

Regression Results

Companion Note to: Leniency Programs and the Design of Antitrust: Experimental Evidence with Free-Form Communication

Peter T. Dijkstra* Marco A. Haan Lambert Schoonbeek

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1 Introduction

In this note, we report on a number of regressions to try to add to our understanding of subjects' behavior in our experiment. We are primarily interested in the effect of a leniency program relative to a situation without a leniency program. Hence, in all the regressions that follow, we do not take the observations of our benchmark treatment into account; we only compare ANTITRUST, PROFOUND and SUPERFICIAL.

2 The emergence of cartels

In Table 1 we do a regression to explain the initiation of cartels. For the subset of periods where a cartel does not yet exist at the start of the period, we estimate a random-effects binomial logit model. From column (1) we see that a cartel that has been discovered in the past is less likely to form anew. This is in line with the conclusion we draw in the main text: in those cases, a new explicit agreement seems unnecessary to still keep prices high. Also, the effect of period is negative and significant. This could be partly due to a selection effect. If a cartel has not formed early then perhaps these market participants are simply not inclined to form a cartel. If that is the case, then such a cartel is also unlikely to form at a later stage. The effect of both leniency treatments is not significant. Past reports also do not have a discernible effect.

*Corresponding author, Netherlands Authority for Consumers & Markets (ACM), PO Box 16326, 2500 BH The Hague, The Netherlands, peter.dijkstra@acm.nl. Phone: +31 70 722 2307. Haan and Schoonbeek: Department of Economics, Econometrics and Finance, University of Groningen, P.O. Box 800, 9700 AV Groningen, The Netherlands.

Table 1: Cartel initiation

	(1)	(2)	(3)
period	-0.108** (0.045)	-0.103** (0.046)	-0.103** (0.046)
profound	-0.902 (0.585)	-1.171* (0.691)	-1.171* (0.691)
superficial	-0.697 (0.573)	-1.141* (0.654)	-1.141* (0.654)
past_discovered	-1.528* (0.878)	-2.257* (1.155)	
disc*anti			-2.257* (1.155)
disc*prof		0.921 (1.391)	-1.336 (1.092)
disc*sup		1.388 (1.469)	-0.869 (1.194)
past_reports	-0.213 (0.861)	0.409 (2.052)	
reports*prof			-0.485 (0.903)
reports*sup		-0.894 (2.353)	0.409 (2.052)
Constant	-0.609 (0.466)	-0.360 (0.547)	-0.360 (0.547)
Observations	794	794	794

Notes: `Cartel initiation` is estimated by means of a random-effects binomial logit model; only periods in which a market was not a cartel at the start of that period are included. Hence, this dummy is 1 when a cartel is started in that period that did not exist in the previous period, it is 0 when there is no cartel, while periods with a cartel that was inherited from the past are not included. `past_discovered` and `disc` indicate whether a cartel has been discovered by the `aa` in the past; `past_reports` and `reports` whether there have been reports in the past. `anti`, `prof` and `sup` denote the antitrust, profound and superficial treatment, respectively. `disc*anti` thus denotes the interaction between the `past_discovered` and `antitrust` dummies, etc. Clustered standard errors at group level in parentheses. *significant at 10%; **at 5%.

In column (2) we add the interaction of the leniency and the `past_discovered` and `past_reports` dummies. Hence, the coefficient of, say, `disc*prof` should be interpreted as the effect of past discovery in PROFOUND relative to the effect of past discovery in ANTITRUST. In this regression, the effects of `period` and `past_discovered` are still negative and significant. Discoveries in PROFOUND and SUPERFICIAL do not have a significantly different effect from discoveries in ANTITRUST. Yet the coefficients for PROFOUND and SUPERFICIAL are now both negative and significant: with leniency cartels are less likely to form in any given period.

In column (3) we no longer include the `past_discovered` and `past_reports` dummies separately, but do include their interactions with all relevant treatment dummies. Hence, the interpretation of the leniency dummies is now different. The coefficient of, say, `disc*prof` now simply measures the effect of past discoveries in PROFOUND relative to a case in which there were no past discoveries in PROFOUND. Necessarily, the other coefficients are unaffected. The regression confirms that there is only a significant effect of past discoveries in ANTITRUST.

