XI

Volume XI, Number 1, May 2008

Journal of Applied Economics

Vasilis Zervos

Whatever happened to competition in space agency procurement? The case of NASA

UNIVERSIDAD DEL CEMA
MCMLXXVIII
UCEMA

Edited by the Universidad del CEMA

Print ISSN 1514-0326
Online ISSN 1667-6726

Journal of Applied Economics. Vol XI, No. 1 (May 2008), 221-236

WHATEVER HAPPENED TO COMPETITION IN SPACE AGENCY PROCUREMENT? THE CASE OF NASA

Vasilis Zervos*

International Space University and Nottingham University Business School

Submitted June 2004; accepted November 2006

Using the U.S. National Aeronautics and Space Administration (NASA) as a case study, this paper examines how conflicting objectives in procurement policies by public space agencies result in anti-competitive procurement. Globally, public sectors have actively encouraged mergers and acquisitions of major contractors at the national level, since the end of the "Cold War", following largely from the perceived benefits of economies of size. The paper examines the impact the resulting industrial concentration has on the ability of space agencies to follow a pro-competitive procurement policy. Using time series econometric analysis, the paper shows that NASA's pro-competitive policy is unsuccessful due to a shift, since the mid-1990s, in the share of appropriations in favour of its top contractors.

JEL classification codes: H57, L50, L60

Key words: procurement, space industry, space agencies, NASA

I. Introduction

Until the 1990s, commercial space markets were small, with space spending dominated by governments. The behavior of space agencies was then analyzed within a traditional public choice framework. In terms of procurement choices, this meant that the space agency followed a policy that weighed two key objectives. The minimization of the cost of space programs and the minimization of rent to the space industry or, put otherwise, "best value for money" for a given space program, whose efficiency and procurement policies can be examined within a cost-benefit approach (Stevens 1993, Mueller 1989). The only dilemma space agencies faced was summed up in the traditional "rent vs cost minimization choice" (for a survey see Laffont and Tirole 1993, Sandler and Hartley 1995).

---

* International Space University, 1 rue Jean-Dominique Cassini, Park d'Innovation 67400 Illkirch, France. Tel: ++33(0)3 88655436, e-mail: zervos@isu.isunet.edu. I would like to thank Keith Hartley, Peter Swann and two anonymous referees for their useful comments, the usual disclaimer applies. The paper benefited from feedback on an earlier version entitled: 'Whatever Happened to Competition in Procurement? Monopsonists Monopolies and NASA' which was presented at the 55th International Astronautical Congress (Fukuoka, Japan) in 2005.

The end of the Cold War resulted in increasing commercial space applications and the growth of an international marketplace, whose suppliers were the historically government-dependent national space industries. The emergence of this international marketplace introduced a third objective in this choice: the objective of a favorable impact of national procurement policies and programs on the competitiveness of the industry in commercial markets (Commission 2002; Zervos 2001). Combined with declining post-Cold War public space budgets, this new objective resulted in a positive attitude towards mergers and acquisitions of space firms in the mid-1990s. Increases in industrial concentration were expected to lead to cost savings through economies of scale and scope, and through avoidance of R&D duplication, making space firms more competitive in newly-developed commercial space markets. As a result, at the level of major contractors, the US industry was comprised of a duopoly of Boeing and Lockheed Martin since the mid-1990s.

However, little attention was paid to the implications the introduction of this third objective had on the ability of space agencies to attain their traditional objectives of competition in contracting, low cost and minimum rent of space programs. Following the results of Florens et al. (1996), which indicate higher profits for the space industry from government procurement, the paper looks at the procurement policies that lead to this result. Specifically, we examine whether NASA contract procurement operates on a non-competitive basis, contradicting NASA's "traditional objectives" by resulting in profit-favoring, and thus explaining the results of Florens et al. (1996). The alternative of using rent-controlling types of contracts to account for lack of competition in tendering is another possibility examined in this paper. The analysis however focuses on the stated importance placed by NASA on competition in contracting, which is expected to become increasingly difficult as the number of prime contractors is diminishing (Commission 2002: E7). A pro-competitive policy in contracting can therefore be in conflict with active support of industrial consolidation on cost-reducing grounds. The analysis in this paper uses time series regression to test whether NASA's stated targets of enhancing competition in contracting is met and affected by industrial consolidation at contractor's level during the mid-1990s.

