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THESIS

EXPLORING THE FINANCIAL BENEFITS OF U.S. ARMS EXPORT PRODUCTION

by

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December 2010

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EXPLORING THE FINANCIAL BENEFITS OF U.S. ARMS EXPORT PRODUCTION

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LIST OF ACRONYMS AND ABBREVIATIONS

AESA	Active Electronic Scanned Array
AUC	Average Unit Cost
CAT	Conventional Arms Transfer [Policy]
CIC	Cost Improvement Curve
COTS	Commercial-Off-The-Shelf
DISAM	Defense Institute of Security Assistance Management
DoD	Department of Defense
EPG	European Participating Governments
FMS	Foreign Military Sales
GAO	Government Accountability Office
IT	Information Technology
NATO	North Atlantic Treaty Organization
OEM	Original Equipment Manufacturer
OLS	Ordinary Least Squares
PDD-34	Presidential Decision Directive 34
R&D	Research & Development
RA CIC	Rate Adjustment Cost Improvement Curve
SAR	Selected Acquisition Report
UC	Unit Cost

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I. INTRODUCTION

A. PURPOSE

Historically, arms exports have been a critical lever of U.S. foreign policy and remain so today (Bajusz and Louscher, 1988; Agmon et al., 1996; DISAM, 2010). The proposed $60 billion sale to Saudi Arabia in 2010—which included 84 F-15 fighters, 60 Apache attack helicopters, and 72 Black Hawk utility helicopters—is a relevant and contemporary example. The publicly stated objective of the sale was to counter the rise of Iran as a regional power (Lee, 2010). While there is great potential that this sale can indeed disrupt the balance of military power in the Near East region, it also initiates a very robust flow of revenues to the U.S. defense industrial base and highlights the fact that arms exports may also be useful economic and financial levers for the domestic industrial base. Arms trade scholars—Bajusz and Louscher, (1988), Sandler & Hartley (1995), Agmon et al., (1996)—argue that arms exports have numerous financial benefits including reducing per unit procurement costs and preserving production lines. However, there is a dearth of research that actually shows that per unit costs to the U.S. Department of Defense have actually been lowered as a result of increased sales to foreign buyers.

President Bill Clinton stated that financial factors are relevant considerations for arms sales, in his 1995 Presidential Decision Directive 34 (PDD-34) that became the Conventional Arms Transfer (CAT) Policy. The President outlined key decision criteria for each proposed arms transfer, with one being the assessment of the impact of the proposed sale on the U.S. defense industrial base. Typically, financial factors are not a cause of discord unless there is a potential financial gain that is associated with a potentially negative foreign policy or security impact (Agmon et al., 1996).

Agmon et al. (1996) assert that the CAT policy gives rise to a two-step decision-making process for proposed arms transfers. First, if the net foreign policy and national security impact is positive, the sale is approved. If the net impact is negative, financial factors may be considered and weighed against the negative impact to national security or foreign policy. It is unlikely the U.S. government will export arms to a nation when the export will have an overtly negative impact on U.S. national security or foreign policy, no matter the magnitude of the financial benefits. Agmon et al. (1996) interpret the CAT policy to specify that when negative national security and foreign policy impacts are marginal and uncertain, the proposition of large financial benefits weighs in favor of approving the arms transfer. However, Agmon et al. (1996) offer a compelling counterargument to this conventional thinking: any arms transfer negatively impacting U.S. foreign policy and national security should be avoided, even if the defense industrial base stands to benefit. The rationale is that these negative effects can entail infringement of political freedoms or lead to armed conflicts. In sum, the consideration of financial factors arising from proposed arms transfers is an important aspect that this research attempts to quantify, in part, through analyzing the financial benefits in arms export production.

B. ORGANIZATION OF THE RESEARCH

This research examines the extent to which the U.S. benefits from producing arms for export. Specifically, this research explores the role of arms export production in reducing U.S. per unit costs when U.S. and export production is concurrent.

Chapter II surveys the U.S. and global defense economic environments. A significant reduction in defense spending occurred after the end of the Cold War that shaped the contemporary defense environment. The reduction in resources spurred a consolidation of the U.S. defense industrial base that significantly reduced the number of defense contractors thereby altering the dynamics of defense economics. As the cost of new weapon systems escalates, arms exports may become increasingly attractive as options for reducing the per unit costs to the U.S. Department of Defense.

Chapter III identifies three sources of potential savings associated with export production: reducing fixed and nonrecurring per unit costs, reducing costs through achieving economies of scale and learning, and preserving production lines.

Chapter IV introduces the F-16 multi-role fighter aircraft program as a case study to quantify the financial gains realized through learning and economies of scale attributed to export production. Using a rate adjustment cost improvement analysis, the case study shows the per unit costs DoD would have incurred without the concurrent export production of F-16s. Chapter IV also discusses the potential benefits to the U.S. associated with keeping the F-16 production line “warm” through export production.

Finally, Chapter V provides concluding remarks on the significance of the cost improvement analysis and discusses the limits on applying these findings in a broader context to other weapon systems.

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II. BACKGROUND OF THE CONTEMPORARY U.S. DEFENSE ECONOMIC ENVIRONMENT

A. A BRIEF HISTORY OF THE POST-COLD WAR DEFENSE INDUSTRIAL BASE

In order to appreciate the importance of financial factors in arms exports decisions, it is necessary to consider the post-Cold War defense economic environment. In 1991, the U.S. emerged from the Cold War with the former Soviet Union, ending a standoff that lasted more than 40 years at a cost in excess of $18.2 trillion in constant 2010 dollars, measured by total defense spending from 1948–1991 (Calhoun, 1996). Previous wars in U.S. history, particularly the Civil War and World War I, resulted in short, sharp defense spending spikes followed by long periods of significantly reduced defense expenditures. Usually a significant post-war drawdown occurred, followed by a period of little or no conflict. World War II would have followed this pattern had the onset of the Korean War not occurred (Sapolsky and Gholz, 1999). However, the Cold War resulted in decades of military build-up that resulted in an abrupt and significant drawdown during the early post-Cold War years.

1. Rise of the "Private" Arsenals

The early years of the Cold War saw robust defense spending and a burgeoning defense industry that was punctuated, somewhat unsurprisingly, during the Korean War, Vietnam War and the buildup during the 1980s under the Reagan administration. The sustained effort to build and modernize America's military consequently raised an army of private defense contractors whose growth and largesse was heretofore an unknown creature to the American economy. President Eisenhower recognized this danger early on and warned the public of the rise of the military industrial complex in his farewell address to the nation in 1961 (Eisenhower, 1961).

In the public-sector defense industry, government retained its technical knowledge and industrial capacity by keeping its civil servants employed in its arsenals and shipyards, even if demand dropped and production rates fell to zero (Sapolsky and Gholz, 1999). This sheltering effect of government employment helped keep the industrial base warm. However, in private industry, once a production run concluded, the firm had no incentive to keep the production line open. The shift from a public defense industrial base to a private-dominated defense industrial base meant that production lines closed when military demand diminished or the contract ended.

2. Era of Consolidation

The conclusion of the Cold War redefined industrial requirements. Coupled with already reduced defense spending levels, post-Cold War requirements no longer supported robust production capacity. The end of the Cold War reduced the requirement to hold a large inventory of weapons. The period between 1985 and 1995 saw the longest continuous post-World War II procurement budget decline (GAO, 1997). For private firms, this reduction in defense spending resulted in production lines closing due to lack of demand and funding. The defense budgets could no longer support the industry's capacity, resulting in firms having significant and costly excess capacity. In addition to diminished defense spending levels, the compounding effect of reduced demand and bountiful Cold War residual inventory crowded out new procurement and compelled many private industry firms to revisit their business strategy for future profitability. Many firms merged with others or exited the industry altogether. Defense industry mergers in the early 1990s were intended to reduce the defense industry's excess capacity.