In Table 2, we take a different approach in studying the formation of cartels. We do a Cox regression to study which factors influence when a cartel is formed, i.e. when we switch from a competition to a cartel regime. Technically, we thus do a survival analysis, where the survival refers to the survival of competition, and the 'death' of such a competition spell represents the formation of a cartel. In the table, the interaction `disc*sup` has not been included as this yields too few events to allow for a robust estimate.

However, this yields a problem. Suppose that on a market, a cartel is already formed in the very first period. In that case, there has never been any competition in the first place, so we cannot include that observation in our analysis of the survival of competition. But that seems odd; our purpose is to study how quickly a cartel is formed and if we do not include observations where cartels are formed right away, we are missing something.

Still, in columns (1) and (2), we do exactly that analysis. We find that past discoveries lower the probability that a new cartel is formed. The leniency treatments have no effect.

To address the problem noted above, we take a slightly different approach in columns (3) and (4). To be able to also take the instances into account where a cartel is immediately formed, we simply add 1 to the length of each competition spell. In other words, we effectively start our analysis in period 0, where arguably competition is in effect by construction. Thus, if subjects decide to form a cartel right away, we interpret this as them forming a cartel after 1 period of competition. If they decide to form a cartel in period 2, we interpret this as them forming a cartel after two periods of competition,

Table 2: Cartel initiation: Cox regression

	(1)	(2)	(3)	(4)
	comp periods		comp periods + 1	
profound	-0.357 (0.496)	-0.412 (0.580)	-1.309*** (0.383)	-1.507*** (0.425)
superficial	-0.233 (0.484)	-0.585 (0.551)	-1.184*** (0.367)	-1.707*** (0.381)
past_discovered	-1.634*** (0.514)		-2.349*** (0.478)	
disc*anti		-1.500** (0.731)		-2.626*** (0.614)
disc*prof		-0.871 (0.784)		-0.864 (0.784)
past_reports	-0.269 (0.567)		-0.384 (0.566)	
reports*prof		-0.227 (0.674)		-0.304 (0.675)
reports*sup		-0.192 (1.053)		0.174 (1.051)
Observations	76	76	104	104

Notes: Cox regression for the survival of competition during every spell of competition. In (1) and (2) all periods are included in which there was competition in the previous period. In (3) and (4) all periods are included in which there was no cartel at the start of the period, and for each event the number of periods with competition is increased by 1. `past_discovered` and `disc` indicate whether a cartel has been discovered by the `aa` in the past; `past_reports` and `reports` whether there have been reports in the past. `anti`, `prof` and `sup` denote the antitrust, profound and superficial treatment, respectively. `disc*anti` thus denotes the interaction between the `past_discovered` and `antitrust` dummies, etc. `disc*sup` has not been added because of too few events. Standard errors in parentheses. *significant at 10%; **at 5%; ***at 1%.

etc. In this way, we can also include instances where a cartel is formed directly.

From column (3) and (4), we now have that a cartel is formed significantly later with a leniency program in place. Past discoveries also have a negative effect, but that seems primarily driven by the `ANTITRUST` treatment. We could not include the interaction between past discoveries and `SUPERFICIAL` as we have too few observations to allow us to do so.

Summing up, we find that *ceteris paribus*, in a given period, a cartel is less likely to form with leniency. More precisely, competition survives longer with leniency. In other

words, cartels take longer to form in that case. Cartels are less likely to form anew when they have been discovered in the past, but that effect is only significant in ANTITRUST, so if there is no leniency program in place.

3 Prices

In Table 3, we study market prices in each period. Using a random-effects linear regression, we explain the price in each period from the period, the treatment, whether trust issues have been raised (`trust_discussed`), threats have been made (`threats_made`), participants engaged in chitchat (`chitchat`) and whether a price agreement has been reached and is (still) valid in this period (`priceagree`). Note that, as all cartels have made a price agreement, the dummy `priceagree` essentially measures whether a cartel is or has been in place.

From column (1), we have that prices are significantly higher with a price agreement. Also, it seems that general chitchat serves as a mechanism to build trust and familiarity; prices are significantly higher if participants have engaged in such chitchat. In later periods, prices are significantly higher.

