Foreign exchange and lost opportunity in the US Department of Defense

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Abstract

This paper examines US Department of Defense (DoD) foreign exchange rate exposure in light of the government’s prohibition against foreign currency hedging. Using data from the United States Air Force and Monte Carlo simulation, we evaluate whether the use of forward foreign exchange contracts or currency options might reduce the financial impact of currency fluctuation. The results strongly indicate that these alternatives outperform the current method for dealing with foreign currency exposure in the DoD. Using forward contracts, expected cost reductions are on the order of 3.5% of current outlays. For options, expected cost reductions increase to 6.4% thereby defining an upper bound of 2.9% on acceptable option premium levels. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Imagine a subsidiary of a multinational corporation that, over a typical 5-year period, incurs foreign currency exposures on its overseas activities of $5.6 billion. Imagine further that this subsidiary is unable to offset these exposures against fluctuations in foreign currency rates. Although not a multinational corporation,
the US Department of Defense (DoD) incurs substantial obligations denominated in foreign currencies through the overseas operation of its four military services. Like enterprises engaged in international procurement, military services may be required to settle using a supplier’s local currency. In addition, the establishment of a significant overseas US military presence in the post-war period has entailed a considerable economic exposure for the Department of Defense. In the process of fulfilling US alliance and security agreements, the DoD’s overseas activities, like those of a multinational firm engaged in overseas production, involve a number of costs and receipts denominated in currencies different from that in which the DoD is funded.

This paper examines DoD foreign exchange rate exposure in light of the government’s prohibition against foreign currency hedging. Using data from the United States Air Force and Monte Carlo simulation, we evaluate whether the use of forward foreign exchange contracts or currency options might reduce the financial impact of currency fluctuation. The results strongly indicate that these alternatives outperform the current method for dealing with foreign currency exposure in the DoD. Using forward contracts, expected cost reductions are on the order of 3.5% of current outlays. For options, expected cost reductions increase to 6.4% thereby defining a 2.9% upper bound on acceptable option premium levels.

We present our findings in the following manner. Section 2 describes the current process used by the DoD to record and monitor its foreign currency exposure. The international economics and multinational finance literature is helpful in placing these procedures in context. Section 3 presents the model and simulation method by which we compare the DoD’s current unhedged approach to budgeting foreign expenditures with an alternative using forward currency contracts. Section 4 presents the simulation results and their application to currency options. Opportunity costs implicit in maintaining the current procedures are also explored. Summary and conclusions follow.

2. Foreign exchange transactions

The magnitude of the DoD’s foreign currency exposure would evoke considerable efforts to control if incurred by a private enterprise. For context, we briefly contrast methods for addressing foreign currency fluctuations employed in the private sector with the DoD’s current system.

For private firms, numerous procedures exist to counter the adverse consequences of foreign currency fluctuations. The literature on exchange rate pass-through focuses on the ability of a firm to adjust its customer pricing in response to changes in exchange rates (Baldwin and Krugman, 1989; Marston, 1990). Lacking the ability to pass such costs along to the consumer, a firm may respond to currency movements by switching the location of production, as countries with

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1 The $5.6 billion is the result of the overseas operations and maintenance expenses of the US Air Force between fiscal years 1991 and 1996.
weak or weakening currencies provide relatively lower cost manufacturing environments (De Meza and Van Der Ploeg, 1987). Alternatively, firms may offset their foreign exchange risk by using various hedging mechanisms available in the financial markets (Taylor and Mathis, 1985). Mello et al. (1995) modeled the relationship between production flexibility and the hedging strategies of multinational firms. They found that the ability to respond to prevailing exchange rates by relocating production determined the need for a hedging strategy while the application of hedging techniques influenced the location of production.

In the case of DoD foreign currency exposure, these latter two alternatives are unavailable. It is politically infeasible for the DoD to exit a country or otherwise relocate military forces between countries in response to exchange rate movements. This inflexibility relative to the location of defense ‘production’ is matched by an inability to employ standard hedging products offered in the financial markets. Pentagon regulations restrict all foreign currency transactions other than for spot (within two business days) delivery (DoD Financial Management Regulation—Foreign Disbursing Operations, Volume 5, Ch. 12). The use of currency options and derivatives is prohibited by law and forward contracts require the express authorization of the Office of the Under Secretary of Defense-Comptroller.