The rest of the paper is organized as follows: Section II looks at the procurement policies and dilemmas faced by NASA with regards to competition in contracting and the types of contacts employed. Section III then presents an empirical analysis of the determinants of competitive contracting by NASA and how its behavior changes over time. The analysis tests in particular for the significance of variations in the awards to the top tier of NASA contractors and whether the lack of competition is caused by the presence of "few and big" contractors. Section IV then looks at whether rent-control in the absence of competition can be compensated for by the pattern of the type of contracts awarded by NASA to the industry. The paper is summarized in Section V.

II. Background of NASA procurement policies

Space agencies are publicly funded organizations that operate under relevant procurement policies. The choices made by a space agency like NASA include the choice of space programs and equipment, the choice of contractor, and the choice of contract (for a detailed discussion see Zervos 2001). In making those choices, the agency seeks to implement the objectives of cost and rent minimization and improvement of competitiveness of the domestic space industry.

Given that the choice of space program is largely a political decision by the administration (a prominent example is the Apollo program), this paper focuses on the choice of contractor (whether it is through competitive tendering and what factors influence this process) as well as the choice of contract.

Government space programs are big business for space firms. This means that the exclusion of a space firm from major government space programs is likely to lead to scaling-down of operations, or even exit the market. In decreasing costs industries, such as the space industry, competition can have controversial results. On the one hand, it pushes in the direction of higher project costs (due to the loss of economies of scale) while on the other hand, it enhances effort and lowers X-inefficiency. Empirical evidence, primarily from the defence industry, point to overall benefits from the presence of competition in contracting (Dews 1979, Lichtenberg 1995). Under closed public space markets, benefits from lack of international competition are expected to take the form of lower production costs due to larger scale (domestic consolidation), while costs are expected in the form of high prices and losses associated with the presence of monopolistic domestic market structures. Net benefits are expected in the case where efficient scale and competition is achieved, which requires the presence of public procurement policies that are open to overseas competition. This is not possible in the case of space programs, as they are typically subject to national security considerations and frequently also subject to export controls (see Commission 2002).

Different types of contracts provide a different mix of incentives towards cost and rent minimization. Fixed-price contracts are mostly associated with competitive tendering and raise adverse selection problems (the contractor that underestimates the technical risk wins the tender, forcing the agency to renegotiate later). This results in fixed-price contracts being unsuitable for high-risk programs. Cost-plus contracts are thus often preferred in the presence of high risk, but raise moral hazard problems (the contractor has no incentive to minimise costs). In sum, fixed-price contracts and the presence of competition are factors that control costs, but less so rent transfers. This traditional dilemma of cost vs. rent minimization in contracting is augmented by the presence of commercial space markets to take into account the fact that minimum rent could harm the competitive position of the national industry in competitive markets. The same adverse effect could be experienced by the presence of minimum cost in government programs, which could result in highly specialized projects with less widespread development of dual-use projects and less generic research.[1]

Other factors that complicate the procurement process are the level of risk of the space program, the presence of asymmetry of information between the principal and the agent and long-term implications (re-negotiation, follow-up and lock-in effects). This makes the analysis of procurement behavior complicated, especially when looking at time-series where procurement paradigms change, organizational re-structuring occurs and new markets develop. Two factors and a policy response affected NASA procurement behavior in the early 1990s: the diminishing government budgets (increasing commercial markets) following the end of the Cold War, the consolidation of the space industry and the change of NASA procurement philosophy with the introduction of Faster-Better-Cheaper (FBC).

FBC was mainly applied to NASA developmental programs and justified on the grounds of diminishing budgets and was designed to drive down costs of space programs (see Norwood 1997, who also discusses the expected benefits of this policy on commercial markets, and also Hoben 1997 for a discussion of precursors to this approach from the 1970s). Despite successes in cutting costs and size of exploration programs, there were a number of failures of high-profile programs that caused criticism in terms of unacceptable high-risk-driven cost savings, as well as major delays (Wheeler 2006).

Such policy changes can potentially impact the level of competition in contracting, types of contracts, and ultimately affect the rent and cost of space

[1] On the other hand, given the future development of commercial space programs (X-price foundation program for suborbital launch vehicles, see Coren 2004), public requirements of space agencies could largely be met by commercial projects resulting in budgetary savings.

programs. It is expected that FBC would result in more competitive tendering and more fixed-price competition contracts, which could act as a counterbalance to the consolidation of the industry and reinforce the bargaining position of NASA. Boeing (1998) states:

> Since 1994 a significant percentage of information, space and defense systems segment business has been in developmental programs under cost-reimbursement-type contracts, which generally have lower profits than fixed-price-type contracts.