In column (2) we also add interaction dummies. The interaction `threats*anti` is not included, as that yields too few observations. Raising trust issues now has a significantly positive effect on prices in SUPERFICIAL, while `threats_made` has a significantly negative effect in SUPERFICIAL.¹ Surprisingly, the effect of `chitchat` in SUPERFICIAL is significantly negative. Hence, general chitchat has a negative effect on prices in SUPERFICIAL compared to its effect in ANTITRUST. Comparing the two coefficients of `chitchat` and `chch*sup`, the net effect is roughly zero. The effect of a price agreement *per se* is now significantly positive in both leniency treatments, but no longer in ANTITRUST.

Similar to Table 1 we also estimate a regression in which we drop the individual trust, threat, chitchat and price agreement dummies, and only include their interactions with all relevant treatments. This is column (3) in Table 3. This regression suggests that raising the issue of trust has a negative and significant effect on prices in PROFOUND, but a positive significant effect in SUPERFICIAL, while the effect in ANTITRUST is not significant. It is hard to see why the effect would be so different in the two leniency treatments. Therefore, our working hypothesis is that this is just a statistical fluke. From (3) we also see that threats have a significant negative effect on prices in both the leniency treatments, while the effect of price agreements is not significant in ANTITRUST.

¹With no threats in ANTITRUST, and the interaction `THREATS*PROF` included in the regression, the effect found must be due to SUPERFICIAL.

Table 3: Market prices

	(1)	(2)	(3)
period	0.119*** (0.025)	0.115*** (0.025)	0.115*** (0.025)
profound	-0.357 (0.819)	-1.044 (1.016)	-1.044 (1.016)
superficial	-0.703 (0.824)	-1.260 (1.023)	-1.260 (1.023)
trust_discussed	1.437 (0.900)	-0.139 (0.430)	
trust*anti			-0.139 (0.430)
trust*prof		-1.901 (1.169)	-2.040* (1.058)
trust*sup		2.680** (1.349)	2.541** (1.273)
threats_made	-1.523 (1.067)	-3.125* (1.768)	
threats*prof		0.895 (2.121)	-2.230* (1.204)
threat*sup			-3.125* (1.768)
chitchat	1.038** (0.408)	1.994** (0.852)	
chch*anti			1.994** (0.852)
chch*prof		0.695 (1.323)	2.689*** (1.015)
chch*sup		-1.833** (0.917)	0.161 (0.342)
priceagree	2.462*** (0.374)	0.842 (0.591)	
pragr*anti			0.842 (0.591)
pragr*prof		1.214* (0.699)	2.056*** (0.362)
pragr*sup		2.380*** (0.837)	3.222*** (0.547)
Constant	5.495*** (0.658)	6.083*** (0.772)	6.083*** (0.772)
Observations	1,040	1,040	1,040
rho	0.675	0.682	0.682

Notes: Random-effects linear regression. **trust_discussed** and **trust** indicate whether trust issues were raised by either subject now or in the past; **threats_made** and **threat** whether threats have been made now or in the past; **chitchat** and **chch** indicate whether subjects engaged in general chitchat, now or in the past; **priceagree** and **pragr** whether a price agreement has been reached and is still in place. **anti**, **prof** and **sup** denote the antitrust, profound and superficial treatment, respectively. **trust*prof** thus denotes the interaction between the **trust_discussed** and **profound** dummies, etc. **threats*anti** not included, for lack of observations. Robust standard errors in parentheses. *significant at 10%; **at 5%; ***at 1%.

