions for each treatment is read just before starting: at the end of each treatment, the experiment is stopped and new instructions are read. Subjects only know that three treatments are to be played. This way, the decisions in one treatment are free from being influenced by the rules to be played in the subsequent one(s). At the beginning of the experiment, three training periods are played to insure

[11] The entire set of parameters used in the experiments is summarized in Appendix A.2. Various figures, based on those parameters, illustrating our theoretical results are also provided as a Supplementary Material.

Table 2: Observed competition intensity

	Number of firms 1	2	3	4	5	6	Total
Benchmark	23.57	23.91	33.33	10.10	7.41	1.68	100.00
Denounce	9.69	22.25	40.97	14.10	9.03	3.96	100.00
Leniency	7.36	7.36	51.32	12.83	14.34	6.79	100.00
Total	11.94	16.47	43.48	12.65	10.85	4.61	100.00

Note. For a given treatment (in row), each cell gives the percentage of firms that experienced the competition intensity presented in column (measured by the number of active firms at the preceding period). In %.

the game is well understood. Participants were encouraged to test a wide range of decisions and check their understanding of the payoffs. It is made common knowledge that the three periods are played for sure (i.e. there is no random survival during training periods) and that earnings will be reset before starting the "true" periods. The experiment ends with a quick computerized questionnaire, in which participants are asked to provide various individual characteristics such as gender, studies field, age, etc.

In order to avoid the "real-life effect", instructions were written using neutral language. Price is referred to as *number*, cost as *option* (A for legal, B for illegal), markets as *groups* and firms as *participants*. The fine was presented as earnings cancellation associated with a fixed loss. In the last two treatments, denunciation of a firm is explained as *checking the box of the corresponding participant*. In order to ensure that instructions were well understood, participants were asked to fill in a questionnaire about the experiment. All answers were publicly commented on before starting.

Overall, 5 experimental sessions were conducted at GATE (Lyon, France), with software developed using *Regate* (Zeileiger, 2000) and 76 subjects participated to the sessions. Participants were first to third-year students in a law, economics or chemistry degree. They earned on average 10 Euros per one hour experiment, which is much higher than the minimum wage in France (slightly less than 6 Euros). The experiment last around one hour.

3.2 Presentation of the experimental markets

Before describing the data provided by the experiment, the next section offers an overview of the way the theoretical model is translated into empirical the variables we thereafter use.

3.2.1 Empirical counter-part of the model

In the model, the size of the industry (variable n) reflects competition intensity. In the empirical application, this is measured thanks to the number of firms that posted the minimum price at the previous period. Competition intensity on experimental markets is described in Table 2.

Proposition 1 states that competition constrains firms to choose underground work. If the market is moreover tacit collusion-proof, the benefits of evasion should be canceled out by competition.

Hypothesis 1 (Bertrand Curse) *In* BENCHMARK, *firm evade taxes but competition leads to zero expected profits.*

Collusive evasion is supported both by tacit collusion and collusive silence. A market is able to sustain tacit collusion if $\gamma - \gamma^c < 0$, whereas collusive silence is sustainable as soon as: $\gamma_F - \gamma > 0$. Further remember that there is room for collusive silence on tacit collusion-proof market when $R > 0$. The observed values of those three variables are summarized in Table 3.

TABLE 3: COLLUSION POSSIBILITIES ON EXPERIMENTAL MARKETS

		Mean	**St. E.**	**Min.**	**Max.**
BENCHMARK	$\gamma - \gamma^c$	-0.259	0.288	-0.750	0.083
	$\gamma_F - \gamma$	0.225	0.304	-0.250	0.750
	$R = \gamma_F - \gamma^c$	-0.034	0.109	-1.000	0.000
DENOUNCE	$\gamma - \gamma^c$	-0.155	0.219	-0.750	0.083
	$\gamma_F - \gamma$	0.073	0.141	-0.250	0.575
	$R = \gamma_F - \gamma^c$	-0.081	0.129	-1.000	0.272
LENIENCY	$\gamma - \gamma^c$	-0.104	0.199	-0.750	0.083
	$\gamma_F - \gamma$	0.204	0.162	-0.250	0.663
	$R = \gamma_F - \gamma^c$	0.100	0.123	-0.357	0.442
Total	$\gamma - \gamma^c$	-0.158	0.237	-0.750	0.083
	$\gamma_F - \gamma$	0.162	0.209	-0.250	0.750
	$R = \gamma_F - \gamma^c$	0.005	0.147	-1.000	0.442

Note. For a given treatment (row), provides the descriptive statistics (in column: mean, standard error, minimum and maximum among observations of firms) regarding collusion possibilities experienced by experimental firms: tacit collusion (first row inside each treatment), collusive silence (second row) and room for collusive silence (third row).