Lower defense procurement budgets disproportionately affected small defense firms. Many of these firms relied on subcontracts from larger original equipment manufacturers (OEMs). A study by Velocci (1994) showed that large contractors cut 50 to 80 percent of their subcontractors from their major weapons programs. Consequently, once the subcontracts dried up, many of the smaller firms exited the defense industry or shifted to commercial applications.

Although the overall market for U.S. arms has expanded since World War II, the private defense industry has experienced significant consolidation. The aircraft sector alone shrunk from twenty-six to seven contractors between 1945 and 1996 (see Figure 1), the number of firms competing in the armored tank industry dropped from sixteen to two, and the number of firms competing in the missile industry dropped from twenty-two to nine (GAO, 1997).

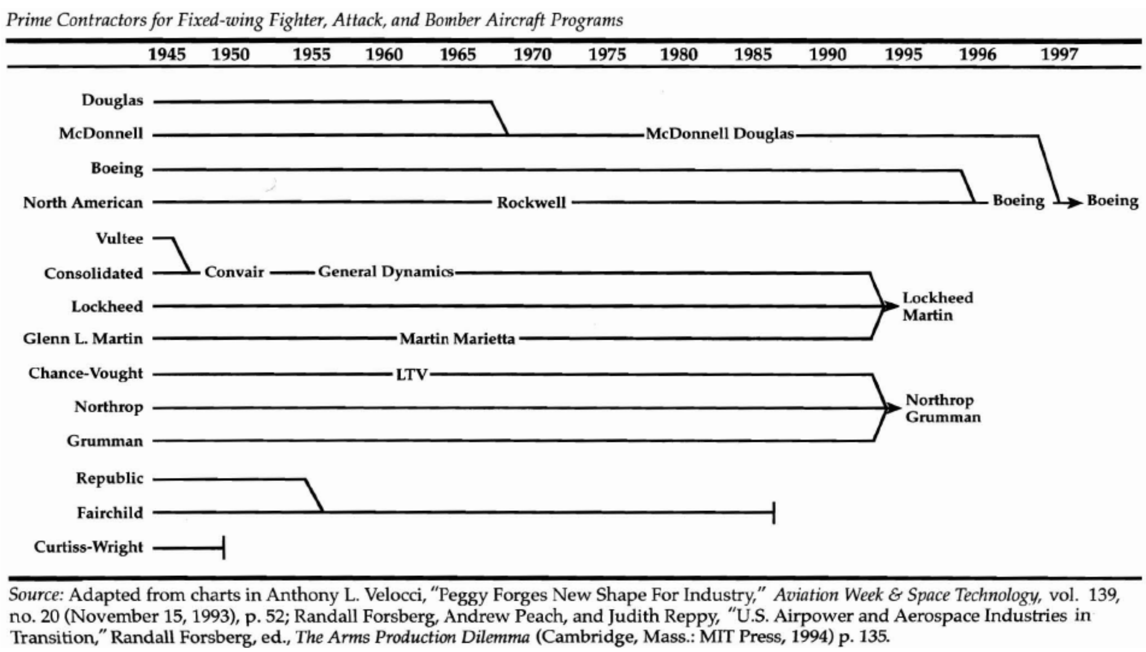
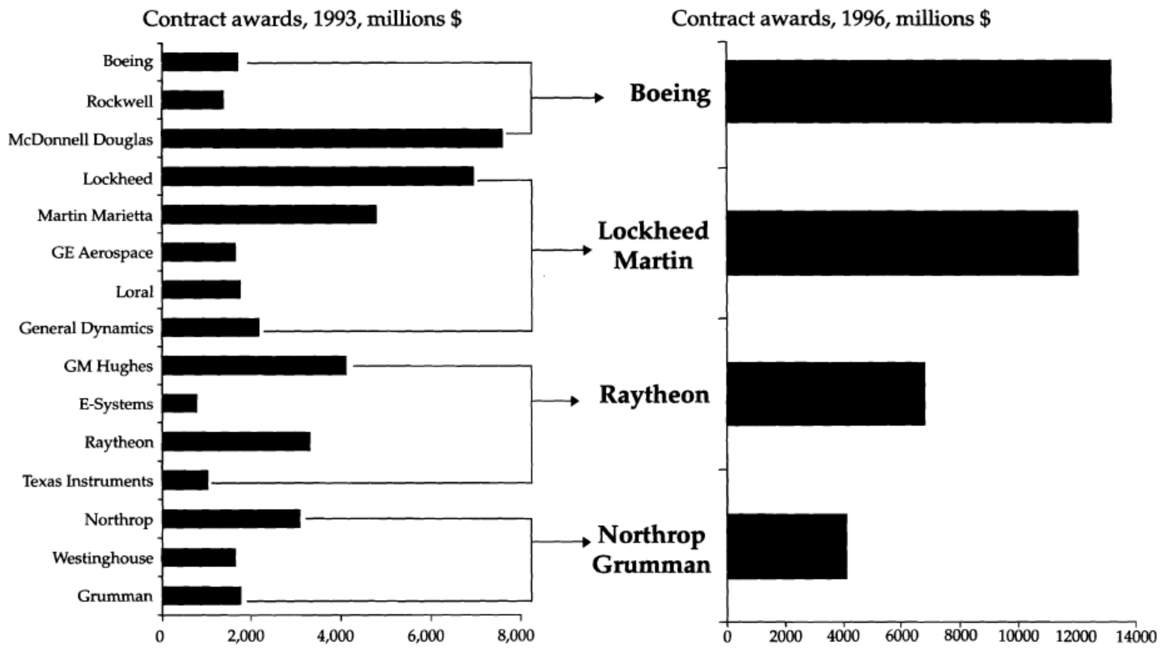


Figure 1. Consolidation of U.S. Military Aircraft Manufacturers, 1945–96 (From Pages, 1999)

Firms that were once defense industry giants, such as Rockwell, Curtiss-Wright and Westinghouse, became footnotes in the history of the wars they fortified or returned to non-defense activities (Pages, 1999). Figure 2 illustrates how the consolidation of defense firms stove-piped from many firms into the current "big four": Boeing, Lockheed-Martin, Raytheon and Northrop-Grumman.



Source: All data are from the Department of Defense publication (P01), *100 Companies Receiving the Largest Dollar Volume of Prime Contract Awards from the Fiscal Years of 1993 and 1996.*

Figure 2. U.S. Defense Mergers in the 1990s (From Markusen and Costigan, 1999)

B. THE ECONOMICS OF DEFENSE

1. The Rising Costs of Weapon System Technologies

The underlying economics of weapon system technologies do not favor DoD efforts to reduce costs. Recent U.S. weapon system programs, such as the F-22 and F-35, show that per-unit research and development (R&D) costs far exceed those of their comparable predecessors and other weapon systems experienced similar cost increases. Hartley (2007) argues these cost increases reflect the “technical arms race” where next generation weapons are more effective than their predecessors, but have significantly higher R&D and production costs. In fact, Kirkpatrick observed a 10 percent annual increase in real unit production costs for combat aircraft (as cited in Hartley, 2007). Given the empirical data, it is reasonable to conclude that a sustained upward trend in per unit weapon system costs will be observed well into the future.