The inability to account fully for such factors, given the difficulties associated with quantifying the adoption and application of such policies, is a limitation of this analysis that must be kept in mind when interpreting the findings. The analysis will focus on a subset of the procurement issues discussed, by first looking into the behavior of NASA towards competition.

In the following analysis empirical evidence is presented to examine NASA's procurement behavior with regards to competitive tendering to the industry and distribution of contract types.

III. Empirical analysis of competition in NASA contracting

This Section analyses the determinants of the level of competition in NASA contracting through time. Table 1 presents a list of variables used and their description.

Figure 1 illustrates that the first half of the 1990s saw a reversal of a pro-competitive trend in NASA contracting, since the end of the Apollo program (early 1970s). Though this trend changed towards the end of the 1990s, there is a balance between competitive and non-competitive contracts awarded towards the end of the 1990s, as opposed to the situation in 1990 when non-competitive contracts were just 18% of the total. Overall, from 1970 to the early 1990's, competitive contracts are increased as a percentage of the total.

The decline in the value of NASA competitive contracts as a percentage of the total value awarded (*NASAc*) in 1986 and 1987 is attributed to effects of changes in reporting practices followed by NASA (NASA 1987: 10):

> It should be recognized that a change was made in reporting categories for this year's report [1987] which had an impact on NASA's reported

Table 1. Description of time series variables

Variable	Description
CPAF	Cost plus award fee contracts (percentage of the total value of contracts awarded by NASA)
CPFF	Cost plus fixed fee contracts (percentage of the total value of contracts awarded by NASA)
FFP	Firm fixed price contracts (percentage of the total value of contracts awarded by NASA)
INC	Incentive contracts (percentage of the total value of contracts awarded by NASA)
NASAc	Value of NASA competitive contracts as a percentage of the total value awarded;
NASAnc	Value of NASA non-competitive contracts as a percentage of the total value awarded.
NASA top10	Contracted value to the top 10 firms as a percentage of the total appropriations made by NASA
SENASA	Space appropriations made by NASA at constant 1999 prices

Note: the inclusion of the letter "L" prior to all variables denotes the log of the respective time series (i.e., LCPAF: log of CPAF). All figures are annual.

Figure 1. Competition in NASA contracts as a percentage of total contracts awarded

Note: NASAc: the value of the NASA competitive contracts as a percentage of the total value awarded; NASAnc: the value of the NASA non-competitive contracts as a percentage of the total value awarded. Data sources: NASA (1983) to (2004a).

> competitive performance. In order to be consistent with established Government wide reporting of competition statistics for Government-owned contractor-operated facilities, we have excluded dollars associated with the contracts for the operation of NASA's Jet Propulsion Laboratory from the procurements available for competition in Fiscal Year 1987. This reclassification of procurement awards resulted in an increase of approximately 10 percent in NASA's competitive percentage for Fiscal Year 1987. Consequently, the Fiscal Year 1986 and 1987 competition data are not completely comparable.

In contrast, from the early 1990's until 1997 *NASAc* is declining, despite consistent reporting practices (Figure 1). In view of the consolidation of the US space industry experienced during the same period, it seems plausible to suggest that this consolidation had a negative effect on the percentage of competitive contracts awarded by NASA that was not counterbalanced by FBC. The increase in the value of the NASA non-competitive contracts as a percentage of the total value awarded (*NASAnc*) towards the end of 1990s is against the spirit of the Competition in Contracting Act of 1984 (CICA) which is applied to all US federal agencies and calls for: "...full and open competition by soliciting sealed bids or requesting competitive proposals, or use other competitive procedures, unless a statutory exception permits other than full and open competition..." (NASA 1985). Such statutory exceptions are of seven general types (NASA 1997): (1) Only one responsible source exists and no other supplies or services will satisfy agency requirements; (2) Unusual and compelling urgency; (3) Industrial mobilization; or engineering, development, or research capability; (4) International agreement; (5) Statutory authorization or requirement; (6) National security; (7) Public interest.

A critical analysis of (1) to (7) would indicate that even though these types seem to ensure the presence of competition in the vast majority of new contracts, there are a number of reasons why they might not be sufficient. To begin with, the recent consolidation of the industry in the US has a direct effect on the first (1) of these justifications, by substantially narrowing down the number of sources and raising the possibility of collusion of space firms, given the diminished numbers.