These proscriptions seem reasonable and necessary considering the responsibility to ensure proper stewardship of public funds and the general inability to predict future exchange rates. Taking a position on foreign currency movements relative to the DoD’s overseas financial obligations is perceived as speculative and improper. Similarly, to avoid cost-of-funds issues, Pentagon regulations disallow payments prior to the receipt of goods or services, such as premium or margin amounts. The DoD deals with the inevitable fluctuations in exchange rates by formally ignoring them. This risk-neutral behavior may stem from the wealth position of the government relative to the DoD’s foreign exchange exposure, as well as the government’s ability to pool risks and extract resources.

The DoD’s inability to apply hedging mechanisms and its unwillingness to appraise future exchange rates constitutes what can be termed a ‘naïve approach’ to foreign currency exposure. This practice has analogies in the private sector (see Klein and Katschka, 1992 for an empirical study of corporate naïve strategy). For many firms, the exposure to foreign currency risk is, like the DoD, small relative to overall operations. Consequently, there is little incentive to incur the cost of developing and maintaining a proactive approach to counter these exposures. However, the magnitude of DoD foreign currency obligations in an environment of declining real defense funding warrants further investigation.

As a result of its naïve approach to foreign currency exposure, the DoD relies on exchange rate pass-through to the taxpayer. The DoD’s exposure originates in the difference between exchange rates applied at the time of program budgeting and those applied when paying final outlays. Each currency’s yearly budget rate is determined by the Office of the Secretary of Defense based on the spot exchange

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2 For example, in fiscal year 1998, $2.8 billion was obligated for overseas operations and maintenance expenses.
rate at an arbitrary point in the budget formulation process. Due to the nature of defense budgeting, initial budget rates are set well in advance of liquidation. The inevitable differences in the ex ante budget rate and the ex post liquidation rate produces variances between the amounts available and the amounts required to pay specific obligations.

Prior to fiscal year (FY) 1979, these differences were absorbed in the annual DoD operating budget or by a reduction in the scale or scope of overseas activities. In both cases, the effects of currency fluctuation were passed along to the taxpayer. Beginning with FY1979, Congress established an account to deal with losses and gains due to exchange rate fluctuations in the operating appropriations of the DoD. To prevent the foreign currency losses from adversely affecting mission readiness and effectiveness, this account—Foreign Currency Fluctuations, Defense—funded the differences between obligations recorded at the budget rate of exchange and the actual liquidated rate.

As outlined in DoD (1987), the Comptroller transfers amounts from the Foreign Currency Fluctuations, Defense Appropriation to the centrally managed allotments (CMA) for each service. These funds are then available to cover currency losses in any of 16 currencies subject to need and budgetary constraints. Overseas activities convert their projected unliquidated foreign currency obligations for the budget year to US dollars using the designated annual budget rate. At the time of liquidation, differences between the dollar equivalent of the foreign obligation recorded at the budget rate and dollar outlay at the then-current rate are charged or credited to the CMA of the relevant component.

The current procedures may be less than optimal for three reasons. First, resource constraints limit the DoD’s continued ability to pass the costs of currency fluctuation along to the taxpayer. Second, the desire to lower operations expenses in favor of increased procurement prompts a reevaluation of the DoD’s current naïve approach. A systematic exploration of alternatives might reveal opportuni-

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3 This usually occurs in late November or early December of the previous fiscal year, although rates can be changed at any point throughout the budget cycle to reflect significant changes in foreign currency markets.

4 In FY1987, a separate account was initiated to isolate the longer-term military construction appropriation. This includes not only expenses for Military Construction, but also Family Housing Construction, Family Housing O&M, and NATO infrastructure. In FY1994, a separate accounting was undertaken within the FCFD account to track differences relative to overseas health care expenses. See DoD Financial Management Regulation—Foreign