As summarized in Proposition 2, those variables describe the whole collusion possibilities for the firms given evasion.

Hypothesis 2 (Collusive evasion) *Evasion gives rise to positive profits either on markets that are able to sustain tacit collusion ($\gamma > \gamma^c$) or when denunciation is credible threat ($\gamma < \gamma^F$).*

3.2.2 Descriptive statistics

We provide here a first look at the behavior observed in the experiments. First, the behavior under BENCHMARK provides strong support to the Bertrand Curse as summarized in Hypothesis 1. As shown in Table 4 evasion is chosen by most of the experimental firms. Table 5 describes the market price in line with competition intensity. The more intense competition is, the lower is the price and hence profits realized thanks to evasion.

Observation 1 *Firms mostly choose evasion although competition tends to eliminate evasion profits.*

Now turn to observed behavior inside the whole three treatments. The two previous observed tendencies still seems to be at stake: firms mostly choose evasion (Table 6) but the chosen price (Table 7) as well as the market price (Table 8) are rather low.

Table 4: Evasion rate under Benchmark

	Number of firms						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Evasion	94.29	91.55	96.97	100.00	100.00	80.00	95.29
Legal cost	5.71	8.45	3.03	0.00	0.00	20.00	4.71
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note. In Benchmark, percentage of experimental firms that chose evasion (first row) or the legal cost (second row) for a given competition intensity (reported in column, measured by the number of active firms at the preceding period). In %.

Table 5: Distribution of market prices under Benchmark

Market Price	Number of firms						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
5	15.71	5.63	7.07	0.00	27.27	100.00	11.11
6	84.29	88.73	92.93	100.00	72.73	0.00	87.54
7	0.00	5.63	0.00	0.00	0.00	0.00	1.35
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note. In benchmark, share of experimental markets on which the observed market price is the one reported in row, for a given competition intensity (reported in column, measured by the number of active firms at the preceding period). In %.

As denunciation becomes less costly (from one treatment to another), however, the price posted as well as the equilibrium price tends to rise for a given competition intensity (number of firms). Denunciation therefore seems to be effective in helping firms to sustain collusive evasion. As shown in Table 9 denunciation impacts firm behavior through the threat becoming more credible rather than thanks to effective use of denunciation. Overall, less than 5% of the observations do make use of denunciation. Among those who did (called *denounciator*), 75% used it while a collusive price is chosen (equal to 6 or higher) and more than 75% against participants (called *denounced*) that have chosen a very low price (equal to 6).

The way collusive evasion is implemented is described in Table 10. To this matter we define CE as being a dummy variable indicating whether collusive evasion is chosen. Collusive evasion corresponds to $CE_i^t = 1$ if firm i choose evasion and a price higher or equal to 6 at period t, $CE_i^t = 0$ otherwise (see (6) below for a formal definition). Each cell of the Table reports mean (in per cent) of CE for a given combination of tacit collusion sustainability (reported horizontally) and the credibility of denunciation (reported vertically). Both seems to increase the likelihood of collusive evasion being chosen.

The next section provide an econometric analysis of those stylized facts.

3.3 Sustaining collusive evasion: Econometric analysis

The theoretical analysis provide in Section 2 describes those markets that should be able to sustain collusive evasion. As common in collusion literature, the model is however silent about what particular price is associated to the collusive strategy. To sum up, the model predicts when a collusive price is

Table 6: Evasion rate

	Number of firms 1	2	3	4	5	6	Total
Benchmark	94.29	91.55	96.97	100.00	100.00	80.00	95.29
Denounce	88.64	93.07	96.77	95.31	97.56	100.00	95.15
Leniency	74.36	89.74	97.79	98.53	100.00	97.22	95.85
Total	87.58	91.94	97.31	97.53	99.28	96.61	95.47

Note. Share of experimental firms that chose evasion in each treatment (first three rows) and overall (last row), for a given competition intensity (reported in column, measured by the number of active firms at the preceding period). In %.

