# Asymmetric Information, Communication, and Cartel Instability[1]

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JEL CLASSIFICATION: L00, D82, C72
KEYWORDS: ASYMMETRIC INFORMATION, DEMAND FLUCTUATION, CARTEL STABILITY

APRIL 17, 2007

***THIS PAPER STUDIES THE EFFECT OF ASYMMETRIC INFORMATION ABOUT DEMAND ON CARTEL STABILITY. IN THIS MODEL, FIRMS IN A CARTEL FACE FLUCTUATING DEMAND IN A REPEATED GAME FRAMEWORK. IN EACH PERIOD, ONE FIRM KNOWS CURRENT DEMAND, AND IS EXPECTED TO COMMUNICATE THIS INFORMATION TO ITS PARTNERS. CARTELS ARE THEN UNSTABLE FOR TWO REASONS. FIRST, AS IS WELL KNOWN, WHEN DEMAND IS HIGH THE BENEFIT FROM CHEATING IS RELATIVELY LARGE COMPARED TO THE EXPECTED REWARDS OF FUTURE COOPERATION. SECOND, WHEN DEMAND IS HIGH, THE INFORMED FIRM CAN MISLEAD THE UNINFORMED FIRMS TO REDUCE OUTPUT RELATIVE TO THE ACTUAL STATE OF DEMAND. HOWEVER, IF THE INFORMED FIRM CHOOSES NOT TO SHARE THIS INFORMATION IN THE COLLUSIVE EQUILIBRIUM THEN CARTELS ARE AS STABLE AS WHEN THERE IS NO DEMAND FLUCTUATION.***

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[1]WE WOULD LIKE TO ACKNOWLEDGE USEFUL INSIGHTS RECEIVED FROM COL FRANCIS BUSH AND THE ANONYMOUS REFEREES FOR THE SEJ. THE USUAL CAVEAT APPLIES.

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# Asymmetric Information, Communication, and Cartel Instability

IN FACT, THIS LEAST CONTROVERSIAL AREA OF ANTITRUST MAY WELL BE THE ONE FOR WHICH ECONOMISTS HAVE THE LEAST SATISFACTORY THEORETICAL MODELS OF HOW ILLEGAL ACTIVITY – TALKING ABOUT PRICES (AND "REACHING AN AGREEMENT") MATTERS. – MICHAEL D. WHINSTON

## 1. INTRODUCTION

VERY LITTLE IS KNOWN ABOUT THE DETERMINANTS OF CARTEL STABILITY UNDER ASYMMETRIC INFORMATION. IN PARTICULAR, AS SUGGESTED IN THE ABOVE QUOTE WHINSTON (2006), EXTREMELY LITTLE IS KNOWN ABOUT THE ROLE OF COMMUNICATION IN CARTEL STABILITY. THIS PAPER EXAMINES A MODEL OF A CARTEL ATTEMPTING TO COORDINATE A COLLUSIVE AGREEMENT IN THE FACE OF ASYMMETRIC INFORMATION ABOUT MARKET DEMAND. WE SHOW THAT, IF THE CARTEL ATTEMPTS TO USE COMMUNICATION TO COORDINATE AROUND A "FAIR" COLLUSIVE AGREEMENT, THEN THE TEMPTATION OF INFORMED FIRMS TO LIE CAN GENERATE REALISTIC LEVELS OF CARTEL INSTABILITY.

ON THE OTHER HAND, IF THE CARTEL ABANDONS THE GOAL OF A FAIR ALLOCATION, AND ALLOWS INFORMED FIRMS TO UNILATERALLY RESPOND TO THEIR PRIVATE INFORMATION, THEN CARTELS CAN BE AS STABLE AS IF THERE ARE NO FLUCTUATIONS IN MARKET DEMAND AT ALL! THIS SUGGESTS THAT ASYMMETRIC INFORMATION ONLY POSES A CHALLENGE TO CARTEL INSTABILITY IF, FOR SOME REASON, MEMBERS OF THE CARTEL MUST COMMUNICATE THEIR PRIVATE INFORMATION IN ORDER TO IMPLEMENT THEIR AGREEMENT.

FOR EXAMPLE, SUPPOSE COMMUNICATION IS NECESSARY TO IMPLEMENT A FAIR ALLOCATION, AS IN THE CURRENT PAPER, OR AN EFFICIENT ALLOCATION, AS IN ATHEY AND BAGWELL (2001). THEN ASYMMETRIC INFORMATION CAN AGGRAVATE CARTEL INSTABILITY. ON THE OTHER HAND, IF COMMUNICATION IS NOT NECESSARY TO IMPLEMENT AN AGREEMENT, THEN DEMAND FLUCTUATIONS WHICH ARE PRIVATE INFORMATION MAY NOT AFFECT CARTEL STABILITY AT ALL.

IT IS WELL KNOWN THAT, IN INFINITELY REPEATED FRAMEWORKS, FIRMS CAN MAINTAIN COLLUSIVE AGREEMENTS IF THEY ARE SUFFICIENTLY PATIENT (FRIEDMAN, 1971, FUDENBERG AND MASKIN, 1986). IN THE STANDARD MODEL HOWEVER, COLLUSION IS VERY EASY. THAT IS, THE RATES OF RETURN ON INVESTMENTS IN COOPERATION ARE GENERALLY VERY LARGE, SO THEY FAR EXCEED ANY REALISTIC INTEREST RATE OR INTERNAL DISCOUNT RATE.[3] THE SIMPLEST MODELS THEREFORE ALLOW COLLUSION, EVEN WHEN THERE ARE MANY IMPATIENT FIRMS IN THE MARKET (LAMBSON, 1984, PECORINO, 1998). WHEN DEMAND FLUCTUATES RANDOMLY, WITH ALL FIRMS KNOWING CURRENT DEMAND, COLLUSION BECOMES LESS STABLE, BECAUSE FIRMS ARE INCLINED TO CHEAT WHEN CURRENT DEMAND IS HIGHER THAN EXPECTED FUTURE DEMAND (ROTEMBERG & SALONER, 1986). HOWEVER, THE RATE OF RETURN ON COLLUSION IS GENERALLY STILL VERY LARGE.

IN THESE MODELS COLLUSION IS EASY. THESE MODELS THEREFORE SEEM TO PREDICT GREATER CARTEL STABILITY THAN IS GENERALLY ACHIEVED. IT IS THEREFORE NOT CLEAR WHY FIRMS DO NOT

[3] EVEN WITH FINITE HORIZONS, THE INTRODUCTION OF A TINY AMOUNT OF IRRATIONALITY (E.G. WILLINGNESS TO ENGAGE IN TIT-FOR-TAT BEHAVIOR) MAKES COLLUSION EASY (RADNER 1980, KREPS ET AL. 1982, CONLON 1996, 2002).

ALWAYS COLLUDE.

THIS PAPER SHOWS THAT ASYMMETRIC INFORMATION CAN GENERATE POTENTIALLY MORE REALISTIC AMOUNTS OF CARTEL INSTABILITY *IF* FIRMS TRY TO SHARE THIS INFORMATION TO COORDINATE THEIR ACTIONS. WE MODEL AN INFINITELY REPEATED COURNOT GAME WITH $N$ FIRMS AND ASYMMETRIC INFORMATION ABOUT MARKET CONDITIONS. IN EACH PERIOD ONE FIRM KNOWS MORE ABOUT THE STATE OF DEMAND THAN THE OTHERS DO. HOWEVER, THE INFORMED FIRM CAN COMMUNICATE WITH THE UNINFORMED FIRMS, THROUGH A TRADE ASSOCIATION, FOR EXAMPLE (VIVES 1990). WE FOCUS ON EQUILIBRIA IN WHICH THE FIRMS COLLUDE. MOREOVER, THE INFORMED FIRM -- AS PART OF THE COLLUSIVE AGREEMENT -- TELLS THE UNINFORMED FIRMS ABOUT THE STATE OF DEMAND. THIS IS CONSISTENT WITH HAY AND KELLEY (1974) AND FRAAS AND GREER (1977), WHO FIND THAT COLLUSION IS OFTEN FACILITATED BY INFORMATION EXCHANGE, THROUGH A TRADE ASSOCIATION, OR SOME OTHER CHANNEL (SEE E.G. HAY AND KELLEY P. 21).

THUS, SUPPOSE THE INFORMED FIRM IS ALWAYS EXPECTED TO REPORT TO THE CARTEL. THE OBJECTIVE OF THIS COMMUNICATION IS TO ENSURE THAT ALL FIRMS GET AN EQUAL SHARE OF OUTPUT. NOW SAY DEMAND IS HIGH. IN THIS SITUATION IF THE INFORMED FIRM CHEATS ON THE CARTEL AGREEMENT THEN IT CAN TAKE ADVANTAGE OF A LARGER MARKET. IT CAN, HOWEVER, ALSO LIE TO THE UNINFORMED FIRMS AND TELL THEM THAT DEMAND IS LOW. THE UNINFORMED FIRMS THEN PRODUCE LESS, BELIEVING DEMAND TO BE LOW. ALL THIS INCREASES THE INFORMED FIRM'S NET PAYOFF FROM CHEATING RELATIVE TO THE REWARDS FROM FUTURE COOPERATION. THUS, COMMUNICATION

ENHANCES THE PAYOFF FROM CHEATING, AND SO, INCREASES CARTEL INSTABILITY.[4]

OF COURSE, THE INFORMED FIRM DOES NOT NEED TO COMMUNICATE. NOW, EVEN WHILE COLLUDING, THE INFORMED FIRM CAN TAKE FULL ADVANTAGE OF A LARGER MARKET WITHOUT HAVING TO CHEAT. THIS ENHANCES THE PAYOFF FROM COLLUDING RELATIVE TO CHEATING AND MAKES CARTELS MORE STABLE.

IN THIS PAPER, THEREFORE, COMMUNICATION (OR THE LACK THEREOF) PLAYS A CRUCIAL ROLE IN DETERMINING CARTEL STABILITY. THIS PAPER THEREFORE CONTRIBUTES TO A SMALL BUT GROWING LITERATURE ON THE CHALLENGES FACED BY CARTEL MEMBERS USING COMMUNICATION TO HELP THEM COORDINATE A COLLUSIVE AGREEMENT IN THE FACE OF ASYMMETRIC INFORMATION.

MAJOR PREVIOUS RESULTS IN THIS LITERATURE INCLUDE FOLK THEOREMS IN GENERAL REPEATED GAMES WITH COMMUNICATION (COMPTE, 1998, KANDORI AND MATSUSHIMA, 1998; SEE ALSO THE SYMPOSIUM ON REPEATED GAMES WITH ASYMMETRIC INFORMATION IN THE JANUARY 2002 ISSUE OF THE *JOURNAL OF ECONOMETRIC THEORY*). HOWEVER, FOLK THEOREMS FOCUS ON AGENTS WHOSE DISCOUNT FACTORS APPROACH ONE. THEY THEREFORE DO NOT ALLOW US TO STUDY THE EFFECT OF ASYMMETRIC INFORMATION ON COLLUSION BETWEEN FIRMS WHICH ARE VERY PATIENT, BUT WHOSE DISCOUNT FACTORS ARE BOUNDED AWAY FROM ONE.

PAPERS FOCUSING ON REPEATED GAME COLLUSION BETWEEN ASYMMETRICALLY INFORMED *FIRMS* INCLUDE AOYAGI (2002), ATHEY AND BAGWELL (2001), AND ATHEY, BAGWELL, AND SANCHIRICO

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[4]TECHNICALLY, WE CONSIDER A STRATEGY PROFILE IN WHICH THE INFORMED FIRM ALWAYS TELLS THE TRUTH. WE THEN ASK WHETHER THE STRATEGY PROFILE IS AN EQUILIBRIUM. UNDER ASYMMETRIC INFORMATION, THE INFORMED FIRM CAN LIE AS WELL AS CHEAT, SO THIS STRATEGY PROFILE IS ONLY AN EQUILIBRIUM IF FIRMS ARE VERY PATIENT.

(2001). AOYAGI (2002) CONSIDERS A BERTRAND-LIKE MODEL, WHERE FIRMS OBSERVE PRIVATE DEMAND SIGNALS *AFTER* CHOOSING THEIR OWN PRICES. THUS, COMMUNICATION IS NOT USED TO ADJUST PRODUCTION TO FLUCTUATIONS IN DEMAND, BUT ONLY TO HELP DISTINGUISH RANDOM DEMAND FLUCTUATIONS FROM SHIFTS DUE TO CHEATING BY COLLUSIVE PARTNERS. IN ATHEY AND BAGWELL (2001), COMMUNICATION HELPS CARTEL MEMBERS COORDINATE THEIR RESPONSES TO *COST* FLUCTUATIONS OBSERVED *BEFORE* CHOOSING PRICES, SO PRODUCTION CAN BE ALLOCATED TO LOW COST FIRMS. ATHEY, BAGWELL AND SANCHIRICO (2001) ALSO FOCUS ON COST FLUCTUATIONS, THOUGH THEY BRIEFLY CONSIDER PUBLICLY OBSERVED DEMAND FLUCTUATIONS AS WELL. IN ADDITION, THIS LATER PAPER DOES NOT ALLOW COMMUNICATION. FIRST OF ALL, NONE OF THESE PAPERS CONSIDER THE PROBLEM OF COORDINATING COLLUSIVE AGREEMENTS IN THE FACE OF ASYMMETRIC INFORMATION ABOUT DEMAND FLUCTUATIONS. SECOND, THEY DO NOT CONSIDER THE POSSIBILITY THAT THE ABILITY TO COMMUNICATE ITSELF MIGHT DETERMINE THE SUCCESS OR FAILURE OF A CARTEL BY COMPARING SITUATIONS WHERE A COMMUNICATION IS POSSIBLE TO WHERE COMMUNICATION IS NOT.