Industrial consolidation also affects (3), since major research capabilities of space firms are increasingly concentrated in the hands of space integrators that have different structures and often specializing in different product areas, trying to establish themselves in different projects and enjoy monopoly rents.

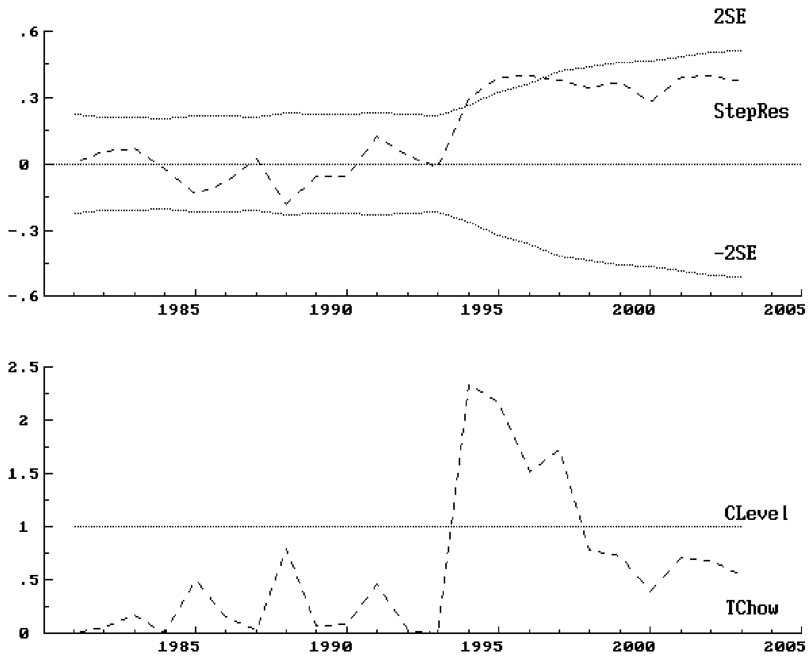
Overall, in analysing the behaviour of the level of competition on NASA contracts, the variables that are expected to affect it are the proportion of contracts awarded to the top contractors through time and NASA space appropriations (SE_{NASA}). Despite NASA's stated pro-competitive policy, industrial consolidation could therefore become a key factor in explaining an increasing number of contracted values on a non-competitive basis as a percentage of the total appropriations (*NASAnc*- the time series includes follow-on contracts awarded on a non-competitive basis). In testing this hypothesis, it is important to consider the impact "mega-mergers" of the mid-1990s had in the relationship between *NASAnc*, SE_{NASA} and the value of the contracts awarded to the top 10 NASA contractors as a percentage of the total (*NASAtop10*).

The econometric tests were initially performed using recursive least squares (RLS), a method whose results are similar to OLS, but in addition tests for structural breaks (see Doornik and Hendry 1995, and Figure 2 for details). The variables used for the estimation were all in logarithmic form to help reduce heteroskedasticity and normalise variables with very differently scaled data to obtain meaningful elasticities from the estimations (*LNASAnc*, LSE_{NASA} and *LNASAtop10* are respective the logs of *NASAnc*, SE_{NASA} and *NASAtop10*). The data sources used for the empirical analysis are NASA annual procurement reports (NASA 1983 to 2004a) and NASA (2004b). The sample was chosen to start from 1974. This was due to the fact that during the late 1960s massive appropriations to NASA were followed by sizeable reductions in the early 1970s which meant that this era's budgetary and contract behaviour was atypical. This was because NASA's original purpose of existence, the Apollo program to send the man to the moon before the end of the 1960s, was successful. This period is characterised by the agency's set-up costs and massive, Apollo program-specific budgetary appropriations that were set to decline post-1969 when the first successful mission to the moon was accomplished and continued to do so until the mid-1970s when the program terminated. The use of RLS reveals the presence of a structural break in 1994 (Figure 2), which leads to the use of a step dummy variable (*s1994*) and a re-evaluation of the relationship using OLS in Table 2.

The step dummy variable is used because the size of the consolidation is only partially captured by *LNASAtop10*. This is because the list of NASA's top contractors does not take into consideration firms, but establishments, which means that it does not fully capture the concentration of contracts to consolidated firms with several divisions.

