CONSOLIDATION OF THE U.S. DEFENSE INDUSTRIAL BASE: *IMPACT ON RESEARCH EXPENDITURES*

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In 1993, there were 21 companies doing major defense aerospace work — today there are five: Boeing, Raytheon, Litton Industries, Lockheed Martin and Northrop Grumman. The battle for the shrinking defense budget has resulted in not only mergers, but also an increased emphasis on the formation of partnerships among defense contractors. As the defense industry has consolidated, the remaining firms have been forced to cut back on internal research and development (R&D) expenditures and other efforts to innovate due to cost pressures. Should we expect a further reduction in internal R&D efforts by contractors? How does the number of competitors vying for a particular contract affect the overall level of R&D? Does it matter whether we have consolidation via acquisition, mergers, or bankruptcy?

John Deutch's (2001) recent article "Consolidation of the U.S. Defense Industrial Base" provides an insightful look at an important problem facing the Department of Defense (DoD). Deutch correctly points out the difficult trade-off between competition and efficiency in order to keep defense costs low as well as maintaining a viable defense infrastructure. As the defense industry has consolidated, the remaining firms have been forced to cut back on internal research and development (R&D) expenditures and other efforts to innovate due to cost pressures.

Yet at the same time, R&D is crucial to the long-term viability of defense firms. Should we expect a further reduction in internal R&D efforts by contractors? How does the number of competitors vying for a particular contract affect the overall level of R&D? Does it matter whether we have

consolidation via acquisition, mergers, or bankruptcy? This article provides additional insights into the effect consolidation will have on internal R&D expenditures.

In 1993, there were 21 companies doing major defense aerospace work, today there are five: Boeing, Raytheon, Litton Industries, Lockheed Martin, and Northrop Grumman (Diamond, 1998). The battle for the shrinking defense budget has resulted in not only mergers, but also an increased emphasis on the formation of partnerships among defense contractors. The Air Force's F-22 is being developed by a team led by Lockheed Martin, Boeing, and Pratt & Whitney. Team ABL, comprised of Boeing, Lockheed Martin, and TRW, is developing the Air Force's Airborne Laser program (Proctor, 1998). Larraine Segil (2000) wrote, "Striking alliances between your business and others is no longer something that's "nice to do" — it's a business imperative. As we head into 2000, 30 percent of the annual revenues of most U.S. companies are going to come from alliances" (p. 1).

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As defense firms form "alliances," the overall impact on the research effort exerted by the defense contractors needs to be studied in a systematic way. As partnerships form to compete with other firms, the degree of research effort expended by any one firm will be strongly influenced by the amount of research conducted by others — their partners and their competitors. Additionally, the resources expended on internal R&D will depend on the expected distribution of work and profits among the firms involved after the prime contractor is selected.

The most commonly used theory of alliances has been that of Olson and Zeckhauser (1966), which applied the theory of private provision of public goods to national defense with military spending as the "public good." Others, like Murdoch and Sandler (1984) and Sandler and Murdoch (1990), extended the Olson-Zeckhauser model by accounting for the impure public good aspects of defense expenditures. Linster (1993b) offered an alternative approach, modeling international competition as a rent-seeking contest that also captured the impure public good nature of defense spending among allies and adversaries. This model was based on a simplified version of Tullock's (1980) rent-seeking model, applying extensions by Hillman and Riley (1989) and Linster (1993a, 1993b).

In a series of experiments, Linster, Fullerton, McKee, and Slate (2001) tested predictions applicable to a three-firm case where two firms share a common interest in opposition to the third firm, and the three firms expend resources (R&D) in an effort to win the contract. The reader is directed to the original article in *Defense and Peace Economics* for a complete description of the theory, experimental design, and conduct of experiments.