MOREOVER, THE ABOVE PAPERS FOCUS PRIMARILY ON THE PROBLEM OF HARD TO DETECT “ON SCHEDULE” DEVIATIONS, IN WHICH ONE TYPE OF PLAYER SIMPLY PRETENDS TO BE A DIFFERENT TYPE OF PLAYER. THUS, A PLAYER’S PRIVATE INFORMATION NEVER BECOMES PUBLIC IN THESE MODELS. WHILE THIS ASSUMPTION IS PLAUSIBLE FOR THE COST SHOCKS CONSIDERED BY ATHEY AND BAGWELL (2001) AND ATHEY BAGWELL AND SANCHIRICO (2001), THEY MAY BE LESS PLAUSIBLE FOR DEMAND SHOCKS. IN FACT, ATHEY, BAGWELL, AND SANCHIRICO (2001) CONSIDER FULLY *PUBLIC* DEMAND SHOCKS.

THIS PAPER, BY CONTRAST, FOCUSES ON COORDINATION IN THE FACE OF DEMAND FLUCTUATIONS WHERE INFORMATION IS INITIALLY PRIVATE BUT EVENTUALLY BECOMES PUBLIC. THIS

ALLOWS US TO FOCUS ON THE IMPLICATIONS OF ASYMMETRIC INFORMATION IN A CONTEXT WHERE THE ONLY DEVIATIONS CARTEL MEMBERS MUST WORRY ABOUT ARE EASIER TO DETECT "OFF SCHEDULE" DEVIATIONS. THUS WE CAN AVOID THE SIGNIFICANT TECHNICAL DIFFICULTIES INVOLVED IN THE IMPERFECT PRIVATE MONITORING LITERATURE. IN PARTICULAR, OUR PAPER DIFFERS FROM OTHERS BY MEASURING THE QUANTITATIVE IMPORTANCE OF ASYMMETRIC INFORMATION IN REDUCING CARTEL INSTABILITY AMONG FIRMS WITH DISCOUNT FACTORS BOUNDED AWAY FROM ONE.

NOTE ALSO THAT THE INFORMATION SHARING IN THIS PAPER IS DIFFERENT FROM THAT IN, E.G., VIVES (1984) AND RELATED PAPERS. IN THAT LITERATURE, INFORMATION IS VERIFIABLE, WHEREAS WE ARE ASSUMING THAT INFORMATION IN OUR MODEL IS NOT VERIFIABLE UNTIL THE NEXT PERIOD.[5] THUS, THE ONLY REASON WHY AN INFORMED FIRM WOULD TELL THE TRUTH IN OUR MODEL IS THE HOPE OF FUTURE COOPERATION. ON THE OTHER HAND, THE POSSIBILITY OF LYING ENHANCES THE INCENTIVE TO CHEAT.

THERE IS AN ONGOING DEBATE ABOUT THE EMPIRICAL PLAUSIBILITY OF THE ROTEMBERG-SALONER FRAMEWORK, WHICH IS THE STARTING POINT OF OUR ANALYSIS.[6] SOME OF THIS DEBATE CONCERNS THE BEHAVIOR OF CARTELS OVER THE BUSINESS CYCLE. HOWEVER, SINCE THE FOCUS OF OUR PAPER IS ON ASYMMETRIC INFORMATION ABOUT DEMAND FLUCTUATIONS, AND SINCE FIRMS ARE LIKELY

[5]AS SUGGESTED BY VIVES (1990, P. 414), THIS OTHER LITERATURE MUST ASSUME VERIFIABILITY SINCE OTHERWISE INFORMED FIRMS WILL ALWAYS GIVE IN TO THE TEMPTATION TO LIE. IN OUR MODEL, FIRMS MUST TELL THE TRUTH IF THEY WANT OTHER FIRMS TO TRUST THEM IN THE FUTURE.

[6]THIS LITERATURE INCLUDES PORTER (1983), ROTEMBERG AND SALONER (1986), DOMOWITZ, HUBBARD AND PETERSEN (1986), HAJIVASSILIOU (1989), TOWN (1991), ROTEMBERG AND WOODFORD (1992), ELLISON (1994), BORENSTEIN AND SHEPARD (1996), CHEVALIER AND SCHARFSTEIN (1996), AND SUSLOW (1998).

TO BE EQUALLY INFORMED ABOUT THE MACROECONOMY, WE ARE PRIMARILY CONCERNED WITH INDIVIDUAL MARKET FLUCTUATIONS UNCORRELATED WITH BUSINESS CYCLES. OF COURSE, THE IMPLICATIONS OF OTHER KINDS OF ASYMMETRIC INFORMATION WOULD BE AN IMPORTANT TOPIC OF FUTURE RESEARCH.

SECTION 2 DESCRIBES THE GAME. IT ALSO EXAMINES THE COLLUSIVE TRIGGER STRATEGY WITH INFORMATION SHARING AND DERIVES THE CRITICAL INTEREST RATE ABOVE WHICH COLLUSION BREAKS DOWN. SECTION 3 PRESENTS THREE PROPOSITIONS ABOUT THE STABILITY OF CARTELS UNDER ASYMMETRIC INFORMATION. PROPOSITION 2 SHOWS THAT ASYMMETRIC INFORMATION GENERALLY EXPLAINS MUCH MORE CARTEL INSTABILITY THAN DEMAND FLUCTUATIONS ALONE. NUMERICAL SIMULATIONS ARE USED TO HELP ILLUSTRATE THIS PROPOSITION. PROPOSITION 3 THEN SHOWS THAT COLLUSION BECOMES LESS STABLE AS DEMAND FLUCTUATIONS BECOME LARGER, AND PROPOSITION 4 SHOWS THAT COLLUSION BECOMES LESS STABLE AS THE DEMAND DISTRIBUTION BECOMES SKEWED TO THE RIGHT.[7] SECTION 4 PERFORMS SOME NUMERICAL SIMULATIONS TO FURTHER ILLUSTRATE THE EFFECT OF ASYMMETRIC INFORMATION ON CARTEL STABILITY. SECTION 5 LOOKS AT THE GAME DESCRIBED IN SECTION 2 WITHOUT INFORMATION SHARING. IN THIS SECTION, WE SHOW THAT IF A FIRM ALWAYS HAS MORE INFORMATION ABOUT THE STATE OF DEMAND THEN CARTELS ARE VERY STABLE IN SPITE OF DEMAND FLUCTUATIONS. SECTION 6 CONCLUDES.

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[7]THROUGHOUT WE ASSUME THE DEMAND CURVE HAS A TWO POINT (BERNOULLI) DISTRIBUTION. THUS, E.G. FOR A DISTRIBUTION TO BE SKEWED RIGHT MEANS THAT LOW DEMAND IS MORE LIKELY THAN HIGH DEMAND. IT WOULD BE INTERESTING TO ANALYZE THE CASE OF A MORE GENERAL DISTRIBUTION.

## 2. PAYOFFS AND CREDIBLE TRIGGER STRATEGIES WHEN INFORMATION IS SHARED

CONSIDER AN INFINITELY REPEATED $N$-FIRM COURNOT OLIGOPOLY, WHERE MARKET DEMAND IS EITHER HIGH OR LOW, WITH DEMAND FLUCTUATING INDEPENDENTLY ACROSS PERIODS. LET THE INVERSE MARKET DEMAND FUNCTION BE

$$P(Q) = A - Q$$

WHERE $A$ IS A RANDOM VARIABLE. IN THE HIGH DEMAND STATE THE INTERCEPT TERM IS $A_H$ AND IN THE LOW DEMAND STATE THE INTERCEPT TERM IS $A_L$, WITH $A_H > A_L$. THE DEMAND CURVES ARE LINEAR FOR SIMPLICITY. ALL FIRMS KNOW THAT THE PROBABILITY OF HIGH DEMAND IS $\phi$ AND THE PROBABILITY OF LOW DEMAND IS $1 - \phi$. IN EACH PERIOD ONE FIRM IS INFORMED AND $N - 1$ FIRMS ARE UNINFORMED. HOWEVER, ALL FIRMS KNOW $A_H$ AND $A_L$ – THOUGH UNINFORMED FIRMS DO NOT KNOW THE CURRENT STATE OF DEMAND. THE IDENTITY OF THE INFORMED FIRM FLUCTUATES INDEPENDENTLY FROM PERIOD TO PERIOD, WITH EACH FIRM EQUALLY LIKELY TO BE CHOSEN AS THAT PERIOD'S INFORMED FIRM. THE INFORMED FIRM IS TOLD CURRENT DEMAND BUT NOT FUTURE DEMAND. THE OTHER $N - 1$ FIRMS KNOW THE IDENTITY OF THE CURRENT INFORMED FIRM, BUT DO NOT KNOW CURRENT OR FUTURE DEMAND.[8] AS PART OF A COLLUSIVE AGREEMENT, THE FIRM THAT

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[8]THIS INFORMATION STRUCTURE IN THIS PART OF THE PAPER IS CHOSEN TO ALLOW FOR THE POSSIBILITY THAT DIFFERENT FIRMS ARE INFORMED IN DIFFERENT PERIODS. THUS, THERE IS NO "LEADING" FIRM WHICH ALWAYS INFORMS THE OTHERS.

THE INFORMATION STRUCTURE IS ALSO RESTRICTIVE IN OTHER WAYS. FOR EXAMPLE, TO THE EXTENT THAT DEMAND FLUCTUATIONS FOLLOW THE BUSINESS CYCLE, INFORMATION ABOUT THESE FLUCTUATIONS MAY TEND TO BE MORE SYMMETRIC. IT WOULD BE INTERESTING TO SEE WHETHER ANY NEW INSIGHTS COULD BE GAINED FROM THESE MORE COMPLICATED INFORMATION STRUCTURES.

HAPPENS TO BE INFORMED IN A PERIOD MAY CONVEY INFORMATION ABOUT THE STATE OF DEMAND TO THE OTHER FIRMS. HOWEVER, THE INFORMED FIRM MAY ALSO LIE TO THE OTHER FIRMS. ALL FIRMS LEARN PREVIOUS DEMAND. SO, ANY LYING BY THE INFORMED FIRM CAN BE DETECTED WITH A ONE PERIOD LAG.

NEXT, TO REDUCE NOTATION, ASSUME THAT PRODUCTION OF THE GOOD IS COSTLESS. WITH CONSTANT MARGINAL COST $C$, WE COULD REPLACE $A_H$ WITH $A_H - C$ AND $A_L$ WITH $A_L - C$ IN THE EQUATIONS BELOW. FINALLY, ASSUME THAT ALL FIRMS DISCOUNT USING THE DISCOUNT FACTOR 1/(1 $R$), WHERE $R$ IS THE INTEREST RATE.

CONSIDER A COLLUSIVE AGREEMENT IN WHICH THE INFORMED FIRM IN EACH PERIOD INFORMS THE OTHER FIRMS ABOUT THE STATE OF DEMAND -- THROUGH A TRADE ASSOCIATION, SAY. SPECIFICALLY CONSIDER THE FOLLOWING STRATEGY PROFILE. IN EACH PERIOD THE INFORMED FIRM TRUTHFULLY REVEALS THE STATE OF DEMAND TO THE OTHER FIRMS. THE FIRMS THEN DIVIDE THE MONOPOLY OUTPUT EQUALLY AMONG THEMSELVES. IF ANY FIRM DEVIATES IN ANY PERIOD, ALL FIRMS REVERT TO THE NON-COOPERATIVE ONE-SHOT EQUILIBRIUM FOR ALL PERIODS THEREAFTER. THE QUESTION IS THEN, FOR WHAT VALUES OF $R$ IS THE STRATEGY PROFILE AN EQUILIBRIUM. THE CARTEL IS THEN UNSTABLE IF THE STRATEGY PROFILE IS ONLY AN EQUILIBRIUM IF FIRMS ARE VERY PATIENT, I.E. $R$ IS VERY LOW.

PART A BELOW DETERMINES THE EXPECTED PER-PERIOD PAYOFF TO EACH OF THE FIRMS IF THEY COLLUDE. THE EXPECTED PAYOFFS DURING THE NON-COOPERATIVE PUNISHMENT PHASE ARE DERIVED IN PART B. PART C DERIVES THE ONE-PERIOD PAYOFF TO THE INFORMED FIRM GIVEN THAT IT LIES AND CHEATS ON THE COLLUSIVE AGREEMENT AT THE EXPENSE OF THE OTHERS WHEN DEMAND IS HIGH.