Table 4: Market prices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All cartel periods			First period each cartel episode			First cartel episode		
period	-0.002 (0.020)	0.005 (0.021)	0.005 (0.021)	-0.014 (0.025)	-0.020 (0.041)	-0.020 (0.041)	-0.027 (0.020)	-0.024 (0.019)	-0.024 (0.019)
profound	0.058 (0.561)	0.613 (0.951)	0.613 (0.951)	-0.055 (0.597)	-0.165 (0.663)	-0.165 (0.663)	-0.103 (0.598)	0.539 (0.750)	0.539 (0.750)
superficial	0.441 (0.435)	1.014 (0.776)	1.014 (0.776)	0.076 (0.782)	0.602 (0.450)	0.602 (0.450)	0.389 (0.444)	0.773 (0.572)	0.773 (0.572)
trust_discussed	0.673** (0.323)	0.167 (0.155)		0.627* (0.366)	0.971 (0.859)		0.886** (0.416)	0.738* (0.437)	
trust*anti			0.167 (0.155)			0.971 (0.859)			0.738* (0.437)
trust*prof		0.362 (0.712)	0.530 (0.693)		-0.565 (1.266)	0.406 (0.988)		-0.029 (0.976)	0.709 (0.880)
trust*sup		0.906 (0.597)	1.074* (0.559)		-0.516 (0.960)	0.455 (0.359)		0.520 (0.745)	1.258** (0.612)
threats_made	0.035 (0.405)	-0.659 (0.444)		0.517 (0.449)	-0.116 (0.357)		-0.046 (0.419)	-0.808 (0.550)	
threat*prof		1.925** (0.864)	1.266* (0.738)		1.572** (0.724)	1.456 (0.913)		2.309** (1.034)	1.501* (0.877)
threat*sup			-0.659 (0.444)			-0.116 (0.357)			-0.808 (0.550)
chitchat	0.032 (0.444)	1.251 (0.781)		-0.662 (0.420)	-0.331 (0.915)		-0.456 (0.297)	0.259 (0.201)	
chch*anti			1.251 (0.781)			-0.331 (0.915)			0.259 (0.201)
chch*prof		-1.964* (1.079)	-0.713 (0.762)		-0.270 (1.289)	-0.601 (0.922)		-1.595* (0.945)	-1.335 (0.920)
chch*sup		-1.581** (0.760)	-0.330 (0.204)		-0.060 (0.981)	-0.391 (0.315)		-0.819*** (0.316)	-0.560** (0.257)
past_discovered	0.805** (0.319)	0.114 (0.348)		-0.697 (0.999)	-0.807 (0.817)				
disc*anti			0.114 (0.348)			-0.807 (0.817)			
disc*prof		1.051** (0.500)	1.165*** (0.359)		2.001** (0.963)	1.193* (0.647)			
disc*sup		0.595 (0.432)	0.709*** (0.207)		-1.603 (3.438)	-2.410 (3.343)			
past_reports	0.211 (0.172)	-0.011 (0.156)		0.103 (0.438)	0.424 (0.310)				
reports*prof		0.143 (0.310)	0.132 (0.296)		-0.198 (0.700)	0.226 (0.711)			
reports*sup			-0.011 (0.156)			0.424 (0.310)			
Constant	9.063*** (0.606)	8.557*** (0.868)	8.557*** (0.868)	9.658*** (0.531)	9.380*** (0.342)	9.380*** (0.342)	9.494*** (0.484)	9.112*** (0.567)	9.112*** (0.567)
Observations	306	306	306	60	60	60	240	240	240

Notes: Random-effects linear regression. Sample: all cartel periods (1-3); the first period of each cartel episode (4-6); all periods in the first cartel episode (7-9). `trust_discussed` and `trust` indicate whether trust issues were raised by either subject now or in the past; `threats_made` and `threat` whether threats have been made by either subject now or in the past; `chitchat` and `chch` indicate whether subjects engaged in general chitchat, now or in the past; `past_discovered` and `disc` indicate whether there have been discoveries in the past; `past_reports` and `reports` whether there have been reports in the past. `anti`, `prof` and `sup` denote the antitrust, profound and superficial treatment, respectively. `trust*prof` thus denotes the interaction between the `trust_discussed` and `profound` dummies, etc. `threats*anti` not included, for lack of observations. Robust standard errors in parentheses. *significant at 10%; **at 5%; ***at 1%.

Arguably, however, we may have an endogeneity problem in Table 3, as the treatment may influence the extent of cartelization, and the extent of cartelization affects prices. To avoid this, in Table 4 we only look at cartel prices. Columns (1)-(3) consider all prices that were set in a cartel period. This regression also allows us to study the effect of past discoveries and past reports on current cartel prices. From column (1), raising trust issues has a significantly positive effect on cartel prices, although we did not find an effect on the overall price level in Table 3. Moreover, cartels that have been discovered in the past charge significantly higher prices on average. Hence, a past discovery seems to focus minds and only make collusion more successful. Past reports do not have a significant effect.