2. U.S. Defense Market

The domestic U.S. defense environment is characterized by a semi-competitive imperfect market (Anderton, 1995). The market itself is a monopsony, with multiple supplying defense firms and only one major buyer—the Department of Defense. As the one and only domestic buyer, DoD controls demand and also serves as the market regulator. These market dynamics afford DoD much control over the size, structure, conduct, performance and ownership of arms industries (Hartley, 2007). Table 1 shows how the various aspects of the defense industrial base are controlled, or heavily influenced by, DoD.

Table 1. U.S. Government Control of the Defense Industry (From Hartley, 2007)

Aspect of the Defense Industrial Base Controlled by the U.S. Government	Example of Control
Size	Changes in defense spending (i.e. war, drawdown) affect the size of a nation's defense industrial base
Structure	Allows or prevents mergers Prevents entry or exit (i.e. bailouts)
Conduct	Specify form and terms of competitions
Performance	Regulates profits on non-competitive contracts and controls exports (both quality and quantity)
Ownership of Arms Industries	Determines whether firms and the industry will be state- or privately-owned

DoD demands goods and services from two types of markets: one that is reasonably competitive and one that is imperfect. The procurement of computers, information technology (IT) infrastructure, office equipment, and garrison transportation equipment are all "commercial-off-the-shelf" (or COTS) items or technologies. Since COTS items have many buyers outside of DoD, these items have a competitive market price driven by supply and demand. At the other extreme, DoD develops requirements for next-generation weapon system technologies for which there is no discernable "market price" (Flamm, 1999). In essence, contracted price and subsequent stated value are determined by the asymmetrical bargaining power of the defense firm or DoD, not market forces. While DoD would seem to have considerable bargaining power as monopsonist, it is actually disadvantaged in contract negotiations for unique and technologically advanced major weapon systems due to a lack of proprietary information regarding the exogenous technology and production variables (Hartley, 2007).

3. Global Arms Market

The contemporary U.S. defense industry itself is a private complex, consisting of profit-maximizing firms. Basic economic theory stipulates that it would have no interest in arms exports if it were not a profitable venture. While the defense industry does have DoD’s interests in mind, given their dynamic symbiotic relationship, they also have another interest in mind—that of their shareholders. Shareholders measure the defense firms’ performance on their increases in quarterly and annual revenues and earnings. Exports open up new markets and sources of revenues—and hopefully profits. The defense firms are therefore incentivized to incorporate export production into their business models.

Unlike the domestic market, the global arms market is much more competitive. The collapse of the Soviet Union and the subsequent privatization of the former Soviet industrial base significantly increased competition among the defense industrial bases of Russia, the U.S., Britain, and Western Europe. Additionally, the end of the Cold War virtually eliminated the regional arms races amongst the superpowers, characterized by substantial arms transfers to nations allied to the U.S. or the U.S.S.R in the form of foreign aid. With a global defense industry relying directly on customer-nations for sales, the customer-nations now have increased buyer power (Johnson, 1995). As a result, customer-nations are increasingly shrewd and demanding, trying to maximize the benefits of their own defense spending (Anderton, 1995). As astute consumers in a global arms trade of imperfect markets, complex transactions and asymmetrical information, customer-nations seek ways to enhance welfare and reduce the total cost of major military imports by recapturing some of their investment in foreign weapon systems (Sandler and Hartley, 1995). One such popular method is the use of offsets, which are one of the most significant macroeconomic issues in the discussion of arms exports (Gold, 1999). By definition, they are contractual arrangements between an exporter and importer that provide the customer-nation with a means of compensation through realizing other economic benefits. Between 1993 and 2008, "U.S. firms reported entering into 677 offset agreements with 45 countries valued at $68.93 billion" representing "70.96 percent of the $97.13 billion in foreign sales of defense items reported during the period" (U.S. Department of Commerce, 2009). Much discussion surrounds the use of offsets that will not be treated in this research. Nevertheless, it is important to acknowledge that offsets are an important fixture of the global arms trade and global defense environment that affects both the U.S. and the customer-nations.

C. CHAPTER CONCLUSION

In sum, the Post-Cold War defense environment is characterized by the emergence of a global arms market characterized by private, profit-maximizing firms seeking greater market share and customer nations – many that previously had neither the wealth to afford nor access to buy advanced weapons – seeking more advanced, lethal products that are affordable to deploy and maintain. The defense industrial base that emerged in the United States after the Cold War was one consolidated into a small handful of large firms. The oligopoly of defense firms on the supply side, as well as the monopsonistic DoD buyer on the demand side, characterize domestic defense economic exchange as a semi-competitive imperfect market. The inefficiencies existing in the domestic market, in conjunction with reduced Post-Cold War spending levels and escalating weapon system technology costs, make arms export production an attractive lever for realizing cost savings within DoD. From a financial standpoint, arms export production appears to be a nexus for both DoD interests in reducing their cost burden in acquiring major weapon systems and defense industrial base interests of maintaining profitability and a competitive advantage in the global arms market.

III. REVIEW OF THE THEORETICAL FINANCIAL BENEFITS OF ARMS EXPORT PRODUCTION

Affordability is a top priority in the acquisition of any weapon system. An easy cost-savings target for the Department of Defense is to seek savings in end-items not yet procured. A popular, contemporary conjecture is that U.S. arms exports financially benefit the Department of Defense, the U.S. defense industrial base, and the nation as a whole. Arms exports can potentially provide substantial gains to the exporting nation and arms trade scholars Bajusz and Louscher (1988), Sandler & Hartley (1995), and Agmon et al. (1996) acknowledge that arms exports theoretically provide financial benefits to the Department of Defense through:

1. Reducing nonrecurring and fixed per unit costs;
2. Reducing per unit costs through achieving economies of scale and learning, and;
3. Preserving production lines.

A. REDUCING NONRECURRING COSTS AND FIXED COSTS

Theoretically, a larger production volume enables total fixed costs to be spread over a larger allocation base. The fixed cost per unit component of total unit cost should then decrease as production increases within the relevant range. However, the U.S. experiences a reduction in such costs to include R&D and production if, and only if, a portion of these nonrecurring costs are allocated to the customer-nation. If DoD incurs the fixed R&D cost, applies it only to domestic orders and waives the R&D cost for export orders, DoD bears the financial burden. The Arms Export Control Act (AECA) Section 21(e)(2)(A) [22 USC Sec. 2761] stipulates that DoD must charge the customer-nation its proportional share of the nonrecurring costs in the Foreign Military Sales (FMS) deal. However, nonrecurring costs for particular sales to NATO and other eligible countries may be waived if the deal significantly advances U.S. interests (DISAM, 2010). Note that the nonrecurring cost waiver only applies to FMS cases administrated by DoD. Direct sales by the contractor are not required to charge the customer-nation its proportional share of recurring cost. The DoD waiving or failing to recoup these costs enables the defense contractor to remain competitive on price.

By waiving nonrecurring costs and not charging customer-nations their proportional share of such costs, direct sales greatly benefit the profit-maximizing defense contractor. The defense contractor can then export the military goods at a price determined by the average variable costs to produce the weapon system and thereby increase its competitiveness in the global arms market. In other words, placing the nonrecurring cost burden on DoD amounts to the *U.S. taxpayers subsidizing foreign arms sales*.