As Table 2 indicates, the performance of the re-estimated model with the incorporation of the step dummy variable to account for the consolidation of the

Figure 2. Recursive graphics



Notes: The recursive graphics are based on the recursive least squares (RLS) estimation with *LNASAnc* as dependent variable and LSE_{NASA} and *LNASAtop10* the independent variables. The use of the RLS method of estimation (see Doornik and Hendry, 1995) is chosen to graphically illustrate the presence of structural breaks. The methodology employed by the recursive method of estimation of a model for a sample with *T* observations is to apply successive OLS estimates to the model starting with *M* observations ($M<T$), and then fit the model to *M+1*, *M+2*,... up to *T* observations (Doornik and Hendry, 1995: 140). This way a number of successive residual sums of squares are obtained based on which a sequence of tests for structural breaks and parameter constancy can be conducted (ibid: 268). Two graphics-based tests for parameter constancy are presented. The top graph presents the one-step residuals test, where the one-step residuals of $y_t - x_t\beta_t$ (S*tepRes*) are bordered by plus and minus two standard deviations from *M* to *T* sample observations (*2SE* and -*2SE*, respectively). Points outside the boundaries reveal coefficient changes. The lower graph presents the one-step Chow test, which is based on one-step forecast tests (*TChow*) following the F-distribution with 1, *t*-*k*-1 degrees of freedom for $t=M,...,T$ and a null of parameter constancy (Doornik and Hendry, 1995: 328). Points above a chosen (5%) level of significance in the diagram (*CLevel*) reveal the time period for which the null is rejected. Both graphs are for M=5 and reveal a major structural break in 1994, as expected.

US industry in the 1990s reveals major improvements over the RLS estimation (Figure 2). All variables are significant, have the expected sign and the explanatory power of the model is very high (89%). As expected, there is a negative and significant relationship between LSE_{NASA} and the relative size of non-competitive contracts with the coefficient of LSE_{NASA} equal to -0.42. The interpretation of this is that a one US$ change in SE_{NASA} leads to a 0.42 cents change in the opposite direction of *NASAnc* contracts. As a result, downward trends in the NASA space expenditure post-Cold War are resulting in upward changes in the non-competitive contracting value.

Table 2 . Modelling *LNASAnc* by OLS (1974 to 2003)

Variable	Coefficient	Std.Error	t-value	r^2
Constant	-0.78	3.15	-0.25	0.00
LSE_{NASA}	-0.42	0.12	-3.39	0.31
LNASAtop10	1.92	0.58	3.31	0.30
s1994	0.58	0.05	12.41	0.86

$R^2 = 0.89$, $F(3, 26) = 71.12$ [0.00] DW = 1.44; RSS = 0.26 for 4 variables and 30 observations.

The diagnostics reveal no problems with autocorrelation, ARCH effects, or normality of the error term (probabilities in brackets):

AR 1- 2F(2, 24) = 1.23 [0.31]
ARCH F(1, 24)= 0.00 [0.95]
Normality Chi(2) = 0.13 [0.94]

Notes: *LNASAnc*: the logarithm of the value of the NASA non-competitive contracts as a percentage of the total value awarded; LSE_{NASA}: the log of NASA space appropriations at constant 1999 prices; *LNASAtop10*: the log of NASA contracted value to the top 10 firms as a percentage of the total appropriations; *s1994*: step dummy variable capturing consolidation-effects of the US space industry in the mid-1990s. Data sources: NASA (1983) to (2004a) and NASA (2004b).

To measure the impact of the structural break taking place around the mid-1990s on the level of competition in NASA contracts, we can re-estimate the relationship of Table 2 without the step dummy variable with sample range from 1974 to 1997 and forecast the period from 1998 to 2003. The numerical difference between the forecasted and the actual value is an approximation of the impact of the industrial consolidation on the level of competition in NASA's contracting behaviour. The forecasts are thus expected to be significantly lower than the actual value of *LNASAnc* throughout the forecast period. The performance of the relevant estimation was much poorer than that in Table 2 (all right hand side variables insignificant and an R-square of 0.2). In addition, the forecast values were persistently lower than the actual ones. On average, from 1998 to 2003, the actual percentage value of contracts awarded by NASA on a non-competitive basis were 12.5% higher than they would be without taking into account the consolidation of the US industry. The forecast error varied between 0.23 in 1998 and 0.21 in 2001 with no strong trend, so a single dummy seems adequate.[2]

Given the absence of empirical evidence on the comparative impact of competitive and non-competitive contracts on profit margins, we must be cautious about making inferences that NASA's awarding policy is expected to lead to an increasing profit stream for the US space industry. A safer conclusion is that since the mid-1990s, NASA procurement with regards to the level of competition applied in the awarding process has resulted in less competitive outcomes, driven primarily by industrial consolidation and a diminished "pool" of contractors.