Table 7: Mean chosen price

	Number of firms 1	2	3	4	5	6	Total
Benchmark	6.57	6.77	6.28	6.20	6.00	7.00	6.45
Denounce	7.09	6.65	6.22	6.25	6.12	5.94	6.38
Leniency	9.49	7.49	6.47	6.15	6.00	6.11	6.63
Total	7.46	6.85	6.35	6.20	6.04	6.14	6.50

Note. Price chosen averaged across experimental firms in each treatment (first three rows) and overall (last row), for a given competition intensity (reported in column, measured by the number of active firms at the preceding period).

selected but do not says anything about the value of this price. In line with this remark, the data is first analyzed as regards to the implementation of collusive silence irrespective to price chosen. We thereafter provide evidence on the way the level of price is chosen given collusive evasion.

Table 8: Mean equilibrium price

	Number of firms 1	2	3	4	5	6	Total
Benchmark	5.89	6.00	5.94	6.00	5.75	5.00	5.93
Denounce	6.50	6.12	6.05	6.00	6.00	5.67	6.09
Leniency	8.43	6.69	6.25	6.00	6.00	6.00	6.42
Total	6.84	6.19	6.13	6.00	5.96	5.80	6.19

Note. Minimum price averaged across experimental markets in each treatment (first three rows) and overall (last row), for a given competition intensity (reported in column, measured by the number of active firms at the preceding period).

Table 9: Observed denunciation behavior

Participant	Chosen price 6	7	8	9	10	11	12	13	Total	Overall
Denounciator	25.00	12.50	4.17	2.08	39.58	4.17	10.42	2.08	100	4.88
Denounced	78.75	2.50	2.50	1.25	8.75	2.50	3.75	0.00	100	8.13

Note. *Upper part*: Among those firms that decided to denounce at least another one, share of firms that chose the price indicated in column at the corresponding period. In %. *Bottom part*: Among those firms that have been denounced by at least another one, share of firms that chose the price indicated in column at the corresponding period. In %. *Last column*: Among all the observed, share of firms that decided to denounce at last another one (first row) or have been dnounced by at least another one (second row). In %.

Table 10: Observed collusive evasion

Tacit Collusion	Collusive silence: Credibility $\gamma > \gamma^F$	Credibility $\gamma < \gamma^F$	Room $R < 0$	Room $R > 0$	**Total**
$\gamma < \gamma^c$	4.6	15.7	11.2	20.3	14.6
$\gamma > \gamma^c$	1.2	10.1	1.2	10.1	7.3
Total	3.1	14.8	10.1	17.0	13.1

Note. Share of observations such that $CE = 1$ (evasion is chosen and the chosen price is higher than 6). In %. *Row*: tacit collusioon proofness ; *Left-hand column*: Credibility of thethreat of denunciation ; *Right-hand column*: Room for collusive silence.

3.3.1 Determinants of collusive evasion

This section focuses on the condition that makes collusive evasion more likely. Collusive evasion is described by CE_i^t, defined as:

$$CE_i^t = \begin{cases} 1 & \text{if } \{p_i^t > 6; W_i^t = w\} \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

Let $I[C]$ denotes the binary variable indicating that condition C is fulfilled. As summarized in Proposition 2, the model formally predicts that collusive evasion likelihood is decreasing in $I[\gamma > \gamma^c]$ (tacit collusion proofness) and increasing in $I[\gamma^F > \gamma]$ (credibility of the threat of denunciation). The econometric model is specified accordingly:

$$\begin{aligned} CE_i^t &= \begin{cases} 1 & \text{if } CE_i^{t*} \geq 0 \\ 0 & \text{otherwise} \end{cases} \\ CE_i^{t*} &= \beta_0 + \beta_c I[\gamma > \gamma^c] + \beta_F I[\gamma^F > \gamma] + \delta_{CE} X_{i,t} + \epsilon_{i,t} \end{aligned} \tag{7}$$

where EC_i^{t*} is a latent variable measuring the propensity of observation i to resort to collusive evasion in period t. Beyond the collusion variables ($I[\gamma > \gamma^c]$ and $I[\gamma^F > \gamma]$), individual characteristics, such as sex or age, and market as well as time-dependent variables are also included in the equation (matrix

$X_{i,t}$). The random term, $\epsilon_{i,t}$ is assumed normal. We moreover take into account unobservable individual heterogeneity by specifying a composed error model:

$$\epsilon_i^t = u_i + \omega_{i,t} \equiv N(\mathbf{0}, \Sigma) \ , \ \Sigma = \begin{pmatrix} \sigma_u & \rho \\ \rho & 1 \end{pmatrix} \tag{8}$$

This Probit model is estimated using Maximum Likelihood. The estimation results, presented in Table 11, give support to Hypothesis 2.