In column (2) we add interaction dummies with the leniency treatments, whereas column (3) adds interaction dummies for all treatments. Hence, again, (2) gives the effect of, say, chitchat in SUPERFICIAL relative to chitchat in ANTITRUST, while (3) gives the effect of chitchat in SUPERFICIAL relative to no CHITCHAT in SUPERFICIAL. From column (3), we have that the effect of threats is driven by PROFOUND; there the effect is positive and significant whereas in SUPERFICIAL it is negative but insignificant. From column (2), the effect of chitchat is negative and significant in both leniency treatments relative to ANTITRUST. From column (3), the effects of past discoveries are driven by the leniency treatments.

Note that columns (1)–(3) look at all periods when there was a cartel. Yet, some cartels last longer than others mainly due to chance. If cartel members are lucky enough to not face an investigation for many periods, then this randomly generates many cartel observations. This could affect our results. Also, if a cartel lasts longer, then price setting behavior later in that cartel episode may be influenced by prices earlier in that episode. To rule out these effects, the regressions in columns (4)–(6) only include the first period in each cartel episode.

In column (4), we find that only `trust_discussed` has a significant effect. The effects of past discoveries that we found in (1), is no longer significant. When we add interaction dummies in (5) and (6), we find a positive effect of threats on cartel price in `Profound` vis-à-vis `ANTITRUST` in (5), and of past discoveries in `PROFOUND` in (6).

Finally, we also look at prices in the first cartel episode of a market, in columns (7)–(9). These regressions thus study the effects of communication on the very first cartel, so any effect of past defections, reports etc. are ruled out. Also, threats and discussions on trust that are a result of past cartel behavior are filtered out, eliminating another possible source of heterogeneity. Note that, unfortunately, we cannot study only the first period of the first cartel episode, as that would yield too few observations.

Again, we see from (7) that raising trust issues significantly increases cartel prices. When focusing on individual treatments in (9), this effect is significant in both ANTITRUST and SUPERFICIAL. Again, threats have a positive and significant effect, but only in PROFOUND. Interestingly, in both leniency treatments, general chitchat now has a *negative* effect on prices relative to ANTITRUST. Arguably, both leniency treatments are rather complicated. When wasting time in the first cartel in engaging in general chitchat, there is not always enough time left to agree on high prices.

Summing up, when looking at all prices we find a positive effect of general chitchat, but that effect is often reversed if we look solely at cartel prices. Similarly, threats leads to lower prices overall, but there is evidence that they lead to higher cartel prices in PROFOUND. Past discoveries do lead to higher cartel prices in both leniency treatments.² Most importantly however, regardless of how we slice the data, we never find a significant direct effect of either leniency treatment on prices. Hence, we find no evidence whatsoever that leniency has any direct effect on prices.

4 Preferred specifications

For our study of cartel initiation, note that Tables 1 and 2 yield qualitatively similar outcomes. Yet, we prefer the Cox regressions in Table 2 as this specification most naturally captures what we are interested in. Also, as argued, it is preferred to use the specification in which we include all periods where there was no collusion at the start of the period in our analysis of the survival of competition. Hence, we prefer the analysis in column (4) in Table 2.

For each regression, we essentially use three different specifications: one with dummies for past events, one where we also interact those dummies with dummies for the leniency treatment, and one in which we include the interactions with all treatments. In terms of interpretation, we prefer the third specification. When we study cartel initiation and prices, we are interested in the effect of introducing leniency, i.e. we are interested in the effect of leniency relative to ANTITRUST. But if we study the effect of, say, past threats, it seems more natural and more interesting to look at the effect of past threats versus no past threats in a given treatment, rather than the effect of past threats in that treatment versus the effect of past threats in ANTITRUST. Hence, we prefer column (3) in Table 3 and columns (3), (6) and (9) in Table 4. Column (6) however does not add much to (3) and (9), so we prefer to drop that.

²We do not find a significant effect of past discoveries when we look at all prices (details available upon request).