IV. Rent control and contract distribution

Rent control can also be achieved in the absence of competition, through the alternative use of specific types of contracts that provide the right type of incentives, but this can be at the expense of higher program-costs as we will see later. Information asymmetries between the agent and the principal and monitoring costs make this mechanism less preferred to the "invisible hand" of competition. In practice, NASA policy calls for price competition when possible, as "Normally effective price competition results in realistic pricing and a fixed-price contract is ordinarily in the Government's interest" (NASA 1998: 4).[3] The preference for fixed price contracts over the cost-plus type of contracts is explained on the grounds that the government bears less of the program risk and the firm has stronger incentives to be cost-efficient.

[2] In contrast, when the estimation of Table 2 was done with 6 forecasts (1998-2003), the forecast standard error varied from 0.116 to 0.123 and the actual percentage value of contracts awarded by NASA on a non-competitive basis from 1998 to 2003 were on average just 3% higher than the forecasted values.

[3] On the other hand, NASA guidelines of contracting include price competition, price analysis, cost analysis, type and complexity of the requirement and urgency of the requirement (NASA 1998). Such guidelines allow room for discretion. The possibility of collusion between major space integrators arises to exploit such discretionary policies especially during the presence of large scale programs (Moon, Mars exploration). For example, the awarding of contracts has to ensure that both Boeing and Lockheed Martin maintain their space business, so there is no possibility of 'winner takes all' procurement policy implementation (see Zervos 2001).

The generic nature and uncertainties of most major government-led space programs, as in other high technology industries, give rise to the formation of incomplete contracts within the industry. Thus, program-specific costs that imply a long term relationship between the supplier and the agency are often necessary, and it is costly (and of uncertain benefit) to include uncertainty clauses in contracts. There are three main contract categories used by NASA: Fixed-price contacts, cost-reimbursement contracts and incentive contracts.

Fixed price contracts (FP) are of two types: Firm-fixed price contracts and fixed price contracts with economic adjustment. As stated earlier, fixed price contracts are in the government interest, provided there is competition in their awarding and there are no major uncertainties associated with the program/components. Cost reimbursement (CR) contracts employed by NASA are of two main types: Cost plus fixed fee (*CPFF*) and cost plus award fee (*CPAF*). Other types, such as cost plus percentage profit are excluded because they give strong incentives to the industry to inflate costs. *CPAF* contracts are classified as such by NASA since 1983; prior to this date the relevant contracts were placed under the "Incentive-contract" classification.[4]

Finally, incentive contracts (*INC*) can be used with regards to cost, or performance incentives, and provide a mix between the extremes of cost-but-no - rent minimization of FP contracts and rent-but-no-cost minimization of CR contracts (see Zervos 2001).

Figure 3 presents data of NASA contract types as a percentage of the total from 1983 to 2004. It is clear from Figure 3 that cost-reimbursement contracts (*CPAF* plus *CPFF*) constitute the largest share of the total since 1983. On this basis, profit minimization, or regulation of profits are seen as major priorities in NASA's behavior in awarding contracts to the industry over time. However, Figure 3 also indicates a decline of cost plus contracts as a percentage of the total since 1990, to be matched by a respective increase in incentive contracts ("mirror image"). This pattern could signal a more rent-favoring approach by NASA from the mid-1990s. Such an approach resulted in 2000 in a contract distribution similar to the mid-1980s (with *CPAF* below the 50% mark and *INC* around the 30% mark). The

[4] Prior to 1983, NASA classification of contract types did not contain cost-plus-award-fee (CPAF) contracts, but only firm-fixed-price (*FFP*), incentive (*INC*) and cost-plus-fixed-fee (*CPFF*). Therefore, for reasons of compatibility the sample of the time series examination of contract distribution is set from 1983 to 2003. Furthermore, given that the relative distribution of contracts is important and to avoid unnecessary price effects the values of the contract-types time series are presented as a percentage of the total value of NASA awards.