In 1998, the Government Accountability Office (GAO) reported that DoD had not recovered $183 million in nonrecurring costs from delivered sales—some of which dated back to 1989 (GAO, 1998). Though the GAO admonished DoD for poor financial management practices, this example highlights the fact that bureaucratic inconsistencies and a lack of coordination can result in not only the failure of the U.S. public to realize cost savings through arms exports but also in the public subsidization of foreign arms transfers.

B. REDUCING PER UNIT COSTS THROUGH ECONOMIES OF SCALE AND LEARNING

A second source of cost savings is in the scale of production. Large production runs can lower costs through economies of scale and learning. Economies of scale refer to the relationship between a firm's cost and output. A firm enjoys economies of scale when it can double its output for less than twice the cost, where marginal cost is less than average cost. Conversely, diseconomies of scale occur when doubling output results in more than twice the cost, where marginal cost is greater than average cost (Pindyck, 1998). Given a production setting for which the long run average cost curve is u-shaped, economies of scale tend to occur when increasing production from lower production levels, while a firm potentially experiences diseconomies when increasing production from higher production levels. Theoretically, DoD benefits from economies of scale if it can augment the lower levels of weapon system production for domestic consumption with foreign orders.

Assuming that augmenting domestic production with foreign orders occurs while the defense contractor experiences increasing returns to scale, increasing production will result in a lower per-unit cost than without foreign orders. Further, not all cost reductions are the same. As illustrated in Figure 3, movement along the long run average cost curve in the downward, negative-sloped region, reveals that marginal cost reductions decrease at a slower rate until reaching constant returns to scale where increases in total cost are proportional to output.

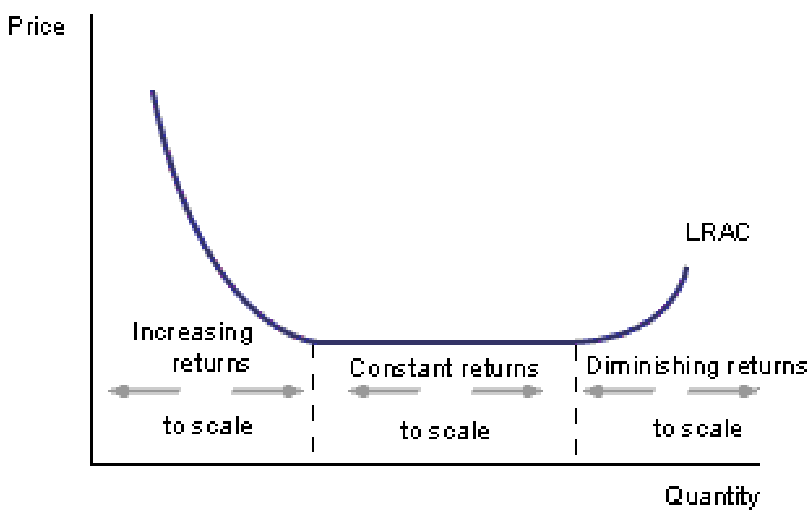


Figure 3. Long Run Average Cost Curve (From Waterson, 2010)

This equates to additive foreign orders theoretically having a greater impact in reducing per-unit cost early when the level of production is low. However, augmenting domestic production with foreign orders will not always provide a lower per-unit cost. Recall the discussion of diseconomies of scale. If the additive foreign orders occur during decreasing returns to scale, the addition of foreign orders would actually provide a higher per unit cost.

Similar to economies of scale, learning curve theory also can reduce per unit costs. Learning curve theory helps estimate the incremental per-unit cost reduction in the production process. Introduced by T.P. Wright in 1936 as a result of his observations in aircraft production, learning curve theory helps estimate unit costs based on cumulative production. It follows that if learning occurs in the production process, each time the volume of production doubles, the per unit cost decreases at a predictable rate (FAA, 2010). Put differently, the cost of the doubled unit equals the cost of the un-doubled unit multiplied by the slope of the learning curve (Nussbaum, 2010). Therefore, the equation defining the learning curve is exponential and negatively sloped. Figure 4 illustrates Wright's learning curve, where *Y* equals cumulative average unit cost, *a* equals theoretical first unit cost, *X* equals cumulative production quantity and *b* equals the slope of the function. The shape of the learning curve makes it evident that more learning and consequently greater per-unit cost reductions occur early in the production process.

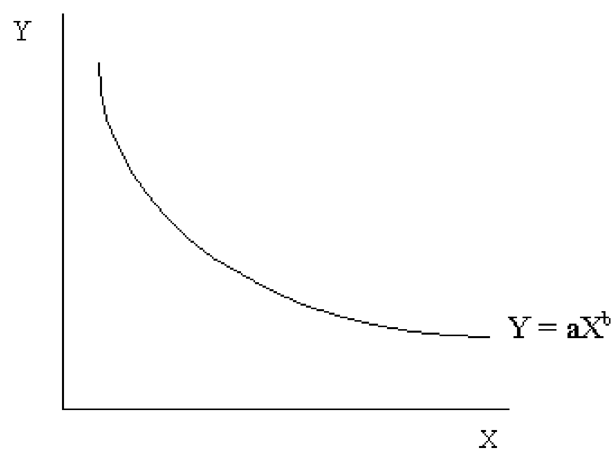


Figure 4. Wright's Learning Curve Model (From Martin, 2010)

Both economies of scale and learning curve theory posit per-unit cost reductions. However, the basis for economies of scale is the scale of production, while learning curve cost reductions rely on cumulative production. Therefore, arms exports theoretically provide the largest cost reductions if they are incorporated at the beginning of production. Conversely, dedicating units of production for export towards the end of a U.S. procurement will have a significantly lesser effect on cost reduction. Making the case for arms exports, unit cost savings depends greatly on both the scale of production and learning already achieved. In practice however, it is difficult to distinguish between economies of scale and learning.

Empirical research shows that it has become increasingly difficult to isolate cost savings between economies of scale and learning (Hartley, 2007). However, Hartley (2007) suggests that the median per unit cost savings by increasing the scale of production from minimum efficiency to ideal conditions was 10–20 percent for all weapon systems studied (Hartley, 2006). Table 2 shows the cost savings associated with different weapon systems as the scale of production moves towards most efficient conditions.

Table 2. Estimated Savings through Minimum to Optimal Production for Selected Weapon Systems (From Hartley, 2006)

Weapon System Type	Costs Savings (Percentage)
Warships	<10
Tanks	<10
Combat Aircraft	20
Conventional Munitions	20-30
Missiles	25-40

Further, Sandler and Hartley (1995) suggest that the production and learning curves associated with aircraft production range from 75 to 80 percent. The production and learning curves associated with other weapon system production, to include aircraft engines, avionics, electronics, missiles, main battle tanks and warships range from 70 to 96 percent (Ibid.). While labor learning is paramount, Hartley (2007) points out that cost reductions associated with learning have been affected by modern manufacturing methods, new materials and business practices, such as computer-aided design/computer-aided manufacturing, lean and six sigma methods, and supply chain changes.

C. PRESERVING PRODUCTION LINES

The U.S. and DoD benefit from production lines with capacity dedicated for export production. Generally, the decision to keep a production line open is a balance between cost and schedule (or response time). An open production line serves as an insurance policy of sorts. First, it provides the U.S. with surge capacity in wartime or in the case of emergent, sudden conflicts; an open production line allows for a quick and cost-effective response. Second, an open production line prevents the cessation of requisite production capabilities and atrophy of employee skill-sets that are needed for production in the near-term. Reconstituting a stagnant production line can incur high restart costs in addition to significant increases in lead times (Gold, 1999).