Table 11: Collusive Evasion

Variable	**Coefficient**	**(Standard Error)**
Collusive Evasion probability (Probit, endogenous variable: CE)		
$I[\gamma > \gamma^c]$	-1.222***	(0.419)
$I[\gamma^F > \gamma]$	0.494*	(0.281)
Denounciator	0.328***	(0.113)
Denounced	0.321*	(0.194)
Age	0.179	(0.146)
Sex	0.353	(0.235)
Education	-0.264	(0.258)
Period	-0.005	(0.015)
Round	-0.067*	(0.040)
Group size	-0.004	(0.217)
Intercept	-4.310	(2.746)
Fixed market effect	*yes*	
Estimated distribution		
$\hat{\sigma}$	0.433	(0.105)
$\hat{\rho}$	0.158***	(0.0643)

Significance levels: *** 10%, ** 5%, *** 1%.

Note. Probit with random individual effects. The endogenous variable (CE) is set to one for an observation that chose collusive evasion (i.e. simultaneously chose evasion and a price above 6). Individual unobserved heterogeneity is incorporated though a random effect assumed normal. The dummy variable $I[\gamma > \gamma^c]$ reflects tacit collusion proofness, being equal to one for a collusion proof market ; the dummy variable $I[\gamma^F > \gamma]$ indicates whether denunciation is a credible threat or not. *Denounciator* is a dummy indicating whether the observation has denounced or not at least another one at the preceding period, *Denounced* a dummy indicating whether the observation has been denounced or not by at least another one at the preceding period. *Age* is measured in years ; *Sexe* is equal to one for a male ; *Education* measures the level of graduate schooling, in years. *Period* is a counter for the repetition of the game during the whole experiment, while *Round* is reset at the beginning of each treatment. The *Group size* is measured for each participant by the size of the group it belongs to.

Observation 2 *Collusive evasion is more likely when tacit collusion is sustainable and when denunciation is a credible threat.*

3.3.2 Equilibrium price selection

We now turn to the way the value of the price is chosen by firms given collusive evasion. To this matter, the latent model is specified in terms of the price chosen by firm i at period t, conditional on collusive

Table 12: Collusive evasion and coordination

	Coefficient	t	Coefficient	t	Coefficient	t
Collusive Evasion probability (Probit, endogenous variable: CE)						
$I[\gamma > \gamma^c]$	-1.136**	-2.44	-1.132**	-2.45	-1.133**	-2.45
$I[\gamma^F > \gamma]$	0.410*	1.88	0.410*	1.88	0.410*	1.88
Denounciator	0.458***	4.66	0.456***	4.70	0.456***	4.70
Denounced	0.560***	3.60	0.560***	3.60	0.560***	3.60
Age	-0.050	-0.79	-0.050	-0.78	-0.050	-0.78
Sex	0.573***	5.52	0.572***	5.51	0.572***	5.51
Education	0.097	0.80	0.097	0.79	0.097	0.79
Round	-0.051*	-1.79	-0.050*	-1.78	-.050*	-1.78
Group size	-0.113	-1.14	-0.113	-1.14	-0.113	-1.14
Intercept	-0.584	-0.52	-0.582	-0.52	-0.582	-0.52
Price selection (Tobit, endogenous variable: p)						
$I[\gamma > \gamma^c]$	-0.673*	-1.66	-0.610	-1.12	-0.610	-1.12
$I[\gamma^F > \gamma]$	0.161	0.35	0.353	0.61	0.353	0.61
Denounciator	0.211	0.91	0.142	0.95	0.142	0.95
Denounced	0.901***	3.34	0.561***	2.89	0.561***	2.89
Age	0.266*	1.85	0.140	0.28	0.134	1.02
Sex	-0.338	-1.08	-0.041	-0.16	0.098	0.39
Education	-0.762***	-3.01	-0.206	-0.28	-0.304	-1.22
Period	0.067*	1.74	0.064	1.34	0.064	1.34
Round	0.078	1.00	0.033	0.45	0.033	0.45
Group size	-0.128	-0.63	0.353	1.13	0.701***	2.72
Intercept	5.997***	2.62	3.038	0.35	2.373	1.07
Individual fixed effects	-	-	yes		yes	
Market fixed effects	-	-	-	-	yes	
Estimated distributions						
$\hat{\sigma}$	1.535	-	1.192	-	1.206	-
$\hat{\rho}$	-0.193**	3.85†	-0.030	0.300	-0.018	0.06

Significance levels: *** 10%, ** 5%, *** 1%.
† Wald test of independent equations.