FFP series show a marginally increase since the early 1990s indicating that the FBC policy did not have a major effect on this type of contract. This means that NASA during the second half of the mid-1990s moved from placing greater emphasis on rent extraction to placing increased priority on cost minimization, reflected in a decreasing proportion of contracts awarded under cost-reimbursement schemes.

Figure 3. Contract types employed by NASA as a percentage

Notes: *CPAF*, *INC*, *FFP* and *CPFF* stand for Cost plus award fee, incentive, firm fixed price and cost plus fixed fee respectively. All variables are percentages of the total value awarded annually. Data sources: NASA (1983) to (2004a).

In order to test whether there was a substitution effect between non-competitive contacts and *CPAF* contracts by NASA towards controlling rent to the industry, the equation in Table 2 was estimated with the inclusion of *LCPAF* (the logarithm of *CPAF*). This had no impact on the explanatory power of the equation; in addition the tests on the significance of right hand variables indicated its absence for *LCPAF*. Overall, correlation and visual inspection indicate the absence of a meaningful link between all the explanatory variables of the behavior of the level of competitive tendering (*LNASAnc*) and the type of contract distribution (*LCPAF*), with the exception of budget size (LSENASA). This means that changes in budgetary appropriations affect the behavior of competitive tendering and type of contract distribution in very different and non-systematic ways. An econometric approach in modeling the behavior of *LCPAF* is expected to be of limited use, given the very small sample size. Nevertheless, the modeling was done for purposes of illustration and to further test for whether competitive tendering affected contract distribution. The inclusion of *LNASAnc* at all stages of the relevant estimation revealed no explanatory power of the relevant variable in affecting the behavior of *LCPAF*. Table 3 shows that budgetary appropriations and program-specific policies (*s2001*) are important determinants of the behavior of *LCPAF* since the early 1980s.

The results in Table 3 are not very good in terms of the diagnostic analysis, given the presence of autocorrelation. The use of first differences, lags, or tests for omitted variables (*LNASAnc*) did not improve the performance. It must be noted that the limitations of econometric approaches in explaining the behavior of NASA's contract distribution through time are significant. Limited sample range availability is a severe constraint on top of the inherent constraint of dealing with variables that relate to centrally controlled procurement choices. The illustration purposes of this exercise further reinforce the visual evidence that post-mid-1990s there has been a decrease in *LCPAF*, which indicates that NASA's contract distribution is unlikely to compensate for the reduction in competitive tendering for the same time-period, as a rent-control mechanism.

Table 3. Modelling *LCPAF* by OLS (1983 to 2003)

Variable	Coefficient	Std.Error	t-value	r^2
LSE_{NASA}	0.85	0.23	3.69	0.43
Constant	-3.91	2.17	-1.80	0.15
s2001	-0.32	0.09	-3.80	0.43

R^2 = 0.57 F(2, 16) = 5.34 [0.02] DW = 0.66; RSS = 0.35 for 3 variables and 21 observations.

The diagnostic tests reveal a problem of autocorrelation, but no problems with ARCH effects, or normality of the error term (probabilities in parenthesis):

AR 1- 2F(2, 16) = 5.34 [0.02]
ARCH F(1, 16) = 2.08 [0.17]
Normality Chi(2)= 0.30 [0.86]

Note: for an explanation of the variables and data sources, see Tables 1 and 2.

In the absence of contestability from foreign firms in the US domestic public space market, this appears to be in line with the results of Florens et al (1996). In policy terms, the diminishing of rent-control mechanisms can have substantial implications for the industry. On the one hand, it is possible that coupled with increased consolidation and the exploitation of economies of scale, efficiency gains can be enhanced by increasing investment in R&D and lower program costs. Commercial markets can also benefit from economies of scope and dual-use technologies and R&D. On the other hand, this procurement pattern can have a negative effect on the competitiveness of the US space industry in commercial markets. The reason for this is that the US space industry has no incentive to improve its competitiveness in commercial space markets, given the high rents it enjoys in the domestic US public market. This can potentially lead to a moral hazard situation, where the US space industry has an incentive to under-perform in commercial space markets. The impact of NASA procurement policy (as seen developed post-mid 1990s) on the efficiency and competitiveness of the US space industry is ambiguous and an important research area for the future.