PART D DERIVES THE DISCOUNTED EXPECTED PAYOFF TO EACH FIRM OVER TIME AND THE CRITICAL INTEREST RATE ABOVE WHICH FULL COLLUSION IS NOT POSSIBLE.

## A. EXPECTED PAYOFFS PER PERIOD IF THE FIRMS COLLUDE

IF THE FIRMS COLLUDE, THE INFORMED FIRM IN EACH PERIOD TELLS THE UNINFORMED FIRMS THE STATE OF DEMAND AND TOGETHER THEY DIVIDE THE MONOPOLY OUTPUT AND PROFITS EQUALLY AMONG THEMSELVES. THUS, EACH FIRM PRODUCES $A_H/2N$ IN THE HIGH DEMAND STATE AND $A_L/2N$ IN THE LOW DEMAND STATE, SO THE PAYOFF TO EACH FIRM IS $A_H^2/4N$ IN THE HIGH DEMAND STATE AND $A_L^2/4N$ IN THE LOW DEMAND STATE. EXPECTED PER-PERIOD PAYOFF TO ANY FIRM IF THE COLLUSIVE AGREEMENT HOLDS IS THEREFORE

$$\pi^{COLL} = \phi(\frac{a_H^2}{4n}) + (1-\phi)(\frac{a_L^2}{4n}) , \tag{1}$$

WHERE THE SUPERSCRIPT $COLL$ STANDS FOR "COLLUSIVE".

## B. STRATEGIES AND EXPECTED PER PERIOD PAYOFFS IN THE PUNISHMENT PHASE

IF ANY FIRM DEVIATES FROM THE COLLUSIVE AGREEMENT THE INDUSTRY REVERTS TO A PERMANENT NON-COOPERATIVE PHASE.[9] IN THE PUNISHMENT PHASE THE FIRMS DO NOT

[9] NOTE THAT WE DO NOT USE OPTIMAL PUNISHMENT STRATEGIES OF THE SORT DISCUSSED IN ABREU (1986) OR ABREU, PIERCE AND STACHETTI (1986). IT WOULD BE INTERESTING TO EXTEND THE ANALYSIS OF OPTIMAL PUNISHMENT STRATEGIES TO ENVIRONMENTS SUCH AS THIS ONE, WITH ASYMMETRIC INFORMATION ABOUT GAME PAYOFF FUNCTIONS. HOWEVER, THIS WOULD ADD

COMMUNICATE SINCE THE UNINFORMED FIRMS NO LONGER TRUST THE INFORMED FIRMS. THUS, UNINFORMED FIRMS DO NOT KNOW DEMAND IN A PARTICULAR PERIOD, THOUGH THEY DO KNOW THE PROBABILITY OF HIGH OR LOW DEMAND IN ANY PERIOD. THIS YIELDS A BAYES-NASH EQUILIBRIUM IN EACH PERIOD. IN THIS EQUILIBRIUM THE QUANTITY PRODUCED BY EACH UNINFORMED FIRM IS GIVEN BY

$$q^{NC,U} = \frac{\phi(a_H - a_L) + a_L}{n+1}, \tag{2}$$

WHERE THE SUPERSCRIPT $NC$ STANDS FOR "NONCOOPERATIVE," AND $U$ STANDS FOR "UNINFORMED." THIS OUTPUT IS INDEPENDENT OF WHETHER DEMAND IS HIGH OR LOW, SINCE THE UNINFORMED FIRM DOES NOT KNOW THE STATE OF DEMAND.

WHEN DEMAND IS HIGH THE INFORMED FIRM PRODUCES

$$q_H^{NC,I} = \frac{(n+1)a_H - (n-1)[\phi(a_H - a_L) + a_L]}{2(n+1)}, \tag{3}$$

WHERE THE SUPERSCRIPT $I$ STANDS FOR "INFORMED." FINALLY, WHEN DEMAND IS LOW THE INFORMED FIRM PRODUCES

$$q_L^{NC,I} = \frac{(n+1)a_L - (n-1)[\phi(a_H - a_L) + a_L]}{2(n+1)}. \tag{4}$$

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CONSIDERABLE COMPLEXITY TO OUR ANALYSIS. ALSO, IT WOULD PROBABLY NOT CHANGE THE QUALITATIVE RESULTS MUCH. OUR RESULTS ARE DRIVEN BY THE INCREASED TEMPTATION TO CHEAT IN GAMES WHERE THE CHEATER CAN ALSO LIE ABOUT THE STATE OF THE WORLD, AND THIS EFFECT SHOULD REMAIN. NOTE THAT ATHEY AND BAGWELL (2001) ASSUME NASH REVERSION PUNISHMENTS IN THEIR NUMERICAL EXAMPLES. AOYAGI (2002) ALSO ASSUMES NASH REVERSION PUNISHMENT STRATEGIES.

USING $p_H = a_H - (n-1)q^{NC,U} - q_H^{NC,I}$ AND $p_L = a_L - (n-1)q^{NC,U} - q_L^{NC,I}$ SHOWS THAT THE MARKET PRICE IN THE PUNISHMENT PHASE WITH HIGH DEMAND IS $p_H = q_H^{NC,I}$, AND WITH LOW DEMAND, $p_L = q_L^{NC,I}$. THE EXPECTED PAYOFF TO AN UNINFORMED FIRM IN A GIVEN PERIOD OF THE PUNISHMENT PHASE IS THEREFORE GIVEN BY

$$\pi^{NC,U} = \phi q^{NC,U} p_H + (1-\phi) q^{NC,U} p_L \quad = \phi q^{NC,U} q_H^{NC,I} + (1-\phi) q^{NC,U} q_L^{NC,I} \tag{5}$$

AND THE EXPECTED PROFIT TO A FIRM IF IT IS INFORMED IS GIVEN BY

$$\pi^{NC,I} = \phi (q_H^{NC,I})^2 + (1-\phi)(q_L^{NC,I})^2. \tag{6}$$

NOW, IN ANY PERIOD, THERE IS A $1/N$ CHANCE OF A FIRM BEING INFORMED AND AN $(N-1)/N$ CHANCE OF IT BEING UNINFORMED. THEREFORE, THE EX ANTE EXPECTED PAYOFF TO THE FIRM IN THE PUNISHMENT PHASE, BEFORE IT KNOWS WHETHER IT IS INFORMED, IS GIVEN BY

$$\pi^{NC} = \frac{1}{n}\pi^{NC,I} + \frac{n-1}{n}\pi^{NC,U}. \tag{7}$$

## C. A LYING CHEATING INFORMED FIRM

IN EACH PERIOD THAT THE COLLUSIVE AGREEMENT IS SUPPOSED TO BE IN PLACE (INCLUDING THE ONE IN WHICH CHEATING OCCURS), THE INFORMED FIRM MAKES A STATEMENT TO THE UNINFORMED FIRMS ABOUT THE STATE OF THE MARKET. THE INFORMED FIRM MAY TELL THE TRUTH OR LIE, BUT THE UNINFORMED FIRMS BELIEVE THE INFORMED FIRM UNLESS THE AGREEMENT HAS BEEN BROKEN PREVIOUSLY.

WITH LOW DEMAND, THE INFORMED FIRM HAS LESS INCENTIVE TO CHEAT, AND SO LESS

INCENTIVE TO LIE. WE THEREFORE FOCUS ON THE HIGH DEMAND SITUATION. IF DEMAND IS HIGH, BUT THE INFORMED FIRM CHEATS, IT WILL ALSO TELL THE OTHER FIRMS THAT DEMAND IS LOW. THUS, THE UNINFORMED FIRMS PRODUCE THEIR SHARE OF THE LOW DEMAND MONOPOLY OUTPUT. THIS IS $A_L/2N$ PER FIRM, OR $(N-1)A_L/2N$ IN THE AGGREGATE.

THE INFORMED FIRM'S PROBLEM IS TO MAXIMIZE PROFITS GIVEN THIS OUTPUT OF THE UNINFORMED FIRMS. THUS, THE CHEATING INFORMED FIRM PRODUCES

$$q_H^{CH,I} = \frac{2na_H - (n-1)a_L}{4n}, \tag{8}$$

WHERE $CH$ STANDS FOR "CHEATING." THE PAYOFF TO THE CHEATING INFORMED FIRM IS THEN GIVEN BY

$$\pi_H^{CH,I} = (\frac{2na_H - (n-1)a_L}{4n})^2. \tag{9}$$

OF COURSE, THE UNINFORMED FIRMS CAN CHEAT TOO. HOWEVER, SINCE THEY CANNOT LIE OR TAKE ADVANTAGE OF HIGH DEMAND, THEIR TEMPTATION TO CHEAT IS LOWER THAN THE INFORMED FIRM'S. THUS THEY DO NOT AFFECT THE CRITICAL POINT AT WHICH COLLUSION BECOMES UNSTABLE.

## D. THE DECISION TO COOPERATE AND THE CRITICAL INTEREST RATE.

WE HAVE MODELED A SITUATION WHERE THE INFORMED FIRM MIGHT LIE AND CHEAT ON A COLLUSIVE AGREEMENT. IN THE EQUILIBRIUM WE ARE CONSIDERING, IF A FIRM CHEATS IN ONE PERIOD, THEN, STARTING IN THE NEXT PERIOD, ALL FIRMS FOREVER ENTER A NON-COOPERATIVE PHASE. IN THIS SECTION WE FIND THE MAXIMUM (CRITICAL) INTEREST RATE CONSISTENT WITH A CREDIBLE TRIGGER

STRATEGY THAT MAINTAINS FULL COLLUSION. IN OTHER WORDS WE CALCULATE THE RATE OF RETURN ON INVESTMENT IN COLLUSION FOR AN INFORMED FIRM IN A HIGH DEMAND STATE.

LET $R$ BE THE INTEREST RATE FIRMS USE TO CALCULATE THE PRESENT VALUE OF FUTURE PROFITS. THUS $R$ MEASURES THE PATIENCE OF A FIRM IN TERMS OF ITS WILLINGNESS TO WAIT FOR FUTURE PROFITS. THE HIGHER THE RATE OF INTEREST, THE LESS IMPORTANT IS THE FUTURE EXPECTED STREAM OF COLLUSIVE PROFITS AND THUS THE GREATER THE RELATIVE ALLURE OF CHEATING TODAY.

THE EXPECTED PAYOFF TO EACH FIRM IF COLLUSION IS MAINTAINED IN THIS AND ALL FUTURE PERIODS, GIVEN THAT CURRENT DEMAND IS HIGH, IS

$$\frac{a_H^2}{4n} + \frac{1}{r}\pi^{COLL} \tag{10}$$

WHERE $\pi^{COLL}$ IS DEFINED IN (1). EXPECTED PRESENT AND FUTURE PAYOFF TO A LYING, CHEATING, INFORMED FIRM, GIVEN THAT CURRENT DEMAND IS HIGH, IS

$$\pi_H^{CH,I} + \frac{1}{r}\pi^{NC} \tag{11}$$

WHERE $\pi_H^{CH,I}$ AND $\pi^{NC}$ ARE DEFINED IN (9) AND (7) RESPECTIVELY. THUS, THE INFORMED FIRM IS WILLING TO SUPPLY TRUTHFUL INFORMATION AND COOPERATE IF AND ONLY IF

$$\frac{a_H^2}{4n} + \frac{1}{r}\pi^{COLL} \geq \pi_H^{CH,I} + \frac{1}{r}\pi^{NC}. \tag{12}$$

THIS INEQUALITY REFLECTS THE FACT THAT, FOR A TRIGGER STRATEGY TO BE CREDIBLE, THE EXPECTED PRESENT DISCOUNTED PAYOFF FROM COLLUDING MUST BE GREATER THAN OR EQUAL TO THAT FROM

CHEATING. IT FOLLOWS THAT FULL COLLUSION IS POSSIBLE THROUGH THIS EQUILIBRIUM IF AND ONLY IF

$$r \leq r^*_{asym} = \frac{\pi^{COLL} - \pi^{NC}}{\pi_H^{CH,I} - \frac{a_H^2}{4n}} \tag{13}$$

WHERE $\pi^{COLL}$, $\pi^{NC}$, AND $\pi_H^{CH,I}$ ARE DEFINED IN (1), (7), AND (9), RESPECTIVELY. PROPOSITION 1 YIELDS A FORMULA FOR THE CRITICAL INTEREST RATE, $r^*_{asym}$. THE FORMAL PROOF IS IN THE APPENDIX.