Gaps in production lines occur due to misalignment of U.S. weapon system procurement or conversion. There are three options to address gaps in production. First, a production line could go “cold,” whereby it will be reconstituted later. Birkler, Large, Smith and Timson (1993) suggest that reconstituting a cold production line can sometimes be the most cost-effective solution, since restarted programs take less time from program start to first delivery and are less expensive and risky than the original program. However, when reconstituting a cold production line is deemed more costly, other options exist. An alternative to letting a production grow “cold” is to keep it “warm” through sustained low-rate production. This is often the desired option when the system is a critical national asset with one supplier and no commercial market because if production ceases, the supplier might go out of business (Birkler et al., 1993). While keeping the production line “warm” might be a lower cost alternative the costs may still be extraordinarily high due to the fact that the existing fixed cost structures were designed for high rate production. The third option is maintaining high rate production and storing any excess or unneeded equipment for later use or contingencies. In this case, it could also mean selling the excess to foreign buyers. Regardless of the option, significant costs are associated with maintaining production capacity in reserve for the future. However, these costs can be reduced if the capacity is allocated for export production because the U.S. will incur neither production costs when there is no actual demand nor the holding costs associated with keeping non-operational systems in the inventory.

Agmon et al. (1996) identified export production as a cost-saving solution to preserving production lines during gaps in U.S. production. They noted that in the M1 main battle tank and AH-64 attack helicopter programs, a period of about two to three years elapsed between the end and resumption of U.S. production. During these periods, only export units remained in production. In the case of the M1 production ending in 1993, maintaining the production base and employment levels through export enabled a one-third cost reduction for the U.S. M1 tank conversion program that commenced in 1995 (OUSD A&T, 1994). Similarly, export production of the AH-64 kept the production line "warm" after U.S. production ended in 1993 and recommenced in 1996 with production of the upgraded AH-64D (OUSD A&T, 1994). In sum, export production provides a convenient lever for maintaining production line, and more broadly, industrial base, "warmth."

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IV. COST ANALYSIS: F-16 CASE STUDY

A. PROGRAM BACKGROUND

It is difficult to accurately isolate the financial benefits enjoyed by the U.S. from foreign arms production. Theoretically, per unit cost reductions occur through increases in production volume due to economies of scale and gains in efficiency through learning. Foreign arms sales present an opportunity to increase production volume and allocate nonrecurring and fixed costs to non-U.S. customers. The Lockheed Martin (formerly General Dynamics) F-16 fighter aircraft is one of the most prolific arms exports to date, flying under twenty-one separate flagged air forces. It is also the most produced fourth-generation western fighter, with 4,519 copies to date (Janes, 2010). Although this program began during the Cold War-era, the merits of using the F-16 as a case study for analysis lie in the fact that the F-16 Multinational Fighter Program involved the European Participating Governments (EPG) of Belgium, Denmark, the Netherlands, and Norway in the early development and later in the co-production of the aircraft. This multinational effort resembles the F-35 joint strike fighter program in that several allied nations entered into an agreement to purchase a common aircraft that could be purchased affordably due to the large numbers of orders. The program began in 1975, with the U.S. receiving its first five aircraft in 1978. Within a decade, close to 2,200 aircraft had been delivered, with foreign customers accounting for 35 percent of the total deliveries.

Beginning 1981, a host of other nations entered into agreements with the U.S. to purchase the F-16 aircraft for their own air forces. As of 2010, 50.1 percent of all F-16 deliveries were to foreign customers. Of those foreign deliveries, 22.8 percent were to the EPG (Janes, 2010). The F-16 production for this analysis can be partitioned into two model generations, the A/B and the C/D. The A and the C models are single-seat aircraft, while the B and D are double-seat variants primarily used for training. This case study will focus on cost reductions that result through larger production quantities as a result of increasing the market of the weapon system through foreign sales.

B. METHODOLOGY

Although the F-16 is one of the most prevalent fighter aircraft programs in modern history, there is a profound dearth of detailed foreign sales and unit production cost data. The DoD's Selected Acquisition Reports (SAR) provide annual data on U.S. procurement cost, U.S. procurement quantity, foreign procurement quantity and U.S. aircraft delivery. The SARs do not contain data regarding foreign deliveries. Foreign delivery data were obtained through F-16 archivist Björn Claes (2010), who compiled a database of F-16 delivery schedules and quantities from Foreign Military Sales documents, official Lockheed Martin datasets and contacts from within foreign air forces.

The SARs provide production and delivery data, covering the years 1975 through 1994. By the end of 1994, the F-16 program reached 90 percent of its expected production delivery and the SARs reporting concluded. In fact, after 1991 the U.S. deliveries significantly tapered off thereby making that year a reasonable upper bound for the analysis. To identify cost reductions with cost improvement analysis, production for the U.S. and foreign customer-nations must be concurrent. The cost and quantity data from 1984 coincides with deliveries of C/D models and the preponderance of foreign sales (excluding EPG). For these reasons and others discussed in the following section, the scope of this case study focuses on F-16 deliveries between 1984 and 1991.

Using cost improvement analysis, this case study takes a counterfactual approach to estimate per-unit cost if export production did not occur. Two main types of cost improvement analysis exist: traditional cost improvement curves (CIC) and a rate adjustment CIC model that includes a rate term. Traditional CICs are synonymous with learning curves and postulate that in production involving repetitive tasks, the per-unit variable costs will decrease by a certain factor with each doubling of cumulative production. Moses (1990) notes that production rates can lead to greater specialization of labor, quantity discounts in raw material purchases, and greater utilization of facilities thereby increasing the production quantity against which fixed overhead costs are allocated. Bemis (1981), Boger and Liao (1990), Large et al. (1974), and Linder and Wilbourn (1973) suggest that together these effects can increase efficiency and reduce production cost (as cited in Moses, 1990). However, Moses (1990) argues that increasing the production rate does not always reduce costs. In fact, increased production rates can actually increase per unit costs due to factors such as over-time pay, lack of skilled labor or additional fixed chunk investments to increase capacity, such as constructing more production facilities. Moses (1990) notes that production rates can therefore lead to both economies and diseconomies of scale.

Moses (1991) found traditional CICs engendered bias due to the existence of fixed costs in total cost and tended to understate the actual costs. The rate adjustment CIC (RA CIC) eliminated this bias; however, Moses (1991) noted a tradeoff between bias and accuracy (Moses, 1991). While in some cases Moses (1991) noted that traditional CICs can be more accurate, the existence of high fixed costs in F-16 production warrants the use of the rate adjustment model. The equation for the RA CIC is expressed by

$$C_R = aQ^bR^c$$

where

C_R = Unit cost of a F-16 at quantity Q and production per period R

Q = Cumulative quantity of F-16 production

R = F-16 production rate during given period

a = Theoretical first unit cost

b = Cost improvement curve exponent

c = Production rate exponent

Given that the unit cost (UC) is a function of cumulative production volume and rate, theoretically a large production volume will decrease the UC. For this case study, cumulative production is conceptualized as the sum of production for U.S. and foreign customer-nations. Therefore, calculating the equation that represents the UC as a function of total cumulative production permits the estimation of the UC had the U.S. decided not to produce F-16 fighters for export.