THE MODEL

Suppose there is a prize for which three firms compete. In the context of contractor competition, we can think of the prize as some lucrative contract in which three

firms have an interest, and they care who wins the contract if they do not. The firms can assign distinct values for different players winning the prize, and each player's valuation can be represented by the vector

$$\mathbf{v}_i = \left(v_{i1}, v_{i2}, v_{i3}\right)^\mathsf{T}$$

where v_{if} is the value to player i if player j wins the prize. Player i chooses an amount x_i to spend in order to win the prize (defense contract) where the probability player i wins is

$$q_i(\mathbf{x}) = x_i / \left(x_1 + x_2 + x_3\right)$$

where

$$\mathbf{x} = \left(x_1, x_2, x_3\right)^\mathsf{T}$$

and the vector of these probabilities or shares is

$$\mathbf{q}(\mathbf{x}) = \left(q_1(\mathbf{x}), q_2(\mathbf{x}), q_3(\mathbf{x})\right)^\mathsf{T}.[1]$$

Using the above notation, player i will choose a level of research expenditure to maximize his profit,

$$U_i(\mathbf{x}) = \mathbf{q}(\mathbf{x})^\mathsf{T} \mathbf{v_i} - x_i.$$

We model the relationships among contractors by considering an increase in the "publicness" of internal R&D expenditures as firms rely more on profit sharing within the partnership. The parameter γ measures the "publicness" of the rent-seeking expenditure. In the limit, as γ approaches unity, the two firms' interests coincide perfectly, and a unit of spending by either firm provides the same benefit as a dollar spent by the other firm in the alliance.

We captured this phenomenon by allowing γ to change in an experimental setting. It is easily shown that firm 1's share of the combined expenditures for players 1 and 2 (total partnership spending) will decrease as γ increases if $v_{11} < v_{22}$. This leads to our first hypothesis.

HYPOTHESIS 1:

If player 1 values winning the prize less than player 2 does, an increase in the publicness of the prize will lead to an decrease in player 1's share of their combined expenditures.

The intuition for this is quite straightforward. As one player's expenditure becomes a better substitute for another's, the player who values the prize less will tend to free ride more. If both partners value the prize equally, they should both reduce their expenditures to the joint effort without a change in relative shares as γ increases.

In addition to the lower valuation player reducing his or her share of the spending, an increase in γ will lead to a decrease in the equilibrium total expenditures. That is, as the prize becomes more of a public good among the partnership members, spending by the partnership as well as total research spending should decrease. We explicitly state this as our next hypothesis:

HYPOTHESIS 2:

If the publicness of the prize between players 1 and 2 increases, all things equal, (a) the total spent by players 1 and 2 will decrease and (b) total rent-seeking expenditure by all three players will decrease.

The intuition is once again clear. If the publicness parameter increases, spending by one partnership member becomes a

better substitute for the other's spending, thus reducing overall spending.

EXPERIMENTAL DESIGN

The experiments designed to test the implications of the model described above were performed at the University of New Mexico's computerized experimental economics laboratory with subjects recruited from undergraduate social science classes. The subjects were randomly assigned to groups of three that correspond to the three types of players in the model above, and they maintained their identities throughout the session. They were told that they must decide how much they wish to spend to obtain a portion of a prize that may have a different value for each player. The subjects did not know the identities of those with whom they were matched. They were told, however, every player's value for the prize, income, and how the payoffs would be calculated. They were also informed that they would play with a different group each round, but they were not told how many rounds would be played.

The experimental design attempted to capture the essential features of the model presented earlier and Linster's (1993a, 1993b) model. The subjects had complete information on v_{11}, v_{22}, v_{33}, and γ, and they accumulated scores in experimental currency referred to as "francs" that were

> "Computerization of the experiments allowed for immediate feedback for the subjects, enhancing their understanding of the payoff function."

converted to dollars at a predetermined exchange rate. We gave the subjects a set of written instructions explaining the game, and they were read aloud.

Since the game is rather complicated, two practice rounds were run so the subjects could become familiar with the rules and the payoff structure after the instructions were read. Following the practice rounds, the subjects were reassigned to different groups. Each player received an endowment of 50 francs at the beginning of each round. They were told they could spend none, all, or any portion of the endowment in their effort to secure a part of the prize. The players received a payoff measured as a share of the prize and the equivalent of a portion of another subject's share, if appropriate. Each subject's payoff at the end of the session was equal to the sum of scores from each round times a predetermined fixed exchange rate.

Computerization of the experiments allowed for immediate feedback for the subjects, enhancing their understanding of the payoff function. The sessions lasted from 40 to 50 minutes and payoffs ranged from about $17 to $32. A session consisted of two practice rounds that had no impact on payoffs and 40 rounds that were used for earning payoffs.