***PROPOSITION 1. THE MAXIMUM INTEREST RATE CONSISTENT WITH A CREDIBLE TRIGGER STRATEGY WITH ASYMMETRIC INFORMATION IS***

$$r^*_{asym} = \frac{4n(n-1)[\phi(a_H - a_L) + a_L]^2}{(n+1)^2[n(2a_H - a_L)^2 - a_L^2]}. \tag{14}$$

THIS $r^*_{asym}$ IS THE MAXIMUM VALUE OF $R$ THAT WILL ALLOW OUR TRIGGER STRATEGY TO BE CREDIBLE. IN OTHER WORDS, $r^*_{asym}$ IS THE RATE OF RETURN ON FULL COOPERATION FOR THE SITUATION WHEN CHEATING IS MOST PROFITABLE (DEMAND IS HIGH, AND CHEATING FIRM INFORMED). ANY HIGHER VALUE OF $R$ WILL MAKE CHEATING RELATIVELY MORE ATTRACTIVE BY DISCOUNTING TOO MUCH THE EXPECTED FUTURE PROFITS FROM COLLUSION. THIS WOULD WEAKEN THE THREAT OF A TRIGGER STRATEGY. THUS, IF $r > r^*_{asym}$, THE FIRMS CANNOT MAINTAIN THE SYMMETRIC, JOINT-PROFIT MAXIMIZING LEVEL OF COLLUSION.

## 3. EFFECT OF INFORMATION ASYMMETRY, DEMAND VARIABILITY, AND SKEWNESS ON CARTEL STABILITY.

IN OUR MODEL THERE ARE TWO FACTORS THAT LEAD TO GREATER CARTEL INSTABILITY. THE FIRST FACTOR IS RANDOMLY FLUCTUATING DEMAND (ROTEMBERG AND SALONER, 1986). THE SECOND FACTOR IS THE TEMPTATION TO LIE TO TAKE ADVANTAGE OF ASYMMETRIC INFORMATION. TOGETHER, THESE FACTORS REDUCE THE RETURN TO COOPERATION MUCH MORE THAN DEMAND FLUCTUATIONS ALONE, AS SHOWN IN PROPOSITION 2. PROPOSITION 2 FOCUSES ON THE LIMITING CASE OF SMALL FLUCTUATIONS. PROPOSITION 3 AND 4 RETURN TO THE GENERAL CASE AND CONSIDER THE EFFECT OF THE SIZE AND DISTRIBUTION OF DEMAND FLUCTUATIONS. PROPOSITION 3 SHOWS THAT GREATER DEMAND VARIABILITY WILL ALWAYS INCREASE CARTEL INSTABILITY. PROPOSITION 4 SHOWS THAT CARTELS ALSO BECOME LESS STABLE AS HIGH DEMAND BECOMES LESS LIKELY RELATIVE TO LOW DEMAND, THAT IS, AS THE DEMAND DISTRIBUTION SKEWS TO THE RIGHT. THE FORMAL PROOFS OF THESE THREE PROPOSITIONS ARE IN THE APPENDIX.

***PROPOSITION 2. AS $A_H$ APPROACHES $A_L$, THE FRACTION OF THE FALL IN $r^*_{asym}$ ATTRIBUTABLE TO ASYMMETRIC INFORMATION APPROACHES THE PROPORTION***

$$\lim_{a_H \to a_L} \frac{r_{sym}^* - r_{asym}^*}{r_0^* - r_{asym}^*} = \frac{n+1}{2n-(n-1)\phi} . \tag{15}$$

***WHERE $r^*_0$ IS THE CRITICAL INTEREST RATE IN THE ABSENCE OF DEMAND FLUCTUATIONS, $r^*_{sym}$ IS THE CRITICAL INTEREST RATE WITH***

***SYMMETRIC (FULL) INFORMATION ABOUT CURRENT DEMAND, AND $r^*_{asym}$ IS THE CRITICAL INTEREST RATE WHEN THE INFORMATION STRUCTURE IS ASYMMETRIC.***

THE DENOMINATOR, $r_0^* - r^*_{asym}$, IN PROPOSITION 2 MEASURES THE TOTAL FALL IN THE CRITICAL INTEREST RATE DUE TO DEMAND FLUCTUATIONS AND ASYMMETRIC INFORMATION. THE NUMERATOR, $r^*_{sym} - r^*_{asym}$, MEASURES THE FALL IN THIS CRITICAL INTEREST RATE DUE TO ASYMMETRIC INFORMATION. THE RATIO THUS GIVES THE PROPORTION OF THE TOTAL FALL IN THIS CRITICAL RATE DUE TO ASYMMETRIC INFORMATION.

TABLE 1 SHOWS THE LIMITING PROPORTION OF THE FALL IN $r^*_{asym}$ DUE TO ASYMMETRIC INFORMATION, FOR A WIDE RANGE OF PARAMETER VALUES. FIRST, FOR MOST VALUES OF $\phi$ AND $N$, INFORMATION ASYMMETRY EXPLAINS MUCH MORE CARTEL INSTABILITY THAN DEMAND FLUCTUATIONS ALONE. THUS, WHILE UNCERTAINTY ALONE MIGHT NOT EXPLAIN MUCH CARTEL INSTABILITY, UNCERTAINTY PLUS ASYMMETRIC INFORMATION MAY GO A LONG WAY TOWARDS EXPLAINING WHY CARTELS ARE NOT UNIFORMLY SUCCESSFUL.

**[INSERT TABLE 1 HERE]**

NOTICE THAT AS $\phi$ RISES, THE PROPORTION OF THE FALL IN $r^*_{asym}$ DUE TO ASYMMETRIC INFORMATION RISES. IN FACT, ACCORDING TO PROPOSITION 2, WHEN $\phi = 1$, ASYMMETRIC INFORMATION IS THE ONLY REASON $r^*_{asym}$ FALLS. ON THE OTHER HAND, AS CARTELS BECOME BIGGER ( $N$ GROWS), ASYMMETRIC INFORMATION FALLS RELATIVELY IN IMPORTANCE.

WE NOTED EARLIER THAT THERE WERE TWO REASONS WHY GREATER DEMAND FLUCTUATIONS LEAD TO A FALL IN THE CRITICAL INTEREST RATE $r^*_{asym}$. FIRST, THE BENEFIT FROM CHEATING TODAY RISES COMPARED TO THE EXPECTED BENEFITS OF FUTURE COOPERATION, EVEN WHEN THERE IS NO INFORMATIONAL ASYMMETRY. THIS IS THE POINT MADE BY ROTEMBERG AND SALONER (1986). SECOND, WITH ASYMMETRIC INFORMATION, THE INFORMED FIRM IS TEMPTED TO LIE TO THE UNINFORMED FIRMS ABOUT THE STATE OF DEMAND. Now, as $\phi$ rises, the expected reward to future cooperation rises relative to cheating profits, which reduces the first reason to cheat.[10] THUS, AS $\phi$ RISES, LESS OF THE FALL IN $r^*_{asym}$ IS ATTRIBUTABLE TO THE FIRST REASON (ROTEMBER AND SALONER, 1986) FOR CHEATING. THIS LEAVES ONLY THE SECOND REASON, I.E. THE INFORMED FIRM'S ABILITY TO LIE UNDER ASYMMETRIC INFORMATION. ULTIMATELY, IF HIGH DEMAND IS ALMOST CERTAIN, $r^*_{asym}$ FALLS BELOW $r^*_0$ ONLY BECAUSE THE INFORMED FIRM CAN LIE. THUS LYING COULD BE A POWERFUL REASON FOR CARTEL INSTABILITY WHEN INFORMATION IS SHARED.

ASYMMETRIC INFORMATION LOSES ITS' POWER TO EXPLAIN CARTEL INSTABILITY AS THE NUMBER OF FIRMS RISE IN A CARTEL. THIS IS NOT SURPRISING. NEVERTHELESS, EVEN WHEN $N$ IS VERY LARGE, ASYMMETRIC INFORMATION ALWAYS EXPLAINS AT LEAST THE FRACTION $1/(2-\phi)$ OF THE FALL IN $R^*$, ACCORDING TO THE APPROXIMATION IN PROPOSITION 2. NOTE THAT THIS FRACTION EXCEEDS ONE HALF FOR ALL $\phi > 0$. THUS, EVEN IN EXTREME CASES, ASYMMETRIC INFORMATION EXPLAINS AT LEAST HALF OF

[10] THIS EFFECT IS EXAMINED FURTHER IN PROPOSITION 4.

THE FALL IN $r^*_{asym}$ IN THE LIMIT.

FINALLY, WE RETURN TO THE GENERAL CASE, WITH $A_H$ NOT APPROACHING $A_L$, AND PROVE TWO ADDITIONAL PROPOSITIONS WHICH FURTHER ILLUMINATE THE BEHAVIOR OF THE THRESHOLD $r^*_{asym}$.

PROOFS ARE AGAIN IN THE APPENDIX.

***PROPOSITION 3. FOR A GIVEN PROBABILITY OF HIGH DEMAND, CARTELS BECOME LESS STABLE AS DEMAND BECOMES MORE VARIABLE; I.E. IF $A_H/A_L$ RISES, $r^*_{asym}$ FALLS.***

AS SUGGESTED BY ROTEMBERG AND SALONER (1986), WHEN THE INFORMED FIRM KNOWS THAT DEMAND IS HIGH, IT WILL BE MORE TEMPTED TO CHEAT. THIS IS BECAUSE IT KNOWS THAT THE BENEFIT FROM CHEATING TODAY IS RELATIVELY LARGE COMPARED TO THE EXPECTED REWARDS OF FUTURE COOPERATION. THE RELATIVE BENEFIT FROM CHEATING IN THE HIGH DEMAND STATE, OF COURSE, GOES UP IF THE SIZE OF THE FLUCTUATION INCREASES, WHICH IS PART OF WHAT DRIVES PROPOSITION 3. MOREOVER, WHEN THE INFORMED FIRM CHEATS IN THE HIGH DEMAND STATE, IT TELLS THE OTHER FIRMS THAT DEMAND IS LOW. THUS, IF THE DIFFERENCE BETWEEN THE HIGH AND LOW DEMAND STATES IS LARGE, THE INFORMED FIRM CAN LEAD THE UNINFORMED FIRMS TO REDUCE OUTPUT A LOT RELATIVE TO THE

STATE OF DEMAND. THIS FURTHER INCREASES THE TEMPTATION TO CHEAT.

*PROPOSITION 4. CARTELS BECOME MORE STABLE AS THE PROBABILITY OF HIGH DEMAND RISES; I.E.* $DR^{*}/D\phi$ *0.*

AGAIN, AS IN ROTEMBERG AND SALONER (1986), WHEN THE INFORMED FIRM KNOWS THAT DEMAND IS HIGH TODAY, IT KNOWS THAT THE BENEFIT TO CHEATING TODAY IS LARGE COMPARED TO THE EXPECTED REWARDS OF FUTURE COOPERATION. HOWEVER, AS THE PROBABILITY OF HIGH DEMAND GOES UP, THE EXPECTED FUTURE REWARDS OF COOPERATING GO UP, WITHOUT AFFECTING THE BENEFIT OF CHEATING TODAY. THIS TENDS TO MAKE COOPERATION MORE STABLE.

## 4. SIMULATIONS

THIS SECTION REPORTS SOME SIMPLE NUMERICAL CALCULATIONS TO FURTHER ILLUSTRATE THE POTENTIAL QUANTITATIVE IMPORTANCE OF INFORMATIONAL ASYMMETRIES. AS MENTIONED ABOVE, THE $A$ PARAMETERS CAN BE INTERPRETED AS $A_H - C$ AND $A_L - C$, FOR THE CASE IN WHICH THE MARGINAL COST IS A NON-ZERO CONSTANT $C$. THE RELEVANT MEASURE OF DEMAND FLUCTUATIONS IS THEN $(A_H - C)/(A_L - C)$, WHICH WE CALL THE "FLUCTUATION RATIO."

TO GET A SENSE OF WHAT THIS FLUCTUATION RATIO MEANS, NOTE THAT, FOR A DEMAND INTERCEPT $A$, AND MARGINAL COST $C$, THE MARKUP OF PRICE OVER MARGINAL COST IS $(A - C)/2$. THUS,

WHEN THE FLUCTUATION RATIO IS 2.00, THIS MEANS THAT, IF WE MOVE FROM THE LOW DEMAND STATE TO THE HIGH DEMAND STATE, THE MONOPOLY MARKUP OVER MARGINAL COST DOUBLES. THE TABLES BELOW REPORT THE CRITICAL INTEREST RATE FOR VARIOUS VALUES OF THIS RATIO, AND VARIOUS VALUES FOR THE TOTAL NUMBER OF FIRMS, $N$. WE ASSUME BELOW THAT THE PROBABILITY, $\phi$, OF THE HIGH DEMAND STATE IS $\phi$ 0.50. TABLE 2 REPORTS THE CRITICAL INTEREST RATES FOR THE *SYMMETRIC* INFORMATION CASE IN WHICH ALL FIRMS KNOW THE STATE OF CURRENT DEMAND (ROTEMBERG AND SALONER 1986; SEE ALSO THE DERIVATION IN THE PROOF OF PROPOSITION 2 IN THE APPENDIX). TABLE 3 REPORTS THE CRITICAL INTEREST RATES FOR THE ASYMMETRIC INFORMATION CASE.[11]

**[PLEASE PLACE TABLES 2 AND 3 HERE]**

TO INTERPRET THESE TABLES, NOTE THAT, WHETHER THE INTEREST RATE IS ANNUAL OR SEMIANNUAL, SAY, DEPENDS ON THE PRODUCTION PERIOD AND/OR SEASONAL DEMAND PATTERNS. THUS, IF DEMAND HAS A STEEP SEASONAL PATTERN, DUE TO HIGH CHRISTMAS SALES, FOR EXAMPLE, THEN WE CAN INTERPRET OUR PERIODS AS YEARS. FOR OTHER INDUSTRIES, A PERIOD MIGHT BE SIX MONTHS OR THREE MONTHS OR WHATEVER. IN THESE CASES A GIVEN $R$ FROM THE TABLE MIGHT REPRESENT AN ANNUAL INTEREST RATE WHICH IS ROUGHLY TWO TIMES LARGER (FOR SIX MONTH PERIODS) OR FOUR TIMES LARGER (FOR THREE MONTH PERIODS) AND SO ON.