V. Conclusions

This paper examined NASA's behaviour with regards to its procurement policies. The analysis shows that the consolidation of the US space industry (with two major integrators Lockheed Martin and Boeing) combined with absence of overseas competition results in a high proportion of non-competitive contracts awarded to the space industry. In addition, the examination of the behaviour of contract types awarded indicates the absence of a rent-controlling mechanism to compensate for the shrinking of competitive tendering contracts. The potential emergence of powerful producer groups and their role needs to be further examined with respect to their impact on the procurement process of NASA and other space agencies. This will assist to understand better the costs incurred by the public sectors in their efforts to improve industrial efficiency and the competitiveness of the domestic industries in commercial markets.

References

Boeing Company (1998), *Annual Report*, Washington, DC, United States Securities and Exchange Commission (Form K-11 available by SEC EDGAR database at http//sec.gov/archives/edgar/data).

Commission on the Future of the United States Aerospace Industry (2002), *Final Report*, Arlington, VA.

Coren, Michael (2004), "Private craft soars into space, history", Monday, June 21st, CNN news (Online at http://www.cnn.com/2004/TECH/space/06/21/suborbital.test/).

Dews, Edmund (1979), *Acquisition Policy Effectiveness: Department of Defence Experience in the 1970s*, Santa Monica, CA, Rand.

Doornik, Jurgen A., and David F. Hendry (1995), *PcGive 8.0 An Interactive Econometric Modelling System*, London, Chapman and Hall.

European Commission (2002), *Star21*, Brussels, European Commission.

Florens, Jean-Pierre, Marrie-Anne Hugo and Jean-François Richard (1996), "Game theory econometric models: Applications to procurements in the space industry", Discussion Document 62, IDEI.

Garcia, Maria, and Paul Levine (2002), "Domestic procurement, subsidies and the arms trade", in J. Brauer and P. Dunne, eds., *Arming the South: The Economics of Military Expenditure, Arms Production and Trade in Developing Countries*, Palgrave, Macmillan.

Hartley, Keith (1998), "Defence procurement, the single market and the European armaments agency", in S. Arrowsmith and A. Davies, eds., *Public Procurement: the Global Revolution*, London, Kluwer International.

Higgs, Robert, and Anthony Kilduff (1993), "Public opinion: A powerful predictor of US defense spending", *Defense Economics* **4**: 227-238.

Hoben, Francis T. (1997), *Where Do you Go after You've Been to the Moon?*, Kriegen Publishing.

Interagency Working Group (2000), *Future Management and Use of U.S. Space Launch Bases and Ranges*, Washington, DC, White House.

Laffont, Jean-Jacques,. and Jean Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, London, MIT Press.

Lichtenberg, Frank R. (1995), "Economics of defence R&D", in K. Hartley and T. Sandler, eds., *Handbook of Defence Economics*, Elsevier Science B. V.

NASA (1983), *Annual Procurement Report, Fiscal Year 1983*, Washington, DC, NASA.

NASA (1985), *Annual Procurement Report, Fiscal Year 1985*, Washington, DC, NASA.

NASA (1987), *Annual Procurement Report, Fiscal Year 1987*, Washington, DC, NASA.

NASA (1992), *Annual Procurement Report, Fiscal Year 1992*, Washington, DC, NASA.

NASA (1997), *Annual Procurement Report, Fiscal Year 1997*, Washington, DC, NASA.

NASA (2004a), *Annual Procurement Report, Fiscal Year 2004*, Washington, DC, NASA.

NASA (2004b), *Aeronautics and Space Report of the President, 2004*, Washington, DC, NASA.

Norwood, Robert (1997), Untitled, *Aerospace Technology Innovation*,Vol. 5, No. 1, January/February, NASA.

Niskanen, William, Jr. (1971), *Bureaucracy and Representative Government,* Chicago, IL, Aldine Atherton.

Rogerson, P. William. (1991), "Incentives, the budgetary process and inefficiently low production rates in defence procurement", *Defence Economics* **3***:* 1-18.

Sandler, Todd and Keith Hartley (1995), *The Economics of Defense*, New York, Cambridge University Press.

Tyson, Laura D'Andrea (1992), *Who's Bashing Whom? Trade Conflict in High-Technology Industries*, Washington DC, Institute for International Economics.

United States Air Force (USAF) (2001), *The Aerospace Force: Defending America in the 21st Century*, White paper, Washington, DC, Department of the U.S. Air Force.

Wheeler, Larry (2006), "Auditors criticize NASA project planning", 23rd of January, *USA Today*.

Zervos, Vasilis (2001), *The Economics of the European Space Industry*, DPhil Thesis in Economics, University of York, York.