Given the lack of detailed data, assumptions were made regarding the nature of production and delivery. A fundamental tenet of cost improvement analysis is that the units produced are homogeneous. By the end of 1984, 99.2 percent of the F-16 A/B models were delivered into the U.S. Air Force inventory. Save the remaining six undelivered A/B models, the follow-on F-16 deliveries to the U.S. were all C/D models. Main differences between the A/B and C/D include improved cockpit avionics and radar. These distinguishing qualities imply heterogeneity and the existence of different cost curves. Within each model generation, additional variation exists between block numbers that denote upgrades. However, the data do not permit disaggregation, so block variation is held constant in the model. As illustrated in Figure 5, a delivery usually occurred two years after procurement. This two-year lag is also assumed to remain constant through the period analyzed.

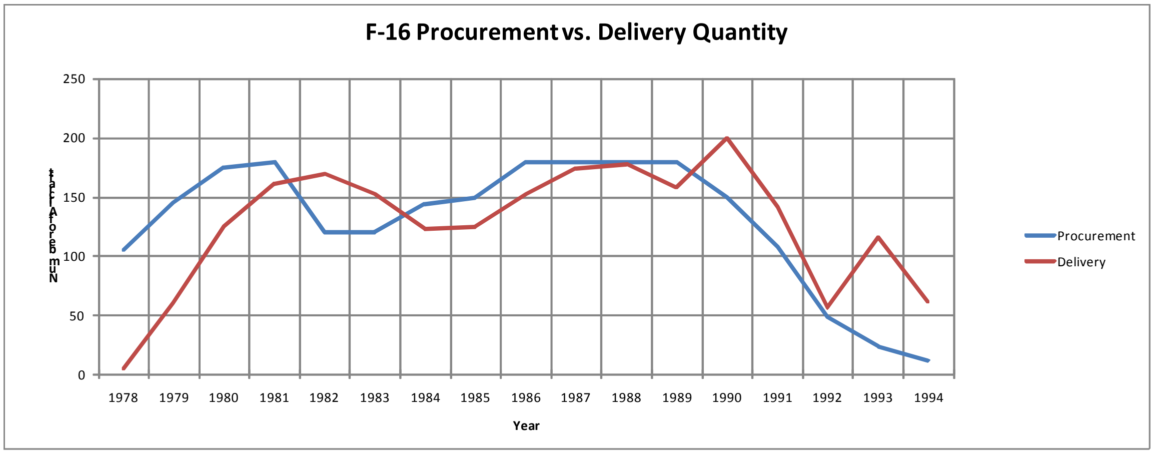

Figure 5. F-16 Procurement vs. Delivery Quantity

Further, deliveries were assumed to follow the same pattern as production—that is, a delivery lot of size 150 succeeds a production lot of size 150. Figure 6 shows actual cost overlaid on U.S. delivery quantity. The figure shows that peaks and troughs in average unit cost occur about two years before increases and decreases in delivery, respectively. Therefore, the analysis will attach cost reductions to the year of delivery. A second tenet of cost improvement analysis is the reduction in UC. The SARs publish procurement annual cost and quantity that permits a unit cost for the U.S. to be calculated for each production year, which in effect becomes an annual average unit cost (AUC). The cost data associated with the foreign sales can be misleading because additional premiums and discounts may be embedded in the foreign sales prices. Therefore, the model will use the annual U.S. AUC as the UC for all annual production. After 1991, the U.S. tapered off its deliveries. Consequently, the high fixed costs and reduced production base contributed to the uptick in AUC after 1991. Due to this cost structure, the post-1991 delivery data is omitted from the analysis.

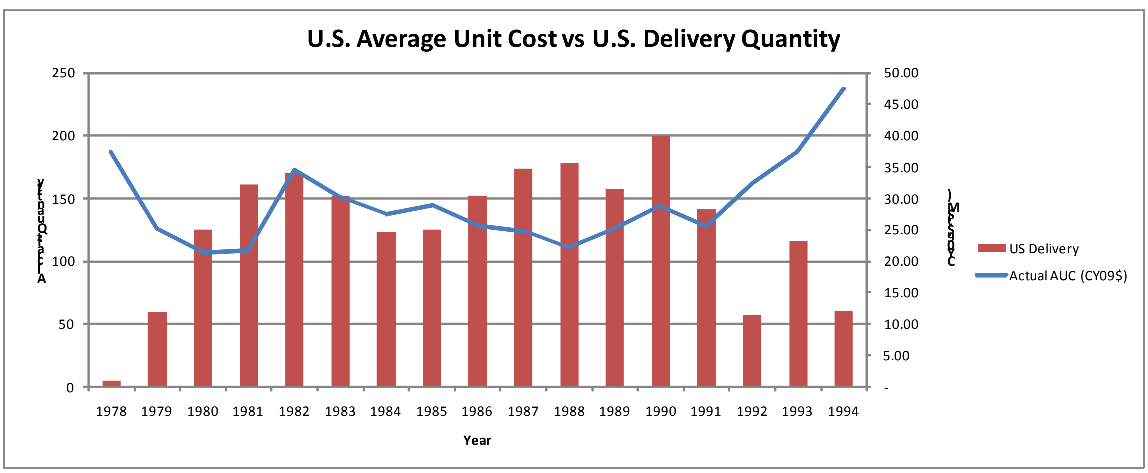

Figure 6. U.S. Average Unit Cost vs. U.S. Delivery Quantity

C. APPLICATION OF THE RATE ADJUSTMENT COST IMPROVEMENT CURVE

The rate adjustment cost improvement curve model expresses the relationship between per-unit F-16 cost, cumulative production and production rate. Using the stated assumptions, the relationship between F-16 cost, cumulative total F-16 production and total F-16 production rate between 1984 and 1991 is expressed by the equation:

$$C_R = 721.3898Q^{-0.3618}R^{-0.1009}$$

The rate adjustment cost improvement model enables the estimation of "what-if" costs to the U.S. if it decided not to produce F-16s for export from 1984-91. The annual delivery AUC is then calculated using the cumulative production in the quantity term and annual production in the rate term. Table 3 and Figure 7 illustrate the annual per unit cost savings, which averages 24 percent during this eight-year period.

Table 3. Estimated F-16 Export Production Cost Savings

Year	Actual U.S. Avg Unit Cost with Export Production (CY09$M)	Estimated U.S. Avg Unit Cost w/o Export Production (CY09$M)	Savings %
1984	27.449	38.960	42%
1985	28.965	37.493	29%
1986	25.670	34.473	34%
1987	24.856	31.891	28%
1988	22.149	30.448	37%
1989	25.166	29.490	17%
1990	28.654	27.663	-3%
1991	25.419	27.498	8%
Average Savings			**24%**