NOW, THE FIRST ROWS OF TABLES 2 AND 3 SHOW THAT, IN THE ABSENCE OF DEMAND

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[11]ONE PROBLEM HERE IS THAT, IF THE NUMBER OF FIRMS AND THE FLUCTUATION RATIOS ARE BOTH LARGE, THE NON-COOPERATIVE PUNISHMENT STRATEGY DERIVED IN SECTION 2B ABOVE REQUIRES THE INFORMED FIRM TO PRODUCE A NEGATIVE QUANTITY WHEN DEMAND IS LOW. WHEN THIS HAPPENS, WE SOLVE THE MODEL AGAIN SUBJECT TO THE CONSTRAINT THAT THE INFORMED FIRM CANNOT PRODUCE NEGATIVE AMOUNTS. THE CALCULATIONS ARE OMITTED, SINCE THEY ADD NO NEW INSIGHTS, THOUGH THEY ARE AVAILABLE UPON REQUEST. THE INTEREST RATES MARKED WITH AN ASTERISK HAVE BEEN CALCULATED WITH THIS CONSTRAINT BINDING.

FLUCTUATIONS ($A_H$ $A_L$), EVEN RELATIVELY LARGE CARTELS ARE EXTREMELY STABLE. EVEN WITH 10 FIRMS IN THE INDUSTRY, FOR EXAMPLE, FULL COLLUSION IS POSSIBLE WITH AN INTEREST RATE OF 33%. THUS, THE QUESTION CEASES TO BE "HOW ARE CARTELS POSSIBLE" AND BECOMES, "WHY AREN'T MORE INDUSTRIES CARTELIZED?"

THE OTHER ROWS OF TABLE 2 PROVIDE A POSSIBLE *PARTIAL* EXPLANATION FOR THIS PHENOMENON. FLUCTUATIONS IN DEMAND PUT PRESSURE ON COLLUSIVE AGREEMENTS. THAT IS, DEMAND FLUCTUATIONS LOWER THE CRITICAL INTEREST RATE, AND SO, MAKE COLLUSION SOMEWHAT MORE DIFFICULT. FOR A TWO-FIRM CARTEL, A FLUCTUATION RATIO OF 2 YIELDS A CRITICAL INTEREST RATE OF ABOUT 35.6%, A DROP OF 53.3 PERCENTAGE POINTS FROM THE CRITICAL INTEREST RATE CORRESPONDING TO NO FLUCTUATIONS. WHEN THERE ARE TEN FIRMS IN THE INDUSTRY, THE CRITICAL RATE FALLS LESS DRAMATICALLY, FROM 33.0% TO 20.7%, OR 12.3 PERCENTAGE POINTS. THUS, EVEN WITH LARGE FLUCTUATIONS IN DEMAND, RELATIVELY LARGE CARTELS REMAIN SURPRISINGLY STABLE. DEMAND FLUCTUATIONS BY THEMSELVES ARE THEREFORE INCAPABLE OF EXPLAINING PLAUSIBLE LEVELS OF CARTEL INSTABILITY.

INTRODUCING *ASYMMETRIC* INFORMATION, HOWEVER, AS IN TABLE 3, DRAMATICALLY INCREASES CARTEL INSTABILITY. THUS, WITH A FLUCTUATION RATIO OF 2 AND *SYMMETRIC* INFORMATION, A FIVE-FIRM CARTEL CAN MAINTAIN A COLLUSIVE AGREEMENT WITH AN INTEREST RATE OF 35%. HOWEVER, IF WE ADD ASYMMETRIC INFORMATION, WITH THE SAME FLUCTUATION RATIO, THE MAXIMUM INTEREST RATE CONSISTENT WITH FULL COLLUSION FALLS TO 11.4%. THIS UNDERSCORES THE POTENTIAL OF ASYMMETRIC INFORMATION TO EXPLAIN CARTEL INSTABILITY. ONCE WE MOVE TO ASYMMETRIC INFORMATION, DEMAND FLUCTUATIONS HAVE THE POTENTIAL TO DRAMATICALLY INCREASE

CARTEL INSTABILITY. THE REASON, AS SUGGESTED ABOVE, IS THAT THE TEMPTATION TO CHEAT IS GREATEST WHEN DEMAND IS HIGH, AND IN THIS SITUATION, THE CHEATING FIRM CAN ALSO LIE TO MISLEAD THE OTHER FIRMS INTO THINKING THAT DEMAND IS LOW.

OF COURSE, THESE CALCULATIONS ASSUME VERY SPECIFIC FORMS FOR THE DEMAND CURVES, COSTS, AND INFORMATION STRUCTURE. IN ADDITION, IT WOULD BE INTERESTING TO COMPARE THESE FLUCTUATION RATIOS TO DEMAND FLUCTUATIONS IN VARIOUS ACTUAL MARKETS. FINALLY, THE DEMAND FLUCTUATIONS HERE MUST BE UNDERSTOOD AS THOSE WHICH THE UNINFORMED FIRMS CANNOT PREDICT. THE UNPREDICTABLE COMPONENTS OF DEMAND FLUCTUATIONS WILL GENERALLY BE SMALLER THAN THE TOTAL FLUCTUATIONS IN DEMAND. NEVERTHELESS, EVEN WITH SMALLER FLUCTUATION RATIOS OF 1.4 AND 1.6, ASYMMETRIC INFORMATION HAS A SIGNIFICANT POTENTIAL TO EXPLAIN WHY SUCCESSFUL CARTELS ARE NOT A UNIVERSAL PHENOMENON.

## 5. CARTEL STABILITY WHEN THE INFORMED FIRM DOES NOT COMMUNICATE

IN THIS SECTION WE SHOW THAT, IF THE INFORMED FIRM DOES NOT SHARE ITS KNOWLEDGE OF DEMAND, THEN CARTELS ARE VERY STABLE. THIS HAPPENS FOR TWO REASONS. FIRST, COLLUSION BECOMES MORE LIKELY WHEN THE INFORMED FIRM CAN TAKE ADVANTAGE OF ITS KNOWLEDGE WITHOUT HAVING TO CHEAT. SECOND, BY NOT SHARING INFORMATION THE KNOWLEDGEABLE FIRM DOES NOT HAVE THE TEMPTATION TO LIE.

WE CONSIDER AN EQUILIBRIUM WHERE FIRMS DO NOT COMMUNICATE IN THE GAME DESCRIBED IN SECTION 2. SPECIFICALLY, ONE FIRM ALWAYS KNOWS THE STATE OF DEMAND WHILE THE OTHER FIRMS

DO NOT. WHILE COLLUDING THE UNINFORMED FIRMS PRODUCE A SHARE OF OUTPUT ( $q_j^U$ ) BASED ON EXPECTED DEMAND WHILE THE INFORMED FIRM PRODUCES A SHARE OF OUTPUT BASED ON ACTUAL DEMAND.

PART A DETERMINES THE COLLUSIVE PAYOFFS TO THE INFORMED AND THE UNINFORMED FIRMS. PART B DETERMINES THE EXPECTED PAYOFFS TO THE INFORMED FIRM AND THE UNINFORMED FIRM IF THEY CHEAT. PART C DERIVES THE PUNISHMENT PAYOFFS TO THE INFORMED AND UNINFORMED FIRMS. PART D OBTAINS THE CREDIBLE TRIGGER STRATEGY FOR WHICH BOTH THE INFORMED AND THE UNINFORMED FIRMS WILL NOT CHEAT AS A FUNCTION OF $q_j^u$. THIS DERIVATION ALLOWS US TO PRESENT PROPOSITION 5, WHICH PROVES THAT IF THE INFORMED FIRM CHOOSES NOT TO COMMUNICATE THEN CARTELS ARE AS STABLE AS WHEN THERE ARE NO DEMAND FLUCTUATIONS.

## A. EXPECTED PER PERIOD PAYOFFS WHEN FIRMS COLLUDE

IF THE FIRMS COLLUDE THEN THE INFORMED FIRM MAKES A PRODUCTION DECISION BASED ON HER KNOWLEDGE OF THE STATE OF DEMAND WHILE THE UNINFORMED FIRMS PRODUCES $q_j^U$. WHEN DEMAND IS HIGH THE INFORMED FIRM MAXIMIZES INDUSTRY PROFITS BY PRODUCING $a_H/2-(n-1)q_j^U$. THE MARKET PRICE IN THIS CASE IS $a_H/2$. THUS, THE PAYOFF TO THE INFORMED FIRM GIVEN HIGH DEMAND IS

$$\pi_H^{COLL,AI} = (\frac{a_H}{2} - (n-1)q_j^U)\frac{a_H}{2}. \tag{16}$$

THE SUPERSCRIPT COLL STAND FOR “COLLUSIVE,” AND THE SUPERSCRIPT AI STANDS FOR “ALWAYS INFORMED.” THE OTHER SUPERSCRIPTS AND SUBSCRIPTS HAVE BEEN DEFINED ABOVE.

SIMILARLY, IN THE LOW DEMAND CASE THE INFORMED FIRM PRODUCES $a_L/2-(n-1)q_j^U$. THE

MARKET PRICE IN THIS CASE IS $a_L/2$ . THUS THE PAYOFF TO THE INFORMED FIRM FROM COLLUDING WHEN DEMAND IS LOW IS

$$\pi_L^{COLL,AI} = (\frac{a_L}{2} - (n-1)q_j^U)\frac{a_L}{2}. \tag{17}$$

EQUATIONS (16) AND (17) IMPLY THAT THE EXPECTED PER PERIOD PAYOFF TO THE INFORMED FIRM FROM COLLUDING IS

$$\pi^{COLL,AI} = \phi\pi_H^{COLL,AI} + (1-\phi)\pi_L^{COLL,AI} \tag{18}$$

THE UNINFORMED COLLUDING FIRM NEVER KNOWS IF DEMAND IS HIGH OR LOW. WHEN COLLUDING IT MERELY AGREES TO PRODUCE $q_j^U$ . THE EXPECTED PER PERIOD PAYOFF TO THE UNINFORMED FIRM IS

$$\pi^{COLL,AU} = \phi q_j^U \frac{a_H}{2} + (1-\phi)q_j^U \frac{a_L}{2} \tag{19}$$

WHERE THE SUBSCRIPT AU STANDS FOR "ALWAYS UNIFORMED."

## B. CHEATING PAYOFFS

WE FOCUS HERE ONLY ON THE HIGH DEMAND SITUATION BECAUSE, OTHER THINGS EQUAL, THE INCENTIVE TO CHEAT IS HIGHER WHEN DEMAND IS HIGH. THUS, THE INFORMED FIRM TRIES TO MAXIMIZE CURRENT PROFITS GIVEN THAT THE UNINFORMED FIRMS CONTINUE TO PRODUCE $q_j^U$ . THE INFORMED FIRM PRODUCES $(a_H - (n-1)q_j^U)/2$ . THE MARKET PRICE THEN TURNS OUT TO BE EQUAL TO THIS QUANTITY. THUS THE CHEATING PAYOFF TO THE INFORMED FIRM IS

$$\pi_H^{CH,AI} = \left(\frac{(a_H - (n-1)q_j^U}{2}\right)^2. \tag{20}$$

THE SUPERSCRIPT CH REFERS TO "CHEATING." ALL THE OTHER SUPERSCRIPTS AND SUBSCRIPTS ARE DEFINED ABOVE.

UNINFORMED FIRMS MIGHT CHEAT EVEN THOUGH THEY HAVE NO INFORMATIONAL ADVANTAGE. A CHEATING UNINFORMED FIRM ASSUMES THAT THE INFORMED FIRM AND THE OTHER UNINFORMED FIRMS WILL CONTINUE TO STICK TO THE COLLUSIVE STRATEGY PROFILE. MOREOVER, THE UNINFORMED FIRM MAKES PRODUCTION DECISIONS ON THE BASIS OF EXPECTED DEMAND. THUS THE UNINFORMED CHEATING FIRM PRODUCES AN OUTPUT $(\phi(a_H - a_L) + a_L + 2q_j^U)/4$ . THE EXPECTED PRICE TURNS OUT TO BE EQUAL TO ITS OUTPUT. THUS, THE EXPECTED CHEATING PAYOFF TO THE UNINFORMED FIRM IS

$$\pi^{CH,AU} = \left( \frac{\phi(a_H - a_L) + a_L + 2q_j^U}{4} \right)^2 . \tag{21}$$

THE SUPERSCRIPTS AND SUBSCRIPTS HAVE ALREADY BEEN DEFINED ABOVE.