Note. Tobit Type II. *Upper part*: The endogenous variable (CE) is set to one for an observation that chose collusive evasion (i.e. simultaneously chose evasion and a price above 6). *Bottom part*: The endogenous variable is the price chosen by the observation if $CE = 1$, 6 otherwise. The dummy variable $I[\gamma > \gamma^c]$ reflects tacit collusion proofness, being equal to one for a collusion proof market ; the dummy variable $I[\gamma^F > \gamma]$ indicates whether denunciation is a credible threat or not. *Denounciator* is a dummy indicating whether the observation has denounced or not at least another one at the preceding period, *Denounced* a dummy indicating whether the observation has been denounced or not by at least another one at the preceding period. *Age* is measured in years ; *Sexe* is equal to one for a male ; *Education* measures the level of graduate schooling, in years. *Period* is a counter for the repetition of the game during the whole experiment, while *Round* is reset at the beginning of each treatment. The *Group size* is measured for each participant by the size of the group it belongs to.

evasion being chosen, according to:

$$
\begin{aligned}
p_i^t &= \begin{cases} p_i^{t*} & \text{if } CE_i^{t*} = 1 \\ 6 & \text{otherwise} \end{cases} \\
p_i^{t*} &= \mu_0 + \mu_c \; I[\gamma^F > \gamma] + \mu_F \; I[\gamma^F > \gamma] + \delta_p \; Z_{i,t} + v_{i,t}
\end{aligned}
\tag{9}
$$

Observable variables are contained in $Z_{i,t}$. The random term $v_{i,t}$ is allowed to be correlated with $\epsilon_{i,t}$ in (7). The bivariate distribution is assumed normal: $N(\mathbf{0}, \Omega)$, $\Omega = \begin{pmatrix} \sigma & \rho_p \\ \rho_p & 1 \end{pmatrix}$ where ρ_p measures correlation between the selection equation (collusive evasion) in (7) and the intensity equation (price value) in (9). As a result, coordination on a particular price given collusive evasion is estimated as a Tobit Type II (Amemiya, 1984).

The estimation results are presented in Table 12. As expected, the collusion variables do not explain the price posted by firms (bottom part of the table). Overall, the price equation poorly explains the pricing behavior of firms given collusive evasion. A notable exception however arises when denunciation happens, since the price chosen by a firm increases after this firm has been denounced.

In addition, the descriptive statistics described earlier (in particular Table 8) clearly show that the price of the legal competitive equilibrium does not constitute the focal point the theoretical model expected.

Observation 3 *Coordination between firms leads to a price lower than the level corresponding to the legal competitive equilibrium.*

4 Discussion

[*Section to be completed*]

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GATE.

A Appendix

A.1 Proof of the illegal competitive equilibrium

[*Only a sketch of the proof, to be completed.*]

We adopt the following simplifying notations. Let evasion be the binary decision described by $\delta = \{L, H\}$. Choosing legality ($\delta = H$) leads to a high marginal cost, denoted c_H. Evasion ($\delta = L$) is associated to a lower marginal cost, c_L, but imposes a fixed cost F. Remember that $D(p)$ is the demand function, p_m the monopoly price and that profit is assumed to be strictly increasing in p given $p \leq p_m$. Given the evasion decision, the gross profit – i.e. before subtracting the fixed cost – assuming the firm is the only supplier on the market is denoted $\pi_\delta(p) = D(p)(p - c_\delta)$, where α is the price chosen by the firm. Last, we denote by $\widetilde{\alpha}$ the price that leads to 0 expected profits under evasion, defined by: $\pi_L(\widetilde{\alpha}) = F$. In case of ties, we assume that demand is equally distributed between the lowest price firms. The gross profit associated to the vector of pure strategies $\{\delta_i, \alpha_i\}^n$ is then:

$$\phi_i\left(\{\alpha_1, \delta_1\}, \{\alpha_2, \delta_2\}, ..., \{\alpha_1, \delta_1\}\right) = \begin{cases} \pi_{\delta_i}(\alpha_i) & \text{if } \alpha_i < \alpha_j \ \forall\ i \neq j \\ \dfrac{\pi_{\delta_i}(\alpha_i)}{m} & \text{if i ties } m-1 \text{ other firms for low price} \\ 0 & \text{otherwise} \end{cases}$$

We make the problem interesting by assuming that the fixed cost is lower enough as compared to the expected decrease in marginal cost.[12]

Assumption a ***(Profitability)*** *There exists α, $\widetilde{\alpha} < \alpha \leq c_H$ such that: $\pi_L(\alpha) > F$.*

Since profit is increasing in price, the assumption ensures that the profit of choosing $\alpha = c_H$ is higher under evasion (i.e. strictly positive) than under legality ($\pi_H(c_H) = 0$ by definition).