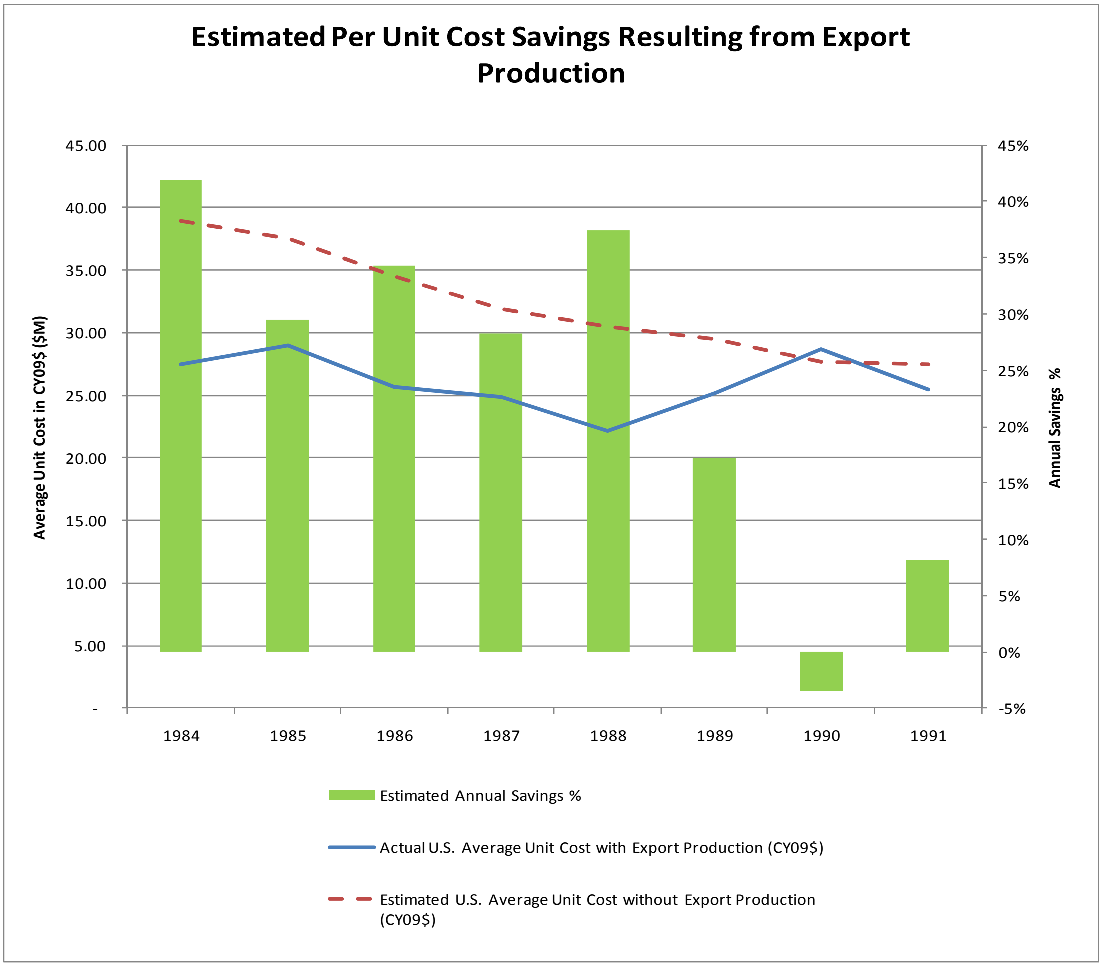

Figure 7. Per Unit Cost Savings from Export Production

As with any analysis, results are only as valid as the underlying assumptions. The assumptions best reflect reality, but the results imply an inherent assumption about U.S. production decision-making and that is in the absence of export production, the U.S. would have followed the same production rate. Data are not available to determine whether the U.S. would have changed its production rate policy. Given the fixed costs and potential excess capacity, the U.S. may have decided to speed up the procurement schedule, and thus conclude production earlier. Nevertheless, in light of the data and analysis presented here, the U.S. experiences an estimated average annual per-unit cost savings of 24 percent as a result of F-16 export production between 1984 and 1991.

D. OTHER BENEFITS OF AN OPEN F-16 PRODUCTION LINE

The U.S. F-16 program reached its 90 percent completion in 1994. After 1994, delivery quantity dropped to a squadron (24 aircraft) or less per year. In fact, the F-16 delivery quantities to DoD dropped to single digits from 1997-2002. The last originally programmed U.S. F-16 delivery was for 1999, yet production continued at Lockheed's Fort Worth plant. Between 1995 and 2007, U.S. F-16 deliveries constituted roughly ten percent of U.S. production and seven percent of all F-16s produced worldwide (Claes, 2010; Aerospace Industries Association, n.d.). Further, the U.S. produced an average of 55 aircraft annually between 1995 and 2007 (Claes, 2010), with F-16 production occurring in overseas plants averaging 21 aircraft per year during this same period. From an operations and maintenance standpoint, DoD stands to benefit from a "warm" F-16 production line with the availability and reduced cost of spare parts. Clearly, by continuing lower rate production beyond the U.S. planned requirement, this "warm" production line retained valuable skill sets. Whether those skill sets can be applied to the production of future, fifth-generation fighter aircraft, such as the F-35 Joint Strike Fighter, is a topic that warrants future research.

Even after the U.S. ceased procurement of the F-16, Lockheed Martin continued to develop the F-16 for its foreign customers. The F-16 E/Fs delivered to the United Arab Emirates in mid-2005 are considered "half of a generation" ahead of the U.S. F-16 inventory (Defense Industry Daily, 2010). These F-16s are equipped with the Northrop Grumman AN/APG-80 AESA radar, making the UAE the first foreign military (other than the U.S. Air Force) to posses this revolutionary technology. Indeed, the avionics and electronics of the F-16 have dramatically progressed. In fact, the current F-16s produced for export have a core computer suite that has 2,000 times as much memory and over 260 times as much throughput as the original F-16s (Defense Industry Daily, 2010). Undoubtedly, the F-16's currently rolling off the Lockheed Martin's Fort Worth plant are much more capable aircraft than the USAF's own F-16 inventory. Should future fifth-generation combat aircraft, such as the F-35, become too costly, the new production F-16s may be a cost-effective solution to supplement U.S. air forces. This solution would be financially beneficial to DoD since export production kept the F-16 line and DoD would not incur the substantial costs of restarting a production line. Further, the evolution of the F-16 was supported through export production. If DoD did decide to procure new late-model F-16s, the costs associated with technology upgrades would have been subsidized through foreign sales, reducing DoD's aircraft upgrade cost burden. In sum, the F-16 production line kept "warm" and evolving through foreign demand provides a potentially cost-effective solution for supplementing U.S. combat aircraft inventory.

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V. CONCLUSIONS

Brzoska (2004) points out that despite numerous analyses, books, and research articles on the global arms trade, very little is known about the financial aspects of arms exports. Further, the acknowledgement of cost savings through arms exports is commonplace, though the magnitude of savings is rarely, if ever, *quantified*. This research suggests that such conjectured savings do exist and they are potentially substantial. However, as indicated in the CAT policy, financial factors are one aspect that must be considered in any proposed arms transfer. Therefore, the quantification of financial benefits realized through export must be weighed against any potentially negative security externalities. While this research does not attempt to explicate the tradeoff between financial benefits and negative security implications arising from the transfer of arms, this research does provide an understanding of the financial gains through export production and insight into comprehending the holistic financial gains associated such proposed arms transfers.

A. AFFORDING FUTURE DEFENSE THROUGH EXPORTS?

Undoubtedly, constrained budgets, coupled with rising weapon system technology costs, compel reduced procurement quantities unless cost savings can be achieved. As illustrated through the F-16 case study, export production can potentially provide generous per unit cost savings and therefore export production looks attractive as resources tighten. Further, export production can provide positive quantifiable externalities by keeping aging production lines open and the industrial base “warm.” However, if arms sales continue after the U.S. has taken ownership of its last buy of a particular weapon system and those sales are priced using only the variable costs of production and research and development, then the U.S. public may actually end up subsidizing arms sales over the long run.

Increased pressure for fiscal prudence can lead to arms export decisions that more heavily weigh the financial factors established in the CAT policy. Unless defense budgets increase or the services are increasingly willing to make do with less, arms export production may likely become a requisite feature of new weapon system programs.