## C. PUNISHMENT PAYOFFS

IN THE PUNISHMENT PHASE BOTH TYPES OF FIRM REVERT TO THE ASYMMETRIC INFORMATION COURNOT EQUILIBRIUM. THUS THE PAYOFFS IN THE PUNISHMENT PHASE ARE THE SAME AS THE PAYOFFS PRESENTED IN SECTION 2 B, EXCEPT THAT THE IDENTITY OF THE INFORMED FIRM NEVER CHANGES.

## D. THE TRIGGER STRATEGY THAT ENSURES COOPERATION

WE CONTINUE TO CONSIDER AN EQUILIBRIUM WHERE, IF A FIRM CHEATS IN ONE PERIOD, THEN, ALL FIRMS PRODUCE THE COURNOT OUTPUT FOREVER AFTERWARDS. WITH THIS IN MIND WE DERIVE THE RATE OF RETURN ON INVESTMENT IN COLLUSION FOR FIRST THE INFORMED AND THEN THE UNINFORMED FIRM. THE INFORMED FIRM WILL HAVE THE GREATEST INCENTIVE TO CHEAT IN THE HIGH DEMAND PHASE. THUS, WE DERIVE THE RETURN ON INVESTMENT IN COLLUSION FOR THE INFORMED FIRM IN THE HIGH DEMAND STATE. THE UNINFORMED FIRM, OF COURSE, DOES NOT KNOW THE STATE OF DEMAND. THE RATE

OF RETURN FROM COLLUSION TO THE UNINFORMED FIRM IS THUS CALCULATED ON THE BASIS OF EXPECTED DEMAND IN ANY GIVEN PERIOD.

WE CONTINUE TO DESIGNATE $R$ AS THE INTEREST RATE USED BY FIRMS IN THIS MODIFIED GAME TO DISCOUNT FUTURE PAYOFFS. HOWEVER, WE WILL DESIGNATE $R_I{}^*$ AS THE RETURN ON COLLUSION TO THE INFORMED FIRM AND $R_U{}^*$ AS THE RETURN ON COLLUSION TO THE UNINFORMED FIRM. THE INFORMED FIRM CHEATS ONLY IF THE MARKET INTEREST RATE IS HIGHER THAN $R_I{}^*$. THE UNINFORMED FIRM CHEATS ONLY IF THE MARKET INTEREST RATE IS HIGHER THAN $R_U{}^*$. NOW, $R_U{}^*$ RISES AND $R_I{}^*$ FALLS AS THE QUANTITY SHARE OF THE OUTPUT PRODUCED BY EACH UNINFORMED FIRM, $q_j^u$, RISES. THUS, WHEN $R^*$ $R_U{}^*$ $R_I{}^*$ THEN BOTH THE INFORMED AND THE UNINFORMED FIRMS CHEAT. WE DERIVE $R_I{}^*$ AND $R_U{}^*$ BELOW. PROPOSITION 5 YIELDS A FORMULA FOR THIS CRITICAL INTEREST RATE $R^*$.

THE INFORMED FIRM'S EXPECTED DISCOUNTED PAYOFF FROM COLLUDING, GIVEN THAT CURRENT DEMAND IS HIGH, IS

$$\pi_H^{COLL,AI} + \frac{1}{r_I}\pi^{COLL,AI} \tag{22}$$

WHERE $\pi_H^{COLL,AI}$ AND $\pi^{COLL,AI}$ ARE DEFINED IN EQUATIONS (16) AND (18) RESPECTIVELY. THE EXPECTED PRESENT AND FUTURE PAYOFFS TO A CHEATING INFORMED FIRM IS

$$\pi_H^{CH,AI} + \frac{1}{r_I}\pi^{NC,I} \tag{23}$$

WHERE $\pi_H^{CH,AI}$ AND $\pi^{NC,I}$ ARE DEFINED IN EQUATIONS (20) AND (6) RESPECTIVELY. THE INFORMED FIRM WILL COOPERATE ONLY IF

$$r_I \le r_I{}^* = \frac{\pi^{COLL,AI} - \pi^{NC,I}}{\pi_H^{CH,AI} - \pi_H^{COLL,AI}}. \tag{24}$$

THE UNINFORMED FIRMS' EXPECTED DISCOUNTED PAYOFF FROM COLLUDING IS

$$\pi^{COLL,AU} + \frac{1}{r_U}\pi^{COLL,AU} \tag{25}$$

WHERE $\pi^{COLL,AU}$ IS DEFINED IN EQUATION (19). THE UNINFORMED FIRMS EXPECTED CURRENT AND FUTURE PAYOFF FROM CHEATING IS

$$\pi^{CH,AU} + \frac{1}{r_U}\pi^{NC,U} \tag{26}$$

WHERE $\pi^{CH,AU}$ AND $\pi^{NC,U}$ ARE DEFINED IN EQUATIONS (19) AND (5) RESPECTIVELY. THE UNINFORMED FIRM WILL COOPERATE ONLY IF

$$r_U \le r_U{}^* = \frac{\pi^{COLL,AU} - \pi^{NC,U}}{\pi^{CH,AU} - \pi^{COLL,AU}} \tag{27}.$$

NOTE THAT THE NUMERATOR IN EQUATIONS (24) AND (27) REPRESENT THE FUTURE RETURN FROM COLLUSION AND THE DENOMINATOR IN THOSE EQUATIONS REPRESENT THE CURRENT GAIN FROM CHEATING. THUS $R_U{}^*$ REPRESENTS THE RETURN TO COLLUSION FOR THE UNINFORMED FIRM WHILE $R_I{}^*$ REPRESENTS THE RETURN TO COLLUSION FOR THE INFORMED FIRM. EQUATIONS (24) AND (27) MERELY REFLECT THE IDEA THAT COLLUDING IS PREFERRED ONLY IF THE RETURN TO COLLUDING IS HIGHER THAN THE MARKET INTEREST RATE.

NOTICE FURTHER THAT $R_U{}^*$ AND $R_I{}^*$ ARE FUNCTIONS OF $Q_L^U$. IF THE UNINFORMED FIRM IS ALLOWED TO PRODUCE A GREATER SHARE OF THE PROFIT MAXIMIZING OUTPUT IN THE COLLUSIVE EQUILIBRIUM, I.E. $Q_L^U$ RISES, THEN THE INFORMED FIRM WILL HAVE A GREATER INCENTIVE TO CHEAT SINCE THE COLLUSIVE EQUILIBRIUM IS BECOMING LESS ATTRACTIVE. ON THE OTHER HAND AS $Q_L^U$ RISES THE UNINFORMED FIRMS HAVE LESS OF AN INCENTIVE TO CHEAT. THUS WHEN $R^{*U}$ $R^{*I}$ $R^*$, BOTH FIRMS WILL HAVE THE HIGHEST INCENTIVE TO CHEAT.

SETTING $q_j^U = (\phi(a_H - a_L) + a_L)/2n$ IN EQUATIONS (24) AND (27) YIELDS PROPOSITION 5. THE FORMAL PROOF IS IN THE APPENDIX.

***PROPOSITION 5. THE RATE OF RETURN ON COLLUSION WHEN DEMAND FLUCTUATES IS THE SAME AS WHEN DEMAND DOES NOT FLUCTUATE AT ALL.***

IF THE IDENTITY OF THE INFORMED FIRM DOES NOT CHANGE AND IF THE INFORMED FIRM KEEPS ITS INFORMATION TO ITSELF THEN BOTH THE INFORMED AND UNINFORMED FIRM WILL CHEAT IF THE MARKET INTEREST RATE IS AT LEAST $R_U^* \quad R_I^* \quad R^* \quad \frac{4n}{(n+1)^2}$.[12] NOTE THAT THIS FORMULA FOR THE CRITICAL INTEREST RATE IS EXACTLY THE SAME AS WHEN THERE ARE NO DEMAND FLUCTUATIONS. FURTHER NOTE THAT A CARTEL MEMBER'S DECISION TO CHEAT IS INDEPENDENT OF THE VARIABILITY OF DEMAND $(\frac{a_H - c}{a_L - c})$. THUS, IF FIRMS DO NOT COMMUNICATE THEY HAVE EXACTLY THE SAME RETURN FROM COLLUDING WHEN THERE ARE DEMAND FLUCTUATIONS AS WHEN THERE ARE NONE. MOREOVER, SINCE DEMAND FLUCTUATIONS ARE NOT RELEVANT TO A FIRM'S DECISION TO CHEAT, INFORMATION ABOUT DEMAND CANNOT AFFECT THE INCENTIVE TO CHEAT. THUS IF FIRMS DO NOT COMMUNICATE THEN EVEN WHEN DEMAND FLUCTUATES AND ONE FIRM HAS AN INFORMATIONAL ADVANTAGE CARTELS ARE AS STABLE AS WHEN DEMAND DOES NOT FLUCTUATE. THIS IS VERY DIFFERENT FROM OUR RESULTS IN SECTION 3 WHERE THE INFORMED FIRM COMMUNICATED WITH THE UNINFORMED FIRMS AND CARTEL INSTABILITY WAS DIRECTLY RELATED TO DEMAND FLUCTUATIONS. WHY DO THE RESULTS DIFFER?

WHEN DEMAND FLUCTUATIONS ARE COUPLED WITH ASYMMETRIC INFORMATION ABOUT DEMAND, RECALL THAT THE INFORMED FIRM CHEATS BECAUSE THE BENEFIT FROM CHEATING IS RELATIVELY LARGE COMPARED TO THE EXPECTED REWARDS OF FUTURE COOPERATION WHEN DEMAND IS HIGH (ROTEMBERG AND SALONER,1986). HOWEVER, EVEN IN THIS SITUATION THE INFORMED FIRM HAS A GREATER INCENTIVE

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[12]SEE PROOF IN APPENDIX.

TO CHEAT IN THE EQUILIBRIUM WHERE INFORMATION IS SHARED COMPARED TO THE EQUILIBRIUM WHERE INFORMATION IS NOT SHARED. THIS HAPPENS DUE TO TWO REASONS. FIRST, THE INFORMED FIRM PRODUCES LESS IN THE IN THE COLLUSIVE PHASE OF THE EQUILIBRIUM WHERE INFORMATION IS SHARED COMPARED TO THE COLLUSIVE PHASE OF THE EQUILIBRIUM WHEN INFORMATION IS NOT SHARED. THIS MEANS THAT AN INFORMED FIRM IS LESS LIKELY TO COLLUDE IN THE INFORMATION SHARING EQUILIBRIUM COMPARED TO THE EQUILIBRIUM WHEN INFORMATION IS NOT SHARED. SECOND, THE INFORMED FIRM GETS TO PRODUCE MORE IF IT CHEATS IN THE INFORMATION SHARING EQUILIBRIUM COMPARED TO THE EQUILIBRIUM WHEN INFORMATION IS NOT SHARED. THESE TWO REASONS SUGGESTS THAT CARTELS ARE MORE STABLE WHEN INFORMATION IS SHARED THAN WHEN IT IS NOT.

FURTHER, WHEN DEMAND IS HIGH, THE INFORMED FIRM CAN MISLEAD THE UNINFORMED FIRMS TO REDUCE OUTPUT RELATIVE TO THE ACTUAL STATE OF DEMAND. HOWEVER, IF THE INFORMED FIRM DOES NOT TALK IT CANNOT LIE – THUS ELIMINATING THIS SECOND REASON FOR CHEATING.

## 6. CONCLUSION

THIS PAPER SUGGESTS THAT ASYMMETRIC INFORMATION MAY INCREASE CARTEL INSTABILITY – THOUGH ONLY IF FIRMS MUST COMMUNICATE TO COORDINATE EFFECTIVELY. AT ANY RATE SOME CAVEATS TO OUR ARGUMENT ARE IN ORDER. FIRST, IT SHOULD BE NOTED THAT OUR MODEL IS VERY SIMPLE. SPECIFICALLY, WE ASSUME VERY SIMPLE FUNCTIONAL FORMS, AND A VERY SIMPLE INFORMATION STRUCTURE. IT MAY BE USEFUL, FOR EXAMPLE, TO COMPARE OUR MODEL'S INFORMATION STRUCTURE TO THE INFORMATION STRUCTURE IN GREEN AND PORTER (1984). SECOND, THE PUNISHMENT STRATEGY WE ASSUME IS ALSO VERY SIMPLE. IF ONE ALLOWED FOR OPTIMAL PUNISHMENT STRATEGIES (SEE ABREU, 1986

AND ABREU, ET AL., 1986), THEN CARTELS WOULD PRESUMABLY BE MORE STABLE. THE ISSUE OF ASYMMETRIC PUNISHMENTS (SEGERSTROM, 1985) ALSO NEEDS TO BE CONSIDERED. THIRD, MAKING DEMAND SHOCKS I.I.D. MIGHT DRIVE SOME OF OUR RESULTS. IF CURRENT STRONG DEMAND IMPLIES STRONGER DEMAND IN THE NEXT PERIOD (HALTIWANGER AND HARRINGTON, 1991) THEN THE INFORMED FIRM'S WILLINGNESS TO LIE AND CHEAT MAY BE OFFSET BY HIGHER COLLUSIVE PROFITS TOMORROW. LAST, IT WOULD BE INTERESTING TO DEVELOP MODELS WHERE FIRMS MUST COMMUNICATE TO COORDINATE AT ALL.