Stated this way, the problem we are addressing shares some interesting common features with a Bertrand competition game with a fixed cost of entry. An important difference with the canonical model of Sharkey & Sibley (1993) is, however, that each firm is *always* present on the market, hence choosing a price, whatever the "entry" decision is. An important result of the simultaneous price/entry game is the non-existence of a pure strategy equilibrium. Despite the distinctive feature we highlighted, the result extends to our model.

Lemma a *There is no pure strategy equilibrium if $n \geq 2$ and $F > 0$*

Proof The proof is adapted from *Theorem 1* in Sharkey & Sibley. If no firm chooses evasion, the Bertrand paradox leads to marginal cost pricing under legality, and profits are 0. If exactly one firm chooses evasion, adopting the monopoly price p_m, the best reply of every other firm is to choose evasion and post a price slightly lower than p_m. If two or more firms choose evasion and p_{min} is the lowest price on the market, every firm with price higher than p_{min} would prefer to avoid fixed cost by choosing legality. Any firm with price equal to p_{min} would prefer to choose a price slightly lower in order to gain the entire market. Last, if two or more firms choose a price equal to $\widetilde{\alpha}$, profits are negative and every firm would prefer legality. ∎

[12] This assumption is formally the same as Assumption 1.2 in the paper.

This result forces us to consider mixed strategy equilibria. A mixed strategy for a firm consists in three distributions. First, a probability of choosing evasion, denoted β ; Second, a price distribution under evasion, denoted $F_L(\alpha)$ and defined on the support $A_L = [\underline{\alpha}_L; \overline{\alpha}_L]$ and last a price distribution under legality, denoted $F_H(\alpha)$ and defined on the support $A_H = [\underline{\alpha}_H; \overline{\alpha}_H]$. Lemma a naturally leads to the following corollary.

Corollary a.1 *In any symetric equilibrium of the game, $0 < \beta < 1$.*

Proof Deduced from Lemma a. ∎

Lemma b *Given non-degenerate distributions, there are no mass points in $F_L(\alpha)$ and $F_H(\alpha)$ on their respective support.*

Proof [*To be completed*] ∎

As a result, the expected profit of every pure strategy included in the support, $\{\delta, \alpha\}$, is:

$$\Pi(\delta, \alpha) = \left[(1-\beta)\left[1 - F_H(\alpha)\right] + \beta\left[1 - F_L(\alpha)\right]\right]^{n-1} \ \Pi_\delta(\alpha) \tag{10}$$

Lemma c *The lower bounds of the supports cannot be lower than the prices giving rise to null profits, $\underline{\alpha}_L \geq \widetilde{\alpha}$ and $\underline{\alpha}_H \geq c_H$; the upper bounds cannot be higher than the monopoly price, $\underline{\alpha}_L \leq p_m$ and $\underline{\alpha}_H \leq p_m$.*

Proof (*Sketch*) *Upper bounds*: every price above the monopoly price is strictly dominated by a lower one. *Lower bounds* : a firm choosing with certainty a price equal to the marginal cost earns null profits. If a lower price is chosen, associated profits are negative. The strategy can then be included in the support only if the probability of winning is null. This implies that the support of at least on competitor is on the left to this price. But this firm therefore earns negative profits and cannot, then, play an equilibrium strategy. ∎

This ensures that the price is never chosen in the range where profits are negative.

Lemma d *The supports of the price distributions are disconnected. Under Assumption a, the bounds verify: $\overline{\alpha}_L = \alpha_0 = \underline{\alpha}_H$, where α_0 s.t. $\pi_H(\alpha_0) = \pi_L(\alpha_0) - F$.*

Proof (*Sketch*) We first show that for every price α, one of the evasion strategy, $\delta = \{L, H\}$, dominates the other. It follows that the support of $F_H(\alpha)$ (respectively $F_L(\alpha)$) only includes those prices for which evasion (resp. legality) dominates legality (resp. evasion).

Single-crossing. The two profit functions associated with the investment decision (π_H and π_L) cross at most one time in $[c_L, p_m]$.

Bounds. Let α_0 be the price such that $\pi_H(\alpha_0) = \pi_L(\alpha_0) - F$. Unbounded profit ensures that α_0 does exists. By way of definition, it this the only price shared by the two supports. By the profitability assumption (Assumption 10), we know that evasion first dominates legality, *i.e.* $\pi_H(\alpha) < \pi_L(\alpha) - F \ \forall \alpha < \alpha_0$. It then follows that: $\overline{\alpha}_L = \alpha_0 = \underline{\alpha}_H$. ∎

We can now state our first result.