B. CONSIDERATIONS IN ARMS EXPORT PRODUCTION

The F-16 case study suggests that indeed F-16 production for foreign customers was a cost saving venture for DoD, with an average annual unit cost savings of 24 percent during the production years analyzed. However, these savings may not be representative of the "average" weapon system program that incorporates export production. As mentioned, the F-16 is one of the most prolific combat aircraft produced and exported. Therefore, given the extremely high export quantities, this analysis is more the exception than the rule. Consequently, this research serves more as an upper bound to potential savings, than the status quo.

From a financial standpoint, decision-makers must be wary in assuming that export production is universally beneficial to DoD. As discussed, if additive export production enables total production to achieve economies of scale, certainly export production is easier to justify in financial terms. Conversely, if the additive export production necessitates substantial over-time labor charges or significant investments for chunk capacity, the export production may actually create diseconomies of scale.

LIST OF REFERENCES

Aerospace Industries Association. (n.d.). *Aerospace Facts and Figures* (Editions 44-57). Arlington: Author.

Agmon, M., Bonomo, J. L., Kennedy, M., Leed, M., Watman, K., Webb, K., & Wolf Jr., C. (1996). *Arms proliferation policy*. Santa Monica: RAND. Retrieved from http://www.rand.org/pubs/monograph_reports/2007/MR771.pdf

Anderton, C. H. (1995). Economics of arms trade. In T. Sandler, & K. Hartley (Eds.), *Handbook of defense economics: Volume 1* (pp. 533–562). Amsterdam: Elsevier Science D.V.

Bajusz, W. D., & Louscher, D. J. (1988). *Arms sales and the U.S. economy*. Boulder: Westview Press.

Birkler, J., Large, J., Smith, G., & Timson, F. (1993). *Reconstituting a production capability: Past experience, restart criteria, and suggested policies*. Santa Monica: RAND. Retrieved from http://www.rand.org/pubs/monograph_reports/2005/RAND_MR273.pdf

Brzoska, M. (2004). The economics of arms imports after the end of the Cold War. *Defence & Peace Economics, 15*(2), 111–123.

Calhoun, M. (1996). *Annual military spending from 1945 to 1996.* Retrieved from http://www.cdi.org/issues/milspend.html

Claes, B. (2010). *F-16.net aircraft dataset.* Retrieved from http://www.f-16.net/fleet-reports.html

Defense Industry Daily. (2010). The UAE's F-16 block 60 desert falcon fleet. Retrieved from http://www.defenseindustrydaily.com/the-uaes-f-16-block-60-desert-falcon-fleet-04538/

Defense Institute of Security Assistance Management. (2010). *Green book* (International Standard Serial No. 1532-0359). Washington, D.C.: Government Printing Office.

Eisenhower, D. D. (1961). *Farewell address.* Retrieved from http://mcadams.posc.mu.edu/ike.htm

Federal Aviation Administration (FAA). (1999). *Pricing guidebook: The learning curve.* Retrieved from http://fast.faa.gov/pricing/98-30c18.htm

Flamm, K. (1999). Redesigning the defense industrial base. In A. R. Markusen, & S. S. Costigan (Eds.), *Arming the future: A defense industry for the 21st century* (pp. 224–248). New York: Council on Foreign Relations Press.

Gold, D. (1999). The changing economics of the arms trade. In A. R. Markusen, & S. S. Costigan (Eds.), *Arming the future: A defense industry for the 21st century* (pp. 249–268). New York: Council on Foreign Relations Press.

Hartley, K. (2006). Defence industrial policy in a military alliance. *Journal of Peace Research*, 43(4), 473.

Hartley, K. (2007). The arms industry, procurement and industrial policies. In T. Sandler, & K. Hartley (Eds.), *Handbook of defense economics: Volume 2 defense in a globalized world* (pp. 1139–1174). Amsterdam: Elsevier Science D.V.

Jane's Information Group. (2010). *Lockheed martin F-16 fighting falcon* Jane's Information Group.

Johnson, J. L. (1994). Financing the arms trade. *Annals of the American Academy of Political and Social Science, 535*(The Arms Trade: Problems and Prospects in the Post-Cold War World), 110–121.

Lee, M. (2010, US to tell congress of Saudi arms deal. *Associated Press,* Retrieved from http://www.msnbc.msn.com/id/39749358

Lockheed Martin Corporation. (2009). *Annual report*

Markusen, A. R., & Costigan, S. S. (1999). The Military Industrial Challenge. In A. R. Markusen, & S. S. Costigan (Eds.), *Arming the future: A defense industry for the 21st century* (pp. 3–34). New York: Council on Foreign Relations Press.

Martin, J. R. *The learning or experience curve.* Retrieved from http://maaw.info/LearningCurveSummary.htm

Martin, S. (1996). Introduction and overview. In S. Martin (Ed.), *The economics of offsets: Defence procurement and countertrade* (pp. 1–14). The Netherlands: Harwood Academic Publishers.

Moses, O. D. (1990). Learning curve and rate adjustment models: Comparative prediction accuracy under varying conditions. (NPS-54-91-001). Monterey: Naval Postgraduate School.

Moses, O. D. (1991). *Learning curve and rate adjustment models: An investigation of bias* (NPS-AS-91-005). Monterey: Naval Postgraduate School.

Nussbaum, D. (2010, August). Learning curves. OA4702. Naval Postgraduate School, Monterey, CA.

Office of the Undersecretary of Defense (Acquisition and Technology). (1994). *World-wide conventional arms trade (1994-2000): A forecast and analysis* Washington D.C.: Government Printing Office. Retrieved from http://handle.dtic.mil/100.2/ADA297008

Pages, E. (1999). Defense mergers: Weapons, cost, innovation, and international arms industry cooperation. In A. R. Markusen, & S. S. Costigan (Eds.), *Arming the future: A defense industry for the 21st century* (pp. 207–223). New York: Council on Foreign Relations Press.

Pindyck, R. S., & Rubinfeld, D. L. (1998). *Microeconomics* (4th ed.). Upper Saddle River, N.J: Prentice Hall.

Sandler, T., & Hartley, K. (1995). In Perlman M. (Ed.), *The economics of defense*. Cambridge, U.K.: Cambridge University Press.

Sapolsky, H. M., & Gholz, E. (1999). Private arsenals: America's post-cold war burden. In A. R. Markusen, & S. S. Costigan (Eds.), *Arming the future: A defense industry for the 21st century* (pp. 191–206). New York: Council on Foreign Relations Press.

U.S. Department of Commerce, Bureau of Industry and Security (2009). *Offsets in defense trade, fourteenth study*. Retrieved from http://www.bis.doc.gov/news/2010/14th_offset_defense_trade_report.pdf

United States General Accounting Office. (1997). *Defense industry: Trends in DoD spending, industrial productivity and competition* (GAO/PEMD-97-3). Washington D.C.: Government Printing Office. Retrieved from http://www.gao.gov/archive/1997/pe97003.pdf

United States General Accounting Office. (1998). *Foreign military sales: Millions of dollars of nonrecurring research and development costs have not been recovered* (GAO/AIMD-99-11). Washington, D.C.: Government Printing Office. Retrieved from http://www.gao.gov/archive/1999/ai99011.pdf

Velocci, A. (1994). U.S. shake-out tests supplier's flexibility. *Aviation Week and Space Technology,* 48–51.

Waterson, M. (2010). *Economies of scale [Biz/Ed virtual developing country].* Retrieved from http://www.bized.co.uk/virtual/dc/farming/theory/th4.htm

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