THIS LINE OF RESEARCH MAY HAVE SOME INTERESTING POLICY IMPLICATIONS AS WELL. THE LACK OF COMMUNICATION IN OUR PAPER HELPS CARTEL STABILITY AND IS THEREFORE INIMICAL TO CONSUMER WELFARE. THE SHERMAN ACT'S PER SE BAN ON PRICE FIXING HINDERS COMMUNICATION AND MAY THEREFORE NOT BE WELFARE ENHANCING. THIS MAY SUGGEST A RULE OF REASON APPROACH. OF COURSE SUCH A COMPARISON WOULD HAVE TO BE BASED ON DIFFERENCES IN ADMINISTRATIVE COSTS OF THE TWO APPROACHES. FURTHER, ONE MIGHT NOTE THAT FIRMS MAY CHOOSE NOT TO COMMUNICATE EVEN WITHOUT ANY ANTI-TRUST LAW.

APPENDIX:

## PROOF OF PROPOSITION 1

THE RATE OF RETURN FROM COOPERATION, $r^*_{asym}$ IS GIVEN IN (13). THE COMPONENTS OF $r^*_{asym}$ ARE $\pi^{COLL}$, $\pi_H^{CH,I}$, AND $\pi^{NC}$. BELOW WE CALCULATE $\pi^{NC}$. THEN WE FIND VALUES FOR $\pi^{COLL} - \pi^{NC}$ AND $\pi_H^{CH,I} - a_H^2 / 4n$. THROUGHOUT, LET

$$A_\phi = \phi a_H + (1-\phi)a_L = \phi(a_H - a_L) + a_L. \tag{A1}$$

FROM EQUATION (7), $\pi^{NC}$ DEPENDS ON $\pi^{NC,U}$ AND $\pi^{NC,I}$. TO FIND $\pi^{NC,U}$, PLUG (2), (3) AND (4) INTO (5) TO GET

$$\pi^{NC,U} = \left(\frac{\phi A_\phi}{n+1}\right)\left(\frac{(n+1)a_H - (n-1)A_\phi}{2(n+1)}\right) + \frac{(1-\phi)A_\phi}{(n+1)}\left(\frac{(n+1)a_L - (n-1)A_\phi}{2(n+1)}\right) . \tag{A2}$$

AFTER CONSIDERABLE SIMPLIFICATION THIS BECOMES

$$\pi^{NC,U} = \frac{A_\phi^2}{(n+1)^2} . \tag{A3}$$

NEXT, TO GET $\pi^{NC,I}$, SUBSTITUTE EQUATIONS (3) AND (4) IN EQUATION (6), OBTAINING

$$\pi^{NC,I} = \phi\left(\frac{(n+1)a_H - (n-1)A_\phi}{2(n+1)}\right)^2 + (1-\phi)\left(\frac{(n+1)a_L - (n-1)A_\phi}{2(n+1)}\right)^2 . \tag{A4}$$

AFTER SIMPLIFICATION THIS BECOMES

$$\pi^{NC,I} = \phi \frac{a_H^2}{4} + (1-\phi)\frac{a_L^2}{4} - \frac{(n-1)(n+3)A_\phi^2}{4(n+1)^2} \quad . \tag{A5}$$

COMBINING (A3) AND (A5) WITH (7) WE GET

$$\pi^{NC} = \phi \frac{a_H^2}{4n} + (1-\phi)\frac{a_L^2}{4n} - \frac{(n-1)^2 A_\phi^2}{4n(n+1)^2} \, . \tag{A6}$$

COMBINING (1) AND (A6) WE GET

$$\pi^{COLL} - \pi^{NC} = \frac{(n-1)^2 A_\phi^2}{4n(n+1)^2} \, . \tag{A7}$$

THIS GIVES THE NUMERATOR OF EQUATION (13).

NOW WE TURN TO THE DENOMINATOR OF EQUATION (13), WHERE WE SUBTRACT $a_H^2 / 4n$ FROM THE CHEATING PROFITS IN (9). THIS GIVES

$$\pi_H^{CH,I} - \frac{a_H^2}{4n} \quad \left(\frac{2na_H - (n-1)a_L}{4n}\right)^2 - \frac{a_H^2}{4n} \quad \left(\frac{n-1}{16n^2}\right)[(2a_H - a_L)^2 n - a_L^2] \, . \tag{A8}$$

FINALLY, PLUGGING (A7) AND (A8) INTO (13) GIVES

$$r_{asym}^* = \frac{Equation(A7)}{Equation(A8)} \quad \frac{4n(n-1)A_\phi^2}{(n+1)^2[(2a_H - a_L)^2 n - a_L^2]} \, . \tag{A9}$$

## PROOF OF PROPOSITION 2

TO PROVE PROPOSITION 2 WE NEED TO FIRST FIND $r^*_{sym}$, AND $r_0^*$. TO FIND $r^*_{sym}$ WE NEED TO COMPARE THE EXPECTED PAYOFF FROM CHEATING WITH THE EXPECTED PAYOFF FROM COLLUDING UNDER SYMMETRIC INFORMATION.

WHEN INFORMATION ABOUT DEMAND IS SYMMETRIC THE CHEATING PROFIT IN THE HIGH DEMAND STATE IS

$$\pi^{CH}_{sym} = (\frac{(n+1)a_H}{4n})^2 . \tag{A10}$$

THERE IS NO DIFFERENCE BETWEEN MONOPOLY PROFITS FOR THE SYMMETRIC INFORMATION AND THE ASYMMETRIC INFORMATION CASES. HOWEVER, THE (NONCOOPERATIVE) PROFITS IN THE PUNISHMENT PHASE WHEN DEMAND IS HIGH IS

$$\pi^{NC}_{H,sym} = (\frac{a_H}{n+1})^2 . \tag{A11}$$

WHEN DEMAND IS LOW IT IS

$$\pi^{NC}_{L,sym} = (\frac{a_L}{n+1})^2 . \tag{A12}$$

THUS, USING (A11) AND (A12), EXPECTED PUNISHMENT PROFITS FOR EACH FIRM WHEN INFORMATION IS SYMMETRIC IS

$$\pi^{NC}_{sym} = \phi(\frac{a_H}{n+1})^2 + (1-\phi)(\frac{a_L}{n+1})^2 . \tag{A13}$$

THUS THE RETURN TO COLLUSION IS

$$r^*_{sym} = \frac{\pi^{COLL} - \pi^{NC}_{sym}}{\pi^{CH}_{sym} - \frac{a_H^2}{4n}}. \tag{A14}$$

PLUGGING (1), (A10), AND (A13) INTO (A14) YIELDS

$$r^*_{sym} = \frac{4n}{(n+1)^2}[\phi + (1-\phi)\frac{a_L^2}{a_H^2}]. \tag{A15}$$

LET $\varepsilon = \frac{a_H - a_L}{a_L}$. THEN THE FIRST ORDER LINEAR EXPANSION OF $r^*_{sym}$ AROUND $\varepsilon = 0$ IS

$$r^{*LE}_{sym} = \frac{4n}{(n+1)^2} - \frac{8(1-\phi)n\varepsilon}{(n+1)^2}. \tag{A16}$$

SIMILARLY, THE FIRST ORDER LINEAR EXPANSION OF $r^*_{asym}$ AROUND $\varepsilon = 0$, USING (A9), IS

$$r^{*LE}_{asym} = \frac{4n}{(n+1)^2} - \frac{4n}{(n+1)^2}[\frac{4n - 2\phi(n-1)}{n-1}]\varepsilon \ . \tag{A17}$$

ALSO WHEN THERE IS NO DEMAND FLUCTUATION, AND THEREFORE NO SCOPE FOR INFORMATIONAL ASYMMETRY IN OUR MODEL, THE RETURN TO COOPERATION BECOMES (SETTING $A_H$ AND $A_L$ EQUAL TO EACH OTHER IN (A15))

$$r^*_0 = \frac{4n}{(n+1)^2} \ . \tag{A18}$$

NOW, THE APPROXIMATE PROPORTION OF THE FALL IN THE RETURN TO COOPERATION DUE TO ASYMMETRIC INFORMATION IS

$$\frac{r_{sym}^{*LE} - r_{asym}^{*LE}}{r_0^{*} - r_{asym}^{*LE}}. \tag{A19}$$

PLUGGING IN (A16), (A17) AND (A18) INTO (A19), THIS BECOMES

$$\frac{n+1}{2n-(n-1)\phi}. \tag{A20}$$

THIS PROVES PROPOSITION 2.

## PROOF OF PROPOSITION 3

FIRST, $r_{asym}^{*}$ IS HOMOGENOUS OF DEGREE ZERO IN $A_H$ AND $A_L$. THUS INCREASING $A_H/A_L$ IS EQUIVALENT TO INCREASING $A_H$. DIFFERENTIATING (A9) WITH RESPECT TO $A_H$ GIVES

$$\frac{dr_{asym}^{*}}{da_H} = \left(\frac{2\phi A_\phi[(2a_H - a_L)^2 n - a_L^2] - 4nA_\phi^2(2a_H - a_L)}{[(2a_H - a_L)^2 - a_L^2]^2}\right)\left(\frac{4n(n-1)}{(n+1)^2}\right) \quad . \tag{A21}$$

SINCE THE NUMBER OF FIRMS, $N$, IS GREATER THAN ONE, (A21) WILL BE NEGATIVE WHENEVER

$$2\phi A_\phi[(2a_H - a_L)^2 n - a_L^2] - 4nA_\phi^2(2a_H - a_L) < 0.$$

BUT

$$2\phi A_\phi[(2a_H - a_L)^2 n - a_L^2] - 4nA_\phi^2(2a_H - a_L)$$

$$2\phi A_\phi(2a_H - a_L)^2 n - 4A_\phi^2(2a_H - a_L)n - 2\phi A_\phi a_L^2$$

$$2A_\phi n(2a_H - a_L)[\phi(2a_H - a_L) - 2A_\phi] - 2\phi A_\phi a_L^2$$

$$- 2A_\phi n(2a_H - a_L)(2 - \phi)a_L - 2\phi A_\phi a_L^2 \ . \qquad \text{(A22)}$$

SINCE $A_H$ $A_L$ 0, AND 0 $\phi$ 1, THE LAST LINE IN (A22) IS NEGATIVE. THUS $dr^*_{asym} / da_H$ 0, SO THE LARGER THE DEMAND FLUCTUATION THE LOWER THE CRITICAL INTEREST RATE FOR A CREDIBLE TRIGGER STRATEGY. THIS PROVES PROPOSITION 3.

## PROOF OF PROPOSITION 4

AS $\phi$ INCREASES, $r^*_{asym}$ IN EQUATION (14) CLEARLY INCREASES AS WELL, SINCE $a_H - a_L > 0$. THIS PROVES PROPOSITION 4.