Proposition a *If profits are unbounded ($\lim_{p \to p_m} \pi(p) = \infty$) every profit $k \in [0, \infty]$ may be achieved as the expected per firm profits in a symmetric mixed-strategy Nash equilibrium of the game.*

Proof Let k denote the expected per firm profit of the equilibrium strategy. It is, thus, the expected profit of every pure strategy included in the support. From Lemma d the following results holds: $F_H(\alpha) = 0 \ \forall \ \alpha \in A_L$ and $F_L(\alpha) = 1 \ \forall \ \alpha \in A_H$. For any $\alpha \in A_L$, the expected profit given evasion then verifies:

$$\Pi(L, \alpha) = [1 - \beta F_L(\alpha)]^{n-1} \ \ \Pi_L(\alpha) = k$$

At the upper bound of the support, one has $F_L(\alpha_0) = 1$, such that: $[1 - \beta]^{n-1} \ \ \Pi_L(\alpha_0) = k$ and then:

$$\beta = \frac{\pi_L(\alpha_0)^{\frac{1}{n-1}} - \pi_L(\underline{\alpha}_L)^{\frac{1}{n-1}}}{\pi_L(\alpha_0)^{\frac{1}{n-1}}}$$

Using simple manipulations, this leads to:

$$F_L(\alpha) = \left(\frac{\pi_L(\alpha_0)^{\frac{1}{n-1}} - \pi_L(k)^{\frac{1}{n-1}}}{\pi_L(\alpha_0)^{\frac{1}{n-1}}}\right)\left(\frac{\pi_L(\alpha)^{\frac{1}{n-1}} - \pi_L(k)^{\frac{1}{n-1}}}{\pi_L(\alpha)^{\frac{1}{n-1}}}\right) \ \forall \alpha \in [\underline{\alpha}_H; \alpha_0]$$

For the lower bound of the support, it is the case that: $F_L(\underline{\alpha}_L) = 0$ such that: $\Pi(L, \underline{\alpha}_L) = \Pi_L(\underline{\alpha}_L) = k$, which uniquely defines the lower bound of a k-equilibrium.

Lastly, using the fact that $F_L(\alpha) = 1$ for any $\alpha \in A_H$, the expected profit given legality verifies:

$$\Pi(H, \alpha) = [(1 - \beta)(1 - F_H(\alpha)]^{n-1} \ \ \Pi_H(\alpha) = k$$

and then: $F_H(\alpha) = 1 - \left(\frac{\pi_H(\alpha_0)}{\pi_H(\alpha)}\right)^{\frac{1}{n-1}} \ \forall \alpha \in [\alpha_0; p_m]$. Summarizing the results, every k-equilibrium strategy (i.e. an equilibrium strategy leading to per firm expected profit equal to k) is defined by:

$$\begin{aligned}
\beta &= \frac{\pi_L(\alpha_0)^{\frac{1}{n-1}} - \pi_L(\underline{\alpha}_L)^{\frac{1}{n-1}}}{\pi_L(\alpha_0)^{\frac{1}{n-1}}} \\
F_L(\alpha) &= \left(\frac{\pi_L(\alpha_0)^{\frac{1}{n-1}} - \pi_L(k)^{\frac{1}{n-1}}}{\pi_L(\alpha_0)^{\frac{1}{n-1}}}\right)\left(\frac{\pi_L(\alpha)^{\frac{1}{n-1}} - \pi_L(k)^{\frac{1}{n-1}}}{\pi_L(\alpha)^{\frac{1}{n-1}}}\right) \ \forall \alpha \in [\underline{\alpha}_H; \alpha_0] \ , \underline{\alpha}_L \text{ s.t. } \pi_L(\underline{\alpha}_L) = k \qquad (11) \\
F_H(\alpha) &= 1 - \left(\frac{\pi_H(\alpha_0)}{\pi_H(\alpha)}\right)^{\frac{1}{n-1}} \ \forall \alpha \in [\alpha_0; p_m]
\end{aligned}$$

This last function is a well defined distribution function iff $\lim_{p \to p_m} F_H(p) = 1$, requiring unbounded profits.