After each round, the subjects' computer screens displayed the results of the round and how their payoffs were calculated. Specifically, the subjects knew how much they spent and how large their payoffs were (including the equivalent of a portion of their partner's share of the prize). In order to aid learning, the players were informed at the end of every round the average spending and average payoff for all players of their type. At the end of

each session, the subjects' scores were displayed on their screens, and they were paid in cash.

In the context of contractor competition, expenditure decisions by the players correspond to research expenditures by firms engaged in competition. The fact that research spending by one firm may be an imperfect substitute for spending by another firm is captured through the publicness parameter, γ.

To test the hypotheses outlined earlier, two sessions of the rent-seeking game were conducted. Since the game is quite difficult to understand, one session consisted only of a single treatment with constant parameter values.

EXPERIMENTAL RESULTS

We conducted two sessions with group sizes of 18. The raw data suggest that the subjects, on average, were equally likely to overspend or underspend relative to that predicted by theory. We find no systematic bias in the data across sessions, but what we did find was that if one member of the partnership tended to overspend, the other member responded by underspending, so that the total amount spent by the partnership was remarkably close to the predicted amount.

In sessions 1 and 2, the session averages of 41.43 and 27.40, respectively, for overall partnership spending are nearly identical to the predicted amounts of 43.37 and 27.42. Thus, we find that the partnership spending by the subjects of our experiment aligned very closely with that predicted by theory. Additionally, total spending by all three subjects was also very close to that predicted by theory —

session averages of 57.33 and 42.93 compared to the predicted values of 58.90 and 46.8, respectively.

The data suggest support for Hypothesis 1. Note that from session 1 to 2, player 1's share of total spending by the partnership was predicted to decrease from 0.41 to 0.10. The actual experimental results in the last 20 rounds have the share decreasing from 0.50 to 0.34. Player 1's average share decreased substantially, by 32 percent, though less than predicted by theory.

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The experimental evidence also supports Hypothesis 2a. Both partnership spending and total spending behaved as predicted when we consider only the last 20 rounds. Across sessions 1 and 2, actual partnership research spending decreased about 30 percent (from 41 to 27) while it was predicted to fall 37 percent (from 43 to 27).

Hypothesis 2b is also supported by the data. Total spending by all subjects was predicted to decline as the degree of publicness increases. We observed a decrease, 57 francs to 43, when comparing sessions 1 and 2, a 25 percent decline. The predicted decrease was a decline of 20 percent, from 59 to 47 francs. Thus, we see a significant decrease in total research expenditures as predicted by the theory.

As we stated earlier, the data from these experiments tend to support the hypotheses. Hypothesis 1 was supported, though actual changes in burden sharing

are not as sensitive to changes in the publicness of the prize as the theory indicates. The data provide stronger support for Hypotheses 2a and 2b. These results imply that total spending for the partners decreases as the publicness of the prize increases and total spending by all three subjects decreases.

CONCLUSION

The theory described in the model provides clear predictions for partnership behavior as the publicness of the prize they pursue changes. The analysis suggests that when relationships among partners change, the fate of the partnership will tend to change along ways conjectured by Olson and Zeckhauser (1966). That is, the partnership will expend more resources if the spending by one member provides less benefit to the other member. These predictions are summarized in Hypotheses 1 and 2.

Although the behavior on the part of partnership members didn't follow the predictions exactly as predicted, there is still strong evidence of a reduction in partnership spending as the publicness of the prize increases. Specifically, we observed a reduction of approximately 30 percent in partnership spending as the publicness increased. Additionally, there is an overall decrease of approximately 25 percent in total research expenditures by all firms competing. The experimental results provide fairly strong support for the Olson and Zeckhauser (1966) conjecture. The implication of our study is clear — as defense contractors rely more and more on partnerships, alliances and/or teams, fewer resources can be expected to be devoted to research.

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ENDNOTE

1. This is an especially simple formulation of Tullock's original model where

$$q_i(\mathbf{x}) = x_i^r / \left(x_1^r + x_2^r + x_3^r \right)$$

for $r \geq 0$.

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