## PROOF OF PROPOSITION 5

EQUATION (24) IMPLIES

$$r^{*I} = \frac{\phi(\frac{a_H}{2} - (n-1)q_j^U)\frac{a_H}{2}) + (1-\phi)(\frac{a_L}{2} - (n-1)q_j^U)\frac{a_L}{2}) - \pi^{NC,I}}{\frac{(a_H - (n-1)q_j^U)^2}{4} - (\frac{a_H}{2} - (n-1)q_j^U)\frac{a_H}{2})} \qquad \text{(A23)}$$

AFTER SUBSTITUTING THE VALUES FOR $\pi^{COLL,AI}$ FROM EQUATION (18), $\pi_H^{COLL,AI}$ FROM EQUATION(16), AND $\pi_H^{CH,AI}$ FROM EQUATION (20). FIRST, SUBSTITUTE THE VALUE FOR $\pi^{NC,I}$ FROM EQUATION (A5). THEN SUBSTITUTE $A_\phi / 2n$ FOR $q_j^U$ INTO (A23). NOTE THAT $A_\phi / 2n$ IS THE OUTPUT PRODUCED IN A COLLUSIVE EQUILIBRIUM WHERE EACH UNINFORMED FIRM HAS AN EQUAL SHARE OF THE EXPECTED MONOPOLY OUTPUT. THESE TWO SUBSTITUTIONS SIMPLIFY (A23) TO

$$r^{*I} = \frac{\frac{(n-1)A_\phi^2}{2(n+1)} - \frac{(n-1)A_\phi^2}{4n} - \frac{(n-1)^2 A_\phi^2}{4(n+1)^2}}{\frac{(n-1)^2 A_\phi^2}{16n^2}}. \tag{A24}$$

EQUATION (A24) CAN BE FURTHER SIMPLIFIED TO

$$r^{*I} = \frac{\frac{1}{n+1} - \frac{1}{2n} - \frac{n-1}{2(n+1)^2}}{\frac{n-1}{8n^2}} = \frac{4n}{(n+1)^2} \tag{A25}$$

EQUATION (27) IMPLIES

$$r^{*U} = \frac{\phi q_j^U \frac{a_H}{2} + (1-\phi) q_j^U \frac{a_L}{2} - \frac{A_\phi^2}{(n+1)^2}}{\left(\frac{A_\phi + 2q_j^U}{4}\right)^2 - \left(\phi q_j^U \frac{a_H}{2} + (1-\phi) q_j^U \frac{a_L}{2}\right)} \tag{A26}$$

AFTER SUBSTITUTING THE VALUES FOR $\pi^{COLL,AU}$ FROM EQUATION (19), $\pi^{NC,U}$ FROM EQUATION (5), AND $\pi^{CH,AU}$ FROM EQUATION (19). BUT IF WE SUBSTITUTE $\frac{A_\phi}{2n}$ FOR $q_j^U$ INTO EQUATION (A26) WE CAN SHOW

THAT

$$r*^U = \frac{\frac{A_\phi^2}{4n} - \frac{A_\phi^2}{(n+1)^2}}{\frac{A_\phi^2}{16}\left(1 + \frac{1}{n^2} + \frac{2}{n}\right) - \frac{A_\phi^2}{4n}} = \frac{4n}{(n+1)^2} \tag{A27}$$

EQUATIONS (A25) AND (A27) SHOW THAT WHEN $q_j^U = \frac{A_\phi}{2n}$ THEN $r*^U = r*^I = \frac{4n}{(n+1)^2}$ THUS PROVING PROPOSITION 5.

## BIBLIOGRAPHY.

ABREU, D. 1988. "ON THE THEORY OF INFINITELY REPEATED GAMES WITH DISCOUNTING." ECONOMETRICA 56:383-396.

ABREU, D. 1986. "EXTREMAL EQUILIBRIA OF OLIGOPOLISTIC SUPERGAMES." JOURNAL OF ECONOMIC THEORY 39:191-225.

ABREU, D., D. PEARCE, AND E. STACCHETTI. 1986. "OPTIMAL CARTEL EQUILIBRIA WITH IMPERFECT MONITORING." JOURNAL OF ECONOMIC THEORY 39:251-69.

AOYAGI, M., 2002. "COLLUSION IN DYNAMIC BERTRAND OLIGOPOLY WITH CORRELATED PRIVATE SIGNALS AND COMMUNICATION." JOURNAL OF ECONOMIC THEORY 102:229-248.

ATHEY, S., AND BAGWELL, K., 2001. "OPTIMAL COLLUSION WITH PRIVATE INFORMATION." RAND JOURNAL OF ECONOMICS 32:428-465.

ATHEY, S., BAGWELL, K., AND SANCHIRICO C., 2001. "COLLUSION AND PRICE RIGIDITY." REVIEW OF ECONOMIC STUDIES, FORTHCOMING.

BAGWELL, K., AND R.W. STAIGER. 1997. "COLLUSION OVER THE BUSINESS CYCLE." RAND JOURNAL OF ECONOMICS 28:82-106.

BASUCHOUDHARY, A., AND J. CONLON. 2000. "ASYMMETRIC MARKET SHARING -- ENSURING CARTEL STABILITY IN THE PRESENCE OF ASYMMETRIC INFORMATION AND DEMAND VOLATILITY." UNPUBLISHED MANUSCRIPT.

BORENSTEIN, S., AND A. SHEPARD. 1996. "DYNAMIC PRICING IN RETAIL GASOLINE MARKETS." RAND JOURNAL OF ECONOMICS 25: 429-451.

CHEVALIER, J.A., AND D.S. SCHARFSTEIN. 1996. "CAPITAL MARKET IMPERFECTIONS AND

COUNTERCYCLICAL MARKUPS: THEORY AND EVIDENCE." AMERICAN ECONOMIC REVIEW 86:703-725.

CHOI, D. AND G.C. PHILIPPATOS. 1983. "FINANCIAL CONSEQUENCES OF ANTITRUST ENFORCEMENT." REVIEW OF ECONOMICS AND STATISTICS 65:501-506.

COMPTE, O. 1998. "COMMUNICATION IN REPEATED GAMES WITH IMPERFECT PRIVATE MONITORING." ECONOMETRICA 66:597-626.

CONLON, J. 1996. "COOPERATION FOR PENNIES: A NOTE ON $\varepsilon$-EQUILIBRIA." JOURNAL OF ECONOMIC THEORY 70:489-500.

CONLON, J. 2002. "HOPE SPRINGS ETERNAL: LEARNING AND THE STABILITY OF COOPERATION IN SHORT HORIZON REPEATED GAMES." JOURNAL OF ECONOMIC THEORY, FORTHCOMING.

DOMOWITZ, I., R.G. HUBBARD, AND B.C. PETERSEN. 1986. "BUSINESS CYCLES AND THE RELATIONSHIP BETWEEN CONCENTRATION AND PRICE-COST MARGINS." RAND JOURNAL OF ECONOMICS 17:1-17.

ELLISON, G. 1994. "THEORIES OF CARTEL STABILITY AND THE JOINT EXECUTIVE COMMITTEE." RAND JOURNAL OF ECONOMICS 25:37-57.

FEINBERG, R.M. 1980. "ANTITRUST ENFORCEMENT AND SUBSEQUENT PRICE BEHAVIOR." REVIEW OF ECONOMICS AND STATISTICS 62:609-612.

FRAAS, A.G., AND D.F. GREER. 1977. "MARKET STRUCTURE AND PRICE COLLUSION: AN EMPIRICAL ANALYSIS." THE JOURNAL OF INDUSTRIAL ECONOMICS 26: 21-45.

FRIEDMAN, J. 1971. "A NON-COOPERATIVE EQUILIBRIUM FOR SUPERGAMES." REVIEW OF ECONOMIC STUDIES 38:1-12.

FUDENBERG, D., AND E. MASKIN. 1986. "THE FOLK THEOREM IN REPEATED GAMES WITH

DISCOUNTING OR WITH INCOMPLETE INFORMATION." ECONOMETRICA 54:533-554.

GREEN, E., AND R. PORTER. 1984. "NONCOOPERATIVE COLLUSION UNDER IMPERFECT PRICE INFORMATION." ECONOMETRICA 52:87-100.

HAY, G.A., AND D. KELLEY. 1974. "AN EMPIRICAL SURVEY OF PRICE FIXING CONSPIRACIES." JOURNAL OF LAW AND ECONOMICS 17:13-38.

HAJIVASSILIOU, V.A. 1989. "TESTING GAME-THEORETIC MODELS OF PRICE-FIXING BEHAVIOUR." COWLES FOUNDATION WORKING PAPER 935.

HALTIWANGER, J., AND J.E. HARRINGTON. 1991. "THE IMPACT OF CYCLICAL DEMAND MOVEMENTS ON COLLUSIVE BEHAVIOR." RAND JOURNAL OF ECONOMICS 22:89-106.

KANDORI, M., AND H. MATSUSHIMA. 1998. "PRIVATE OBSERVATION, COMMUNICATION AND COLLUSION." ECONOMETRICA 66:627-652.

KREPS, D., P. MILGROM, J. ROBERTS, AND R. WILSON. 1982. "RATIONAL COOPERATION IN THE FINITELY REPEATED PRISONERS DILEMMA." JOURNAL OF ECONOMIC THEORY 27:245-252.

LAMBSON, V.E. 1984. "SELF ENFORCING COLLUSION IN LARGE DYNAMIC MARKETS." JOURNAL OF ECONOMIC THEORY 34(2) PP. 282-91.

PECORINO, P. 1998. "IS THERE A FREE RIDER PROBLEM IN LOBBYING? ENDOGENOUS TARIFFS, TRIGGER STRATEGIES, AND THE NUMBER OF FIRMS." AMERICAN ECONOMIC REVIEW 88(3) PP. 652-60.

PORTER, R.H. 1983. "A STUDY OF CARTEL STABILITY: THE JOINT EXECUTIVE COMMITTEE, 1880-1886." BELL JOURNAL OF ECONOMICS 14:301-314.

REKSULAK, M., W. F. SHUGHART II, R.D. TOLLISON, AND A. BASUCHOUDHARY. 2004. "TITAN AGONISTES: THE WEALTH EFFECTS OF THE STANDARD OIL (N.J.) CASE." RESEARCH IN LAW AND ECONOMICS 21:63–84.

ROTEMBERG, J.J., AND G. SALONER. 1986. "A SUPERGAME-THEORETIC MODEL OF BUSINESS CYCLES AND PRICE WARS DURING BOOMS." AMERICAN ECONOMIC REVIEW 76:390-407.

ROTEMBERG, J.J., AND M. WOODFORD. 1992. "OLIGOPOLISTIC PRICING AND THE EFFECT OF AGGREGATE DEMAND ON ECONOMIC ACTIVITY." JOURNAL OF POLITICAL ECONOMY 100:1153-1207.

SEGERSTROM, P.S. 1985. "SYMMETRIC AND ASYMMETRIC PUNISHMENTS IN THE THEORY OF NONCOOPERATIVE COLLUSION." ECONOMETRICS AND ECONOMIC THEORY WORKSHOP PAPERS 8504.

SUSLOW, V.Y. 1998. "CARTEL CONTRACT DURATION: EMPIRICAL EVIDENCE FROM INTERNATIONAL CARTELS." WORKING PAPER.

SPROUL, M.F. 1993. "ANTI-TRUST AND PRICES." JOURNAL OF POLITICAL ECONOMY 101:741-754.

STIGLER, G.J. AND J.K. KINDAHL. 1970. *THE BEHAVIOR OF INDUSTRIAL PRICES*. NEW YORK: COLUMBIA UNIVERSITY PRESS.

TOWN, R.J. 1991. "PRICE WARS AND DEMAND FLUCTUATIONS: A REEXAMINATION OF THE JOINT EXECUTIVE COMMITTEE." U.S. DEPARTMENT OF JUSTICE ANTITRUST DIVISION DISCUSSION PAPER EAG91-5.

VIVES, X. 1984. "DUOPOLY INFORMATION EQUILIBRIUM: COURNOT AND BERTRAND." JOURNAL OF ECONOMIC THEORY 34:71-94.

VIVES, X. 1990. "TRADE ASSOCIATION DISCLOSURE RULES, INCENTIVES TO SHARE INFORMATION, AND WELFARE." RAND JOURNAL OF ECONOMICS 21:409-430.

VIVES, X. 1999. *OLIGOPOLY PRICING: OLD IDEAS AND NEW TOOLS*. MIT PRESS, CAMBRIDGE, MA.

WHINSTON, M.D. 2006. ***LECTURES ON ANTITRUST ECONOMICS.*** MIT PRESS, CAMBRIDGE, MA.

TABLE 1. APPROXIMATE PERCENTAGE FALL IN $r^*_{asym}$ EXPLAINED BY ASYMMETRIC INFORMATION, AS A FUNCTION OF THE PROBABILITY OF HIGH DEMAND, $\phi$ , AND NUMBER OF FIRMS, $N$.

| $\phi$ | N 2 | N 5 | N 10 |
|---|---|---|---|
| 0.1 | 76.92% | 62.5% | 57.59% |
| 0.2 | 78.95% | 65.22% | 60.44% |
| 0.5 | 85.71% | 75% | 70.97% |
| 0.8 | 93.75% | 88.24% | 85.94% |
| 1 | 100% | 100% | 100% |

TABLE 2 - CRITICAL INTEREST RATE (FULL INFORMATION)

| $(A_H - C)/(A_L - C)$ | N 2 | N 5 | N 10 |
|---|---|---|---|
| 1.0 | 88.9% | 55.6% | 33.0% |
| 1.2 | 75.3% | 47.1% | 28.0% |
| 1.4 | 67.1% | 41.9% | 25.0% |
| 1.6 | 61.8% | 38.6% | 23.0% |
| 1.8 | 58.2% | 36.3% | 21.6% |
| 2.0 | 35.6% | 34.7% | 20.7% |

TABLE 3 -CRITICAL INTEREST RATE (ASYMMETRIC INFORMATION)

| $(A_H - C)/(A_L - C)$ | N 2 | N 5 | N 10 |
|---|---|---|---|
| 1.0 | 88.9% | 55.6% | 33.0% |
| 1.2 | 36.8% | 30.6% | 19.4% |
| 1.4 | 23.4% | 21% | 13.6% |
| 1.6 | 17.3% | 16.2% | 10%* |
| 1.8 | 13.9% | 13.3% | 8.9%* |
| 2 | 11.8% | 11.4% | 7.7%* |