By construction, the expected profit of the strategy is $\Pi(\delta, \alpha) = k \ \forall \ \delta = \{L, H\}, \alpha \in A_\delta$. Given evasion, it does not pay for firm i to price below $\underline{\alpha}_L$ since the firm would win the entire market for certain but earn profits strictly less than k. Similarly, the price chosen given legality must be higher than α_0, since legality would otherwise be dominated by evasion. Thus, the strategy in (11) constitutes a symmetric mixed-strategy Nash equilibrium of the game. ∎

The equilibrium strategy can be seen as encompassing two previously analyzed model. On the one hand, the strategy associated with evasion, $\{\beta; F_L(\alpha)\}$ is the counterpart of what Sharkey & Sibley (1993) obtain as an equilibrium of their simultaneous entry/price game. On the other hand, the price distribution under legality, $F_H(\alpha)$, is the mixed strategy equilibrium of one shot Bertrand games (Baye & Morgan, 1999). In particular, unbounded profits is a necessary condition of existence in this last context just as in ours (see also Kaplan & Wettstein (2000) for similar results in the particular case of an iso-elastic demand function).

In our model, however, a mixed strategy equilibrium does exists even if profits are bounded. The reason is that firms can mix not only on the price chosen given legality, but also on evasion and the price chosen in this case.

Proposition b *If profits are bounded, the expected per firm profits are zero in the only symmetric mixed-strategy Nash equilibrium of the game.*

Proof If profits are bounded, the strategy in (11) is not an equilibrium due to $F_H(\alpha)$ being strictly lower than 1. The following strategy remains as the only symmetric mixed strategy Nash equilibrium:

$$\begin{aligned}
\beta &= \frac{\pi_L(\alpha_0)^{\frac{1}{n-1}} - F^{\frac{1}{n-1}}}{\pi_L(\alpha_0)^{\frac{1}{n-1}}} \text{ where } \alpha_0 = c_H \\
F_L(\alpha) &= \left(\frac{\pi_L(\alpha_0)^{\frac{1}{n-1}} - F^{\frac{1}{n-1}}}{\pi_L(\alpha_0)^{\frac{1}{n-1}}}\right)\left(\frac{\pi_L(\alpha)^{\frac{1}{n-1}} - F^{\frac{1}{n-1}}}{\pi_L(\alpha)^{\frac{1}{n-1}}}\right) \forall \alpha \in [\widetilde{\alpha}; \alpha_0] \qquad (12) \\
F_H(\alpha) &= \begin{cases} 1 & \text{if } \alpha \geq c_H \\ 0 & \text{otherwise} \end{cases}
\end{aligned}$$

By construction, the expected profits of the strategy are 0. Prices lower than the lower bound of each support (respectively c_H or $\widetilde{\alpha}$ given either legality or evasion) are excluded by virtue of Lemma c. A firm choosing a price higher than c_H can earn positive profits, but the probability of winning the market is 0, whatever the evasion decision is. ∎

A.2 Parameters used in the experiment

The demand function links the gross quantities sold on the market Q to the equilibrium price p according to: $Q = d - lp$. The cost function is: $C(Q) = W.Q$, $W = \{w, (1+\tau)w\}$ depending on whether the low cost (option A) or the high cost (option B) is chosen. Those functions are implemented using the following parametrization:

Demand	: d =40 , l =2 , γ =0.25
Cost	: w =5 , τ =0.8
Punishment	: α =0.05 , F =20 , F' =10

As a result, the legal competitive equilibrium price is p^c =9 and leads to quantities Q^c = 22 . Evasion gross profit for the whole industry is therefore set equal to: π_F = 83.6 .

The demand function is presented to the participants by means of a table such as the one reproduced in Table A.

Table A: Table gave to the participants (Groupe size = 6 here)

p \ n	1	2	3	4	5	6
5	30.0	15.0	10.0	7.5	6.0	28.0
6	28.0	14.0	9.3	7.0	5.6	4.7
7	26.0	13.0	8.7	6.5	5.2	4.3
8	24.0	12.0	8.0	6.0	4.8	4.0
9	22.0	11.0	7.3	5.5	4.4	3.7
10	20.0	10.0	6.7	5.0	4.0	3.3
11	18.0	9.0	6.0	4.5	3.6	3.0
12	16.0	8.0	5.3	4.0	3.2	2.7
13	14.0	7.0	4.7	3.5	2.8	2.3
14	12.0	6.0	4.0	3.0	2.4	2.0
15	10.0	5.0	3.3	2.5	2.0	1.7
16	8.0	4.0	2.7	2.0	1.6	1.3
17	6.0	3.0	2.0	1.5	1.2	1.0
18	4.0	2.0	1.3	1.0	0.8	0.7
19	2.0	1.0	0.7	0.5	0.4	0.3
20	0.0	0.0	0.0	0.0	0.0	0.0