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Using Cost Estimating Relationships to Develop A Price Index for Tactical Aircraft

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Panel 22. Enhancing Cost Estimating Techniques

Thursday, May 15, 2014	
3:30 p.m. – 5:00 p.m.	**Chair: Daniel A. Nussbaum,** Naval Postgraduate School, former Director, Naval Center for Cost Analysis ***A Robust Design Approach to Cost Estimation: Solar Energy for Marine Corps Expeditionary Operations*** Susan Sanchez, Naval Postgraduate School Matthew M. Morse, United States Marine Corps Stephen Upton, Naval Postgraduate School Mary L. McDonald, Naval Postgraduate School Daniel A. Nussbaum, Naval Postgraduate School ***The Budding SV3: Estimating the Cost of Architectural Growth Early in the Life Cycle*** Matthew Dabkowski, U.S. Army/University of Arizona Ricardo Valerdi, University of Arizona ***Using Cost Estimating Relationships to Develop A Price Index for Tactical Aircraft*** Stanley Horowitz, Institute for Defense Analyses Bruce Harmon, Institute for Defense Analyses Daniel Levine, Institute for Defense Analyses

Using Cost Estimating Relationships to Develop a Price Index for Tactical Aircraft

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Abstract

This paper reports on an analysis of cost indexes carried out by the Institute for Defense Analyses (IDA) for the Cost Assessment and Program Evaluation (CAPE) directorate in the Office of the Secretary of Defense (OSD). The research is designed to help CAPE meet the task it was given by the 2009 Weapon Systems Acquisition Reform Act (WSARA), now part of Public Law 111-23, of assessing and updating the cost indexes that the Department of Defense (DoD) employs to ensure the use of realistic cost estimates. Our broader research carries out analysis of three questions: What problems are escalation rates meant to solve, how well do current indexes solve them, and are there other indexes that might do a better job? This paper includes a summary of the findings on the first two questions and focuses the most attention on the third.

Introduction

Problems Escalation Rates Are Meant to Solve

The DoD uses price indexes and growth rates for project management and oversight. Specific uses include the following:

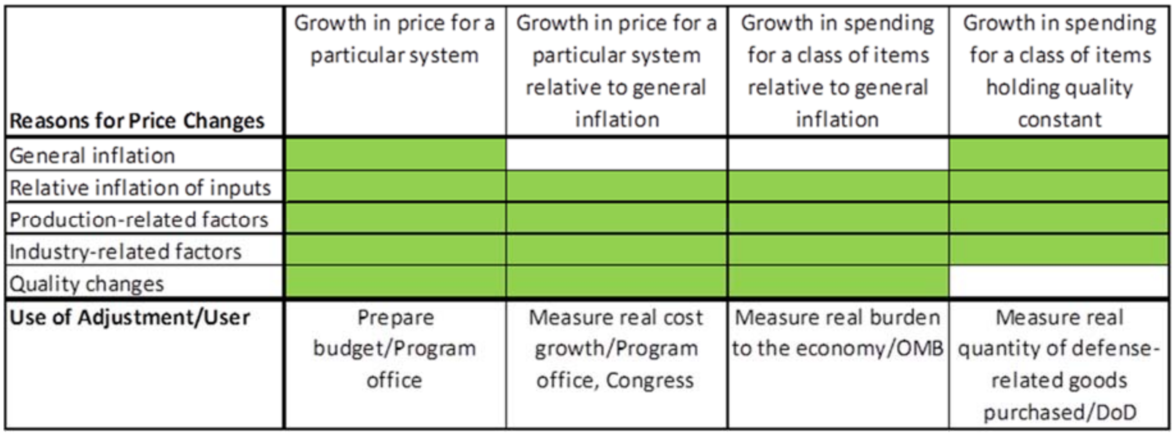
- DoD program office estimates of future prices of weapon systems in then-year dollars for purposes of budgeting individual acquisitions
- Program office and congressional measures of real cost growth of programs
- Office of Management and Budget (OMB) estimates of the burden of the defense procurement budget (or portions thereof) on the economy
- DoD leadership estimates of the volume of items of standardized quality that could have been purchased with the procurement budget (or portions thereof)

Table 1 lists the sources of the price changes measured by indexes that support these goals. Using aircraft procurement for illustration, the first column of bars indicates that program office budget estimates include the growth in prices due to all reasons for price change:

- The *costs of inputs*, measured by (1) the general inflation of the U.S. market basket of goods and services, and (2) the increase in relative prices, beyond general inflation, of the labor, material, and capital inputs that are specific to the aircraft's production.

- *How aircraft are produced*, which captures the production-related factors of labor and capital productivity, including movements along learning curves (declining cost as contractors learn more efficient production techniques)
- The *economic context* of production, capturing industry-related factors that involve changes in the market demand and supply of aircraft that affect producer selling prices and profits
- *The characteristics of what is produced*, often referred to as "quality" changes, referring to improvements in physical and operational specifications such as the aircraft's weight and speed that affect its ability to perform the missions for which it is designed.

Table 1. Application of Price Indexes and Growth Rates



Reasons for Price Changes	Growth in price for a particular system	Growth in price for a particular system relative to general inflation	Growth in spending for a class of items relative to general inflation	Growth in spending for a class of items holding quality constant
General inflation	🟩			🟩
Relative inflation of inputs	🟩	🟩	🟩	🟩
Production-related factors	🟩	🟩	🟩	🟩
Industry-related factors	🟩	🟩	🟩	🟩
Quality changes	🟩	🟩	🟩	
Use of Adjustment/User	Prepare budget/Program office	Measure real cost growth/Program office, Congress	Measure real burden to the economy/OMB	Measure real quantity of defense-related goods purchased/DoD

The second and third columns refer to the growth of "real" prices or spending for particular and general classes of defense goods, prices that are measured in constant dollars that omit the increases due to general inflation. Real price measures are usually constructed by dividing nominal prices by the Gross Domestic Product (GDP) deflator, the summary price measure of goods and services in the U.S. market basket the OMB currently mandates that the DoD use for calculating real prices. The real price growth referred to in the second column is applied in Nunn-McCurdy analyses that are currently used to identify individual weapon acquisition programs that have had significant cost growth and thus require management attention. Management attention is indicated when a system's constant-dollar price during procurement exceeds the price estimate developed during an initial baseline by a congressionally-set percentage.

Deflation by a general inflation index is not only applied to individual weapons for purposes of project management but is also applied by OMB to large classes of expenditures, including the total defense procurement budget, in order to gain insight into the real burden of a portion (or all) of defense spending on the economy. At the all-DoD level, changes in spending deflated in this way are sometimes referred to as "real" growth in defense spending.

Increases in the quantity of defense goods, measured by the last column, are also described in terms of real growth, but real growth here describes how much more equipment *of a given quality* can be purchased for a portion of the defense budget. This might be termed real growth in defense program content, or real defense program growth. It captures increases in the quantity of items purchased and in their quality. Calculating it requires deflating expenditures by a price index that reflects all the reasons for price growth except changes in quality. To the extent that prices for defense-related purchases have risen by more than the general inflation index, deflating expenditures with a general inflation index will overstate real defense program growth.

Assessment of Current Indexes

Figure 1 compares four price indexes related to or often used in aircraft procurement: the Producer Price Index (PPI), published by the Bureau of Labor Statistics (BLS) for civilian aircraft procurement; the National Defense deflator for military aircraft, published by the Bureau of Economic Analysis (BEA) and referred to as the BEA index; the index developed by the Naval Air Systems Command (NAVAIR), which is based on analysis of the cost of individual resource categories; and the Gross Domestic Product (GDP) deflator published by BEA, that OMB mandates for calculating constant-dollar budgets.

We made an effort to understand the source of the zero (slightly negative) growth rate of the BEA index, which is quite inconsistent with both the BLS deflator and the perception of DoD budget analysts that prices of military aircraft (even adjusted for quality improvements) have grown by several percent annually over recent years. Military and civilian aircraft are substantially different, of course, but they are similar enough to raise the question of why their growth rates should be so different. (The difference with the GDP deflator is not puzzling, since military aircraft are a negligible subset of the entire U.S. market basket and there is no reason why military aircraft prices should behave like the average of all prices.) We did not examine the NAVAIR index in any depth. We note that it rose slightly more than the GDP deflator.

We found that the different deflator algorithms used by BEA and BLS do not explain the disparity. The problem may lie with the uncertainty involved in estimating the quality change of new-design aircraft, which is involved in calculating the quality-constant price deflator. BEA analysts find, for example, that estimating the cost of quality change in a radically new-design aircraft such as the F-35 over the F-15 is difficult as a practical matter, and they instead use the full price difference that is reduced by the degree of anticipated learning (with some adjustment for general inflation). Underestimating the learning adjustment would therefore lead to overestimating the cost of quality change, leaving less of the price increase remaining for assignment to the growth of input costs that are captured by the price deflator. We lacked access to the BEA and BLS data needed for definitive analysis of this question.

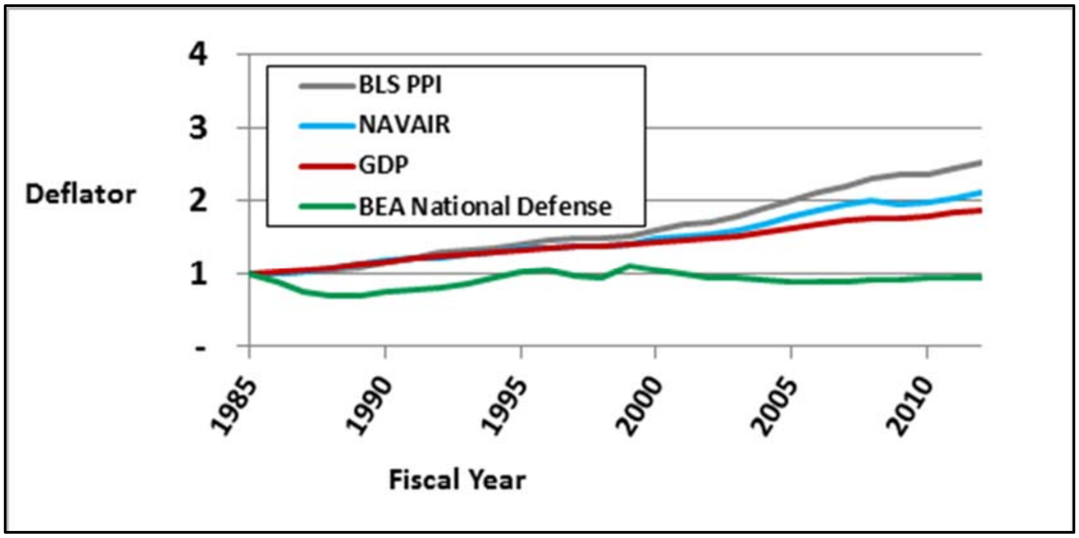


Figure 1. **Deflators Commonly Used in Aircraft Analysis**

Hedonic Indexes for Tactical Aircraft

Introduction

This section responds to the WSARA "update" task mentioned above, which was to identify a price index that is better than current indexes at meeting the DoD's need for a sound basis for cost estimation.

As described above, the BEA and BLS currently calculate quality-constant indexes for aircraft by starting with system prices and subtracting the estimated unit procurement costs of the quality changes. Here we take an entirely different approach, adopting a hedonic methodology described by Equation 1. Statistical regression is used to relate system cost in nominal, then-year dollars to data describing year, the physical and operational quality variables rather than their procurement costs, and control variables. The coefficient of time is identified as the price index, which the presence of the quality variables ensures is calculated holding quality constant.

$$\text{nominal system prices} = \text{f(year, quality variables, other control variables)} \quad (1)$$

Building hedonic indexes is similar to development of cost estimating relationships (CERs), which also relate system price to quality variables, but in which the price index has a much different role. In most CER analysis, described by Equation 2, an economy-wide price index such as the GDP deflator is used to first generate the aircraft's price in real, or constant-dollar, terms before regression on the quality variables.

$$\frac{\text{nominal system prices}}{\text{general price index}} = \text{real prices} = \text{f(quality variables, other control variables)} \quad (2)$$

Hedonic indexes possess two major advantages. First, the price index is a fallout of the analysis that depends on the features of the aircraft under analysis. The CER, by comparison, uses an economy-wide, non-aircraft-specific price index to calculate the dependent variable. Second, the physical and operational quality variables of the hedonic regression are available from legal contracts and from Developmental Test and Evaluation (DTE) and Operational Test and Evaluation (OTE). They are not infected with the uncertainties that are inherent in estimates of the procurement cost of the quality features.

The remainder of this section describes the data and analysis of several hedonic indexes for military tactical aircraft.

Data

The hedonic analysis used in this chapter follows the direct time-dummy variable approach formulated by Triplett, an early developer of hedonic analysis (Triplett, 2006). Table 2 shows the explanatory or independent variables: five quality variables describing the aircraft; two variables describing the quantity, or number of aircraft produced for use in incorporating the effects of learning and production rate in the procurement process; and time.

Table 2. Explanatory Variables

Quality variables
- Empty weight in pounds
- Maximum speed in knots
- Advanced structural materials percentage
- Dummy variable for 5th generation aircraft[a]
- Dummy variable for STOVL aircraft[b]

Quantity variables
- Cumulative production
- Per-lot production

Time dummy variables

[a] 5th generation aircraft are characterized by stealth, internal weapons carriage, avionics with information fusion and support of net-centric operations. In our sample, the F-22 and F-35 A/B/C are classified as 5th generation aircraft.

[b] The AV-8B and F-35C, aircraft with Short Take-Off and Vertical Landing (STOVL) capability that can operate from small aircraft carriers and short unimproved airfields.

The database is pooled cross-section and time-series data, often called *panel data* in the econometrics literature. Time can be measured in the present analysis either by fiscal years or aircraft production lots. The time-series covers the fiscal years (or lot numbers) for the 40-year period 1973 to 2012. Each year other than the base year, 2012, is given a different time dummy in order to calculate different price indexes for each year. The cross-sections are the 22 aircraft programs shown in Table 3, consisting of 11 “original designs” plus 11 “derivatives” of these designs from series or block changes.[1]

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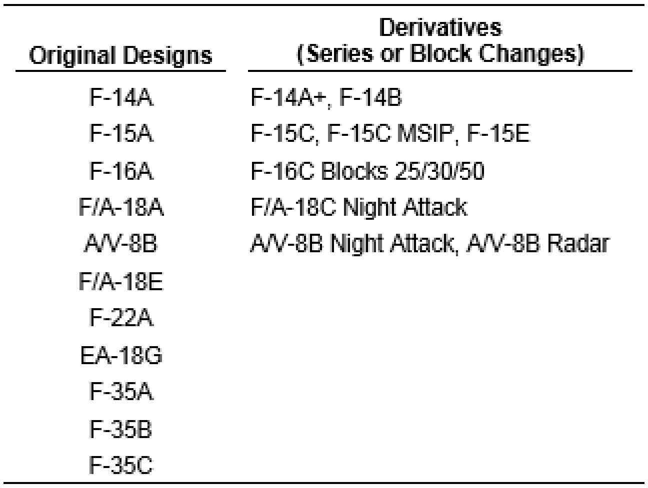
[1] Military aircraft are described by MDS (Mission-Design-Series). For the F-14A, for example, mission = F (fighter), design = 14, and series is A. The aircraft in the left column of Table 3 were treated in the regression as a single time-series panel. They are the first series of a new design with two exceptions: the F/A-18E, which was a major change from the previous F/A-18s, and the three F-35 variants which were built for different missions and produced in parallel. The aircraft in the right column are either new series (e.g., F-14B) or new block upgrades (e.g., the F-14A+ and the F-16C 25/30/50).

Table 3. Aircraft Programs



Original Designs	Derivatives (Series or Block Changes)
F-14A	F-14A+, F-14B
F-15A	F-15C, F-15C MSIP, F-15E
F-16A	F-16C Blocks 25/30/50
F/A-18A	F/A-18C Night Attack
A/V-8B	A/V-8B Night Attack, A/V-8B Radar
F/A-18E	
F-22A	
EA-18G	
F-35A	
F-35B	
F-35C	

The quality changes associated with derivative aircraft, as well as smaller year-to-year quality changes, are captured by changes in empty weight from year to year.

Models for Analysis

Overview

This section introduces the three models in broad terms.

Full CER Hedonic Model. The Full CER model regresses nominal system prices on all the explanatory variables listed in Table 2. It fits the data with a high R^2 of 0.97, and the coefficients of the quality variables were all positive as expected (they all represent added cost) and statistically significant at the 5% level or better.

Coefficients on weight ($weight^{0.83}$), speed ($speed^{0.30}$) and materials composition ($1.67^{\text{advanced materials percentage}}$) were consistent with those reported in past CER studies (Harmon, 2012; Harmon, Nelson, & Arnold, 1991; Resetar, Rogers, & Hess, 1991; Younossi, Kennedy, & Graser, 2001); unit prices increase with higher weight, higher maximum speed, and more advanced materials. Estimates for the STOVL and 5th generation aircraft indicated 10% and 11% premiums for those capabilities. The 5th generation premium is consistent with values from an earlier IDA study on the cost of stealth (Nelson, Harmon, Bontz, & Devers, 2001).

By including the quantity variables in the regression, the coefficients of the quality variables are calculated holding quantity constant. But quantity affects system price as does quality, so holding them constant defeats the purpose of a price index. The price index should reflect changes in productivity that are normalized away by the quantity changes.

Alternative Hedonic Model. The Alternative model avoids this problem by omitting the quantity variables. The reduction in the number of explanatory variables leads to a poorer but still reasonably high R^2 of 0.84. Excluding explanatory variables associated with quantity, however, results in problems in estimating the quality variables. Aircraft with more capability or higher quality are usually bought in smaller quantities, and aircraft produced more recently are more capable (e.g., 5th generation capabilities) and are also bought in smaller quantities. This resulted in the model producing empirically unacceptable estimates for the coefficients of the quality variables: a negative coefficient for maximum speed, an unreasonably large premium for advanced materials ($3.97^{\text{advanced materials percentage}}$) and an 85%

premium 5th generation aircraft that is much higher than estimated by Nelson et al. (2001). These are severe drawbacks; therefore, this model will not be discussed further.

Preferred Hedonic Model. The Preferred model proved satisfactory on statistical and empirical grounds. It leaves out the quantity variables, to be consistent with the purposes of a price index, but avoids the unacceptable results just described by fixing the quality variables at the values that were obtained from estimating the Full CER model. The coefficient of time, identified as the price index, is therefore the only variable to be estimated. The results of the model, described below, meet acceptable statistical and empirical criteria.

Detailed Analysis

This section discusses the Full CER and Preferred models in depth.

Full CER Model. The Full CER model and definition of terms are shown below:

$$ln\ \llbracket UC \rrbracket_{tk}^{TY} = ln\left[f\left(Q_{(t-1)k,} q_{tk}, \mathbf{Z}_k, D_t, \boldsymbol{\beta}, \boldsymbol{\varphi}, \delta_t\ , \ldots\right) + \varepsilon_{\mathrm{jk}}\right] \quad (3)$$

Where

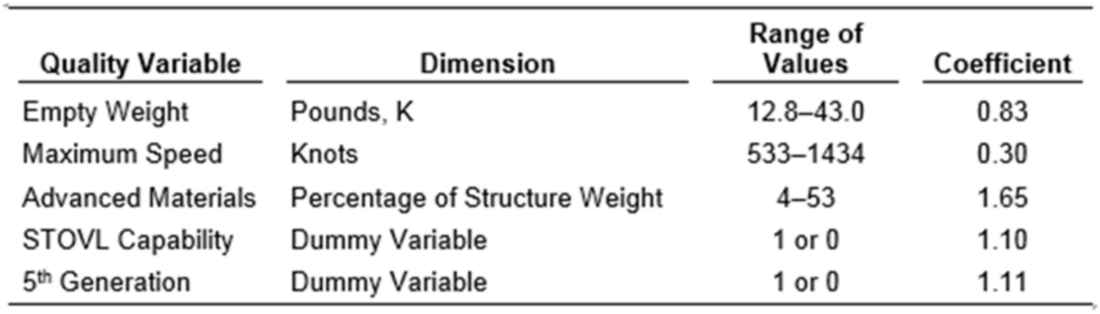
1. UC_{tk}^{TY} is the unit recurring flyaway cost in nominal (then-year) dollars for the kth aircraft program in year (or lot) t. The aircraft programs are listed in the earlier Table 3, and the data run from 1973 to 2012.
2. $\mathbf{Z}_{\mathrm{k}}$is the vector of five quality variables for the kth aircraft (Table 4). (There is no t subscript because all the aircraft of type k are described by the same quality variables.) $\mathbf{Z}_1$, for example, is the vector of quality variables for the F-14A.
3. Q and q are the quantity variables. $Q_{(t-1)k}$ is the cumulative quantity of the kth aircraft produced through $t-1$, and therefore available at the start of t. q_{tk} is the quantity of aircraft produced in lot t.
4. D_t is the time dummy variable for lot t.
5. $\boldsymbol{\beta}$ is the vector of coefficients for the quality variables.
6. $\boldsymbol{\varphi}$ is the vector of coefficients for the quantity variables.
7. δ_t are the coefficients of the time dummy variables (i.e., the price indexes).
8. $\varepsilon_{\mathrm{jk}}$ is the normally distributed error term.

The model requires etimating coefficients for 55 variables:

- Five quality variables (the variables are the same over aircraft programs and time)
- Four quantity variables (the variables are the same over aircraft programs and time)
- Forty time dummies (the 41 years during 1973 to 2013 less one for the 2012 base year)
- Five program-specific dummies (which are also related to learning and fixed cost)
- One intercept

There are enough data, however, to estimate all the coefficients: 150 non-zero values for the 441 aircraft-year combinations (11 original aircraft programs during the 40 years between 1973 and 2013). The time dummies were structured such that ${\delta_{FY12}}^{D_{FY12}} = 1$, making FY 2012 the base value. The model was estimated using the maximum likelihood technique. The coefficients for the full model are shown in Table 4.

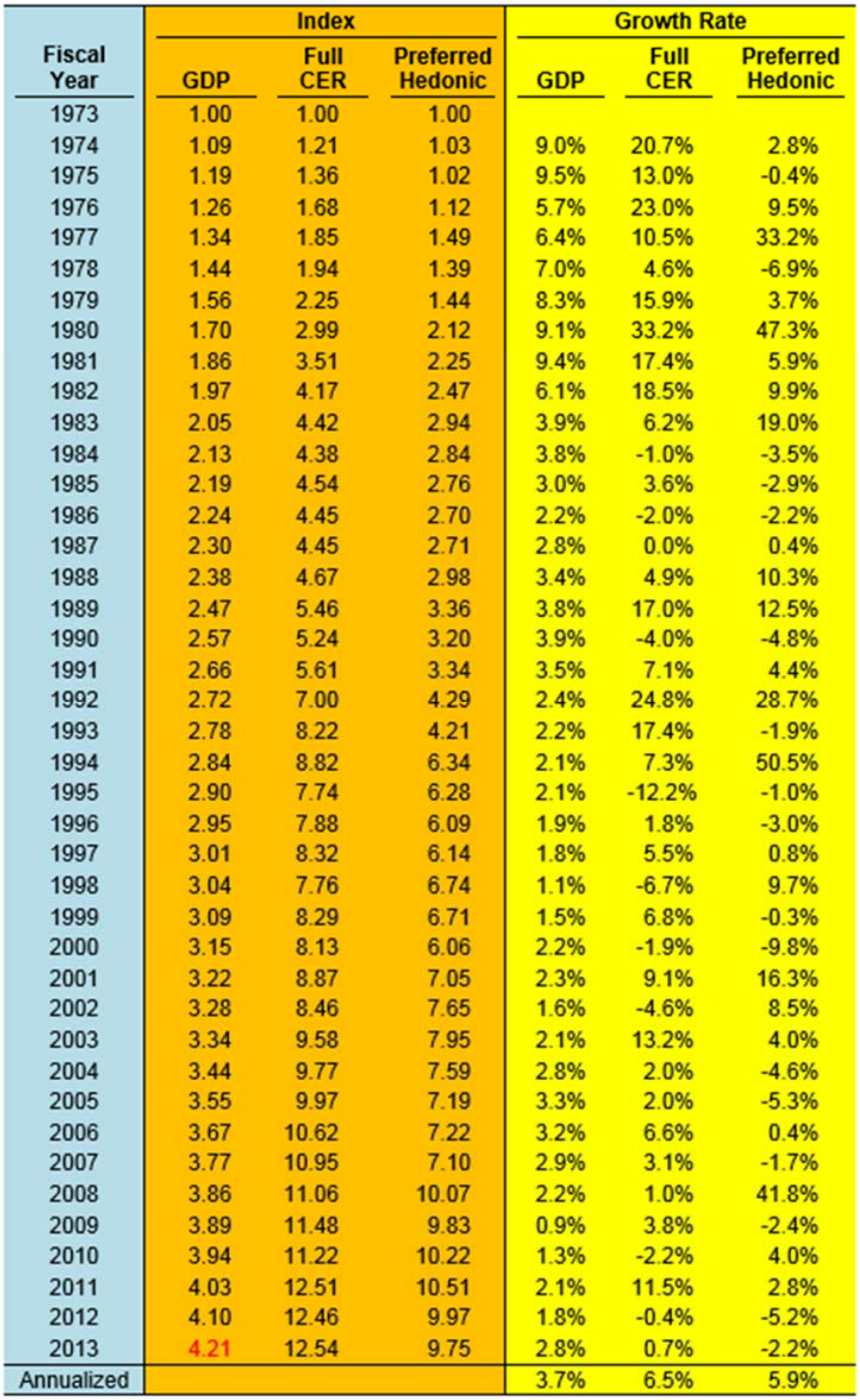
Table 4. Quality Variables and Parameter Estimates



Quality Variable	Dimension	Range of Values	Coefficient
Empty Weight	Pounds, K	12.8–43.0	0.83
Maximum Speed	Knots	533–1434	0.30
Advanced Materials	Percentage of Structure Weight	4–53	1.65
STOVL Capability	Dummy Variable	1 or 0	1.10
5th Generation	Dummy Variable	1 or 0	1.11

Table 5, Figure 2, and Table 6 compare the GDP with the two hedonic deflators by their annual indexes, annual growth rates (AGRs), and annualized growth rate for the entire period 1973 to 2013. (The GDP deflator for 2013 was extrapolated using the trend line calculated from the preceding 10 years.) The hedonic models show much larger growth than the GDP deflator, in line with DoD manager expectations. They also show much greater year-to-year variability, reaching huge values in a few years.

Table 5. GDP and Hedonic Indexes and Growth Rates



Fiscal Year	Index GDP	Index Full CER	Index Preferred Hedonic	Growth Rate GDP	Growth Rate Full CER	Growth Rate Preferred Hedonic
1973	1.00	1.00	1.00			
1974	1.09	1.21	1.03	9.0%	20.7%	2.8%
1975	1.19	1.36	1.02	9.5%	13.0%	-0.4%
1976	1.26	1.68	1.12	5.7%	23.0%	9.5%
1977	1.34	1.85	1.49	6.4%	10.5%	33.2%
1978	1.44	1.94	1.39	7.0%	4.6%	-6.9%
1979	1.56	2.25	1.44	8.3%	15.9%	3.7%
1980	1.70	2.99	2.12	9.1%	33.2%	47.3%
1981	1.86	3.51	2.25	9.4%	17.4%	5.9%
1982	1.97	4.17	2.47	6.1%	18.5%	9.9%
1983	2.05	4.42	2.94	3.9%	6.2%	19.0%
1984	2.13	4.38	2.84	3.8%	-1.0%	-3.5%
1985	2.19	4.54	2.76	3.0%	3.6%	-2.9%
1986	2.24	4.45	2.70	2.2%	-2.0%	-2.2%
1987	2.30	4.45	2.71	2.8%	0.0%	0.4%
1988	2.38	4.67	2.98	3.4%	4.9%	10.3%
1989	2.47	5.46	3.36	3.8%	17.0%	12.5%
1990	2.57	5.24	3.20	3.9%	-4.0%	-4.8%
1991	2.66	5.61	3.34	3.5%	7.1%	4.4%
1992	2.72	7.00	4.29	2.4%	24.8%	28.7%
1993	2.78	8.22	4.21	2.2%	17.4%	-1.9%
1994	2.84	8.82	6.34	2.1%	7.3%	50.5%
1995	2.90	7.74	6.28	2.1%	-12.2%	-1.0%
1996	2.95	7.88	6.09	1.9%	1.8%	-3.0%
1997	3.01	8.32	6.14	1.8%	5.5%	0.8%
1998	3.04	7.76	6.74	1.1%	-6.7%	9.7%
1999	3.09	8.29	6.71	1.5%	6.8%	-0.3%
2000	3.15	8.13	6.06	2.2%	-1.9%	-9.8%
2001	3.22	8.87	7.05	2.3%	9.1%	16.3%
2002	3.28	8.46	7.65	1.6%	-4.6%	8.5%
2003	3.34	9.58	7.95	2.1%	13.2%	4.0%
2004	3.44	9.77	7.59	2.8%	2.0%	-4.6%
2005	3.55	9.97	7.19	3.3%	2.0%	-5.3%
2006	3.67	10.62	7.22	3.2%	6.6%	0.4%
2007	3.77	10.95	7.10	2.9%	3.1%	-1.7%
2008	3.86	11.06	10.07	2.2%	1.0%	41.8%
2009	3.89	11.48	9.83	0.9%	3.8%	-2.4%
2010	3.94	11.22	10.22	1.3%	-2.2%	4.0%
2011	4.03	12.51	10.51	2.1%	11.5%	2.8%
2012	4.10	12.46	9.97	1.8%	-0.4%	-5.2%
2013	4.21	12.54	9.75	2.8%	0.7%	-2.2%
Annualized				3.7%	6.5%	5.9%

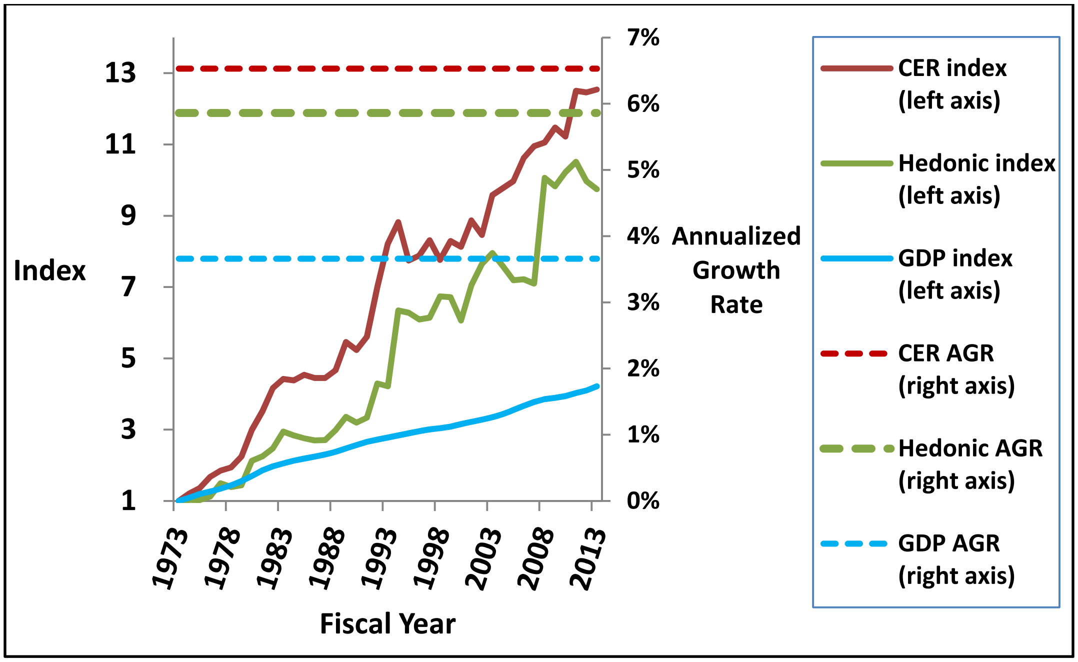
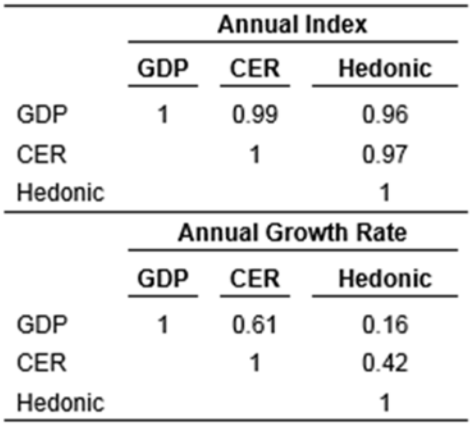


Figure 2. Hedonic and GDP Deflators

Table 6. Index Correlations



	Annual Index		
	GDP	**CER**	**Hedonic**
GDP	1	0.99	0.96
CER		1	0.97
Hedonic			1
	Annual Growth Rate		
	GDP	**CER**	**Hedonic**
GDP	1	0.61	0.16
CER		1	0.42
Hedonic			1

The model fits the data with a high adjusted R^2 of 0.97 and a standard error in log space of 0.09. The coefficients were all positive, as expected, and statistically significant at the 5% level or better. The coefficients of time, moreover, led to reasonable deflators (estimates of growth) discussed below and shown in Figure 5.

The estimated exponent of cumulative quantity is -0.25, which corresponds to an 84% learning curve slope, a rate commonly reported in the aircraft econometrics literature.[2] The effect of production rate was calculated by estimating the annual fixed cost for each

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[2] In the learning curve, $Cost = Q^{\log_2 S}$, so if $\log_2 S$= -0.25, S = 0.84.

program.[3] Learning spillovers due to commonality between the EA-18G and F/A-18E/F and F-35 variants were included in the model.[4] Loss of learning due to series/block changes was also accounted for.

Figure 3 provides additional information through a Quality Index for each of the 22 aircraft programs. The Index was calculated for each program as the product of values of its quality variables each weighted by the variable’s regression coefficient and normalized to the calculated value for the F-35A. This type of exhibit can serve as a top-down check on more detailed costs.

Figure 4 shows the fit of the model by comparing the prices predicted by the regression to the actual system prices of the aircraft programs shown by the 150 data points represented by triangles. Note that although the regression is carried out for all 22 aircraft programs, the curves in Figure 4 combine results for the 11 original designs and their derivatives. The curve labeled F-14A/B, for example, shows how well the regression fits the data for the original design F-14A and its derivatives F-14A+ and F 14B.

Although the dependent variable of the regression, Equation 3, is nominal price, the data for Figure 4 were first adjusted to FY 2012 constant dollars using the estimated price index values: $UC_{tk}^{FY12} = \frac{UC_{tk}^{TY}}{{\delta_t}^{D_t}}$. The price index estimated by this model has a 6.7% compounded average growth rate (CAGR) from 1973 to 2012, compared with a CAGR of 3.7% for the GDP deflator for the same time period.

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[3] Higher production rate leads to higher lot quantities, so that the fixed costs per lot are spread over more units with a resulting decrease in the unit fixed costs per lot. Fixed costs for each aircraft program were estimated as a function of peak estimated variable costs.

[4] Learning is incorporated in the regression by assuming that production of the kth aircraft program in lot t, for example, is increased by the production of the other programs in lot t: $Q_{tk} = Q_{(t-1)k} + q_{tk} + \lambda \sum_{l=1}^{k-1} q_{tl}$, where Q_{tk} is the cumulative number of aircraft of program k produced through lot t, $Q_{(t-1)k}$ is the number of aircraft of program k produced up to but not including lot t, and $\lambda \sum_{l=1}^{k-1} q_{tl}$ is the number of aircraft produced by all other programs (represented by $k-1$) in lot t. The regression allowed for three different spillover parameters λ: one for the EA-18G and F/A-18E, one for the F-35B/C, and one for all other designs.

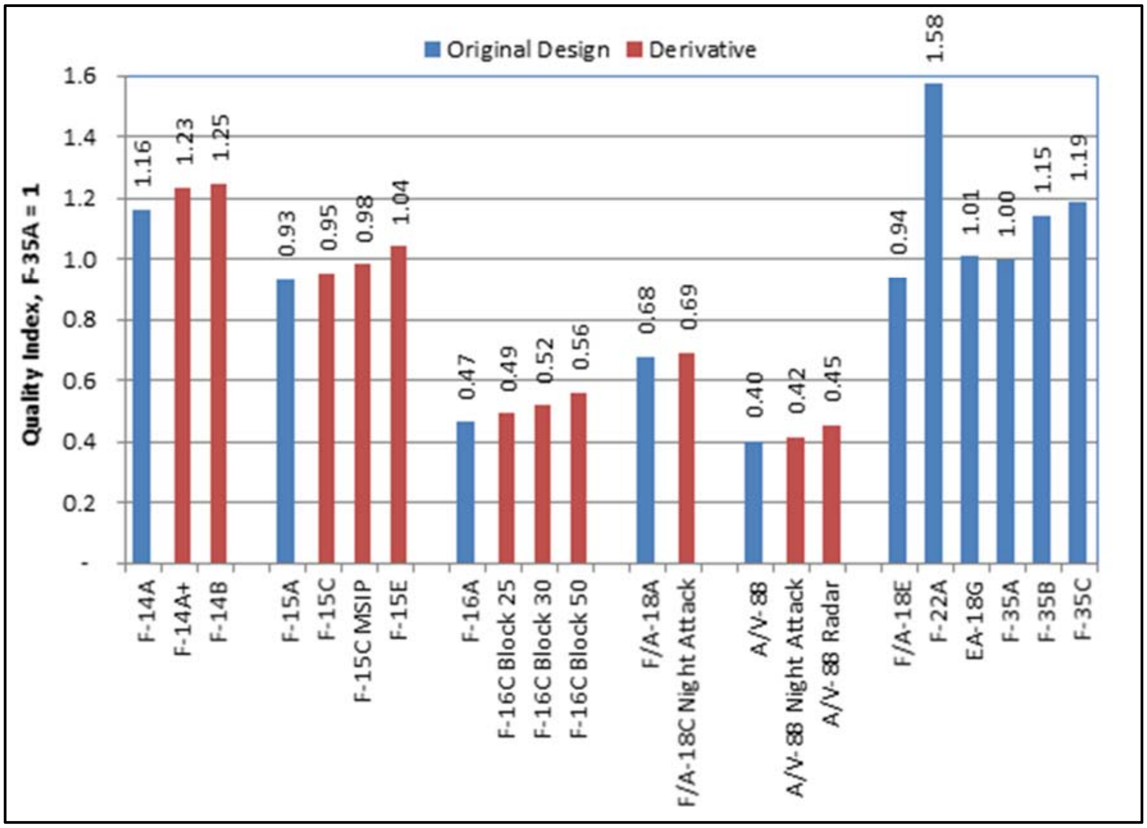


Figure 3. Estimated Quality Index for Tactical Aircraft (F-35A = 1): Full CER Model Estimates

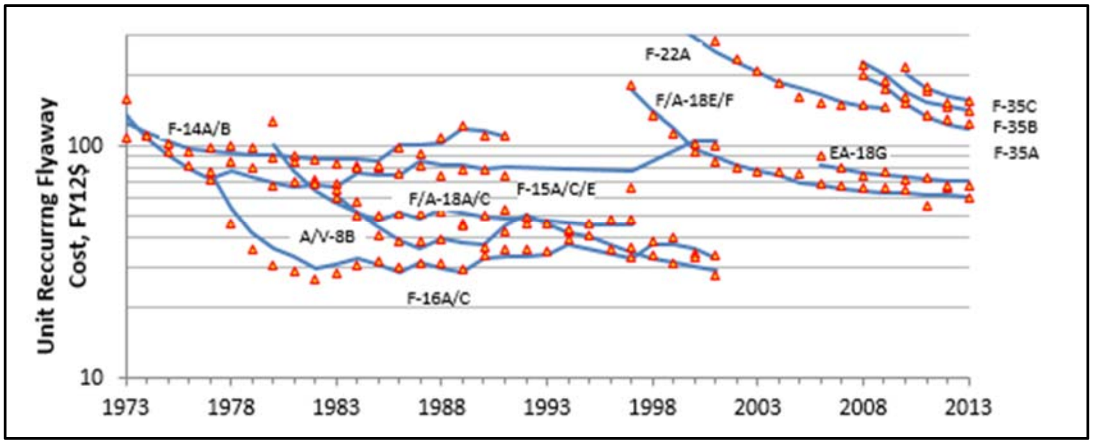


Figure 4. Fit of the Full CER Model to the Data

Preferred Hedonic Price Index Model. The functional form for the Preferred Hedonic model is shown in Equation 4. As described above, the quantity variables are omitted, and the coefficients of the quality variables are set equal to their values obtained from estimating the Full CER model (indicated by the bar over $\boldsymbol{\varphi}$). The only parameters to be estimated are the coefficients of the 40 time dummy variables and an intercept term. The quality index values are therefore the same as in Figure 4.

$$lnUC_{tk} = ln\left[f(\,\mathbf{Z}_k, D_t, \overline{\boldsymbol{\varphi}}, \delta_t) + \varepsilon_{\mathrm{jk}}\right] \qquad (4)$$

The Preferred model uses fewer explanatory variables than the Full CER model, which lowers the model's fit to an adjusted R^2 of 0.72 and a standard error in log space to 0.34.

Comparison of Price Indexes

Figure 5 and Table 7 compare the growth rates of all indexes analyzed in this study. The two hedonic indexes have a relative high growth rate that agrees with the perception in the DoD acquisition community that the GDP deflator understates annual quality-constant price increases, which puts pressure on funding. All the other aircraft-specific indexes show a much higher growth rate than the BEA index.

Comparing all these growth rates admittedly raises a question of interpretation: the indexes are calculated using different algorithms and data. The military aircraft analyzed by the BEA index, for example, are a very small subset of the goods and services in the national market basket described by the GDP deflator. And the military and civilian aircraft analyzed by BEA and BLS involve fundamental differences. The comparison is motivated, however, by the facts that the growth rates are all applied to aircraft analysis in one way or another and that all have been designed to hold quality constant.

Turning to the question of which index is best, as we pointed out in the introduction to the Hedonic Indexes for Tactical Aircraft section, hedonic deflators appear most appealing on two grounds:

- **Specificity**. The hedonic indexes are based on specific design features such as empty weight in pounds and maximum speed in knots, rather than the costs of these features, which are measured or estimated with considerable uncertainty.
- **Transparency**. The design features are known to analysts from the detailed provisions of legal contracts and from DTE and OTE. The ways in which the non-hedonic indexes develop estimates of the cost related to quality changes are not available for detailed examination.

The hedonic analysis of tactical aircraft prices supports a common position in the DoD acquisition community that the GDP deflator understates quality-constant price increases and thus overestimates the real purchases of tactical aircraft.

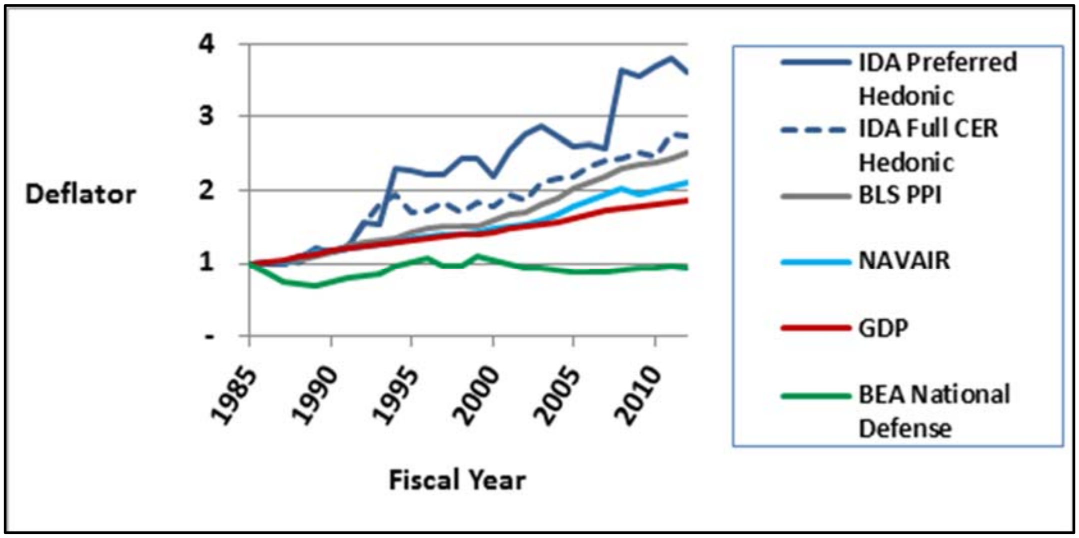
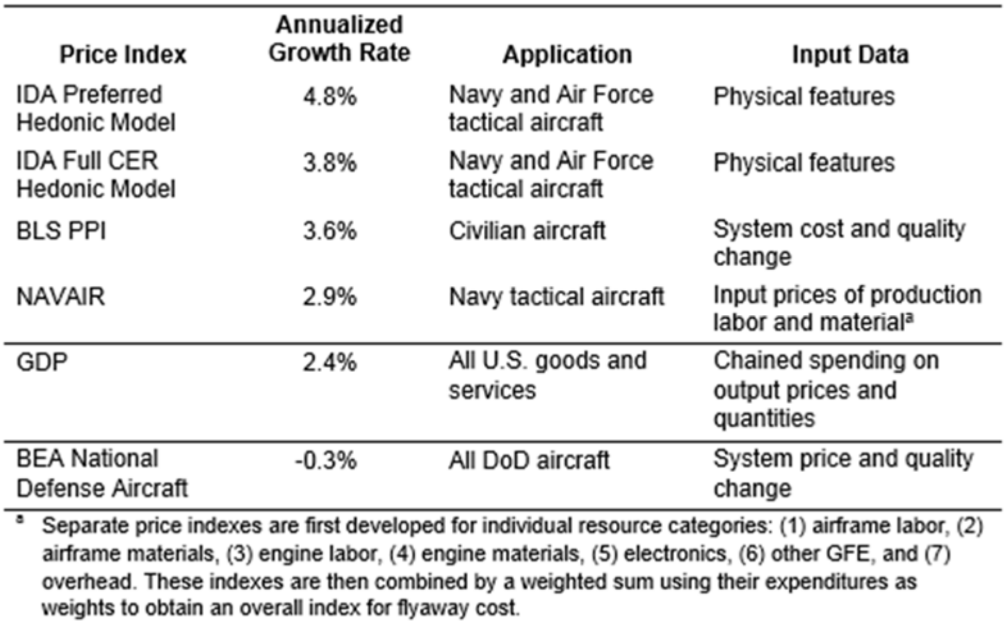


Figure 5. Comparison of Price Indexes, 1985–2012

Table 7. Deflator Growth Rates, 1985–2012



Price Index	Annualized Growth Rate	Application	Input Data
IDA Preferred Hedonic Model	4.8%	Navy and Air Force tactical aircraft	Physical features
IDA Full CER Hedonic Model	3.8%	Navy and Air Force tactical aircraft	Physical features
BLS PPI	3.6%	Civilian aircraft	System cost and quality change
NAVAIR	2.9%	Navy tactical aircraft	Input prices of production labor and material[a]
GDP	2.4%	All U.S. goods and services	Chained spending on output prices and quantities
BEA National Defense Aircraft	-0.3%	All DoD aircraft	System price and quality change

[a] Separate price indexes are first developed for individual resource categories: (1) airframe labor, (2) airframe materials, (3) engine labor, (4) engine materials, (5) electronics, (6) other GFE, and (7) overhead. These indexes are then combined by a weighted sum using their expenditures as weights to obtain an overall index for flyaway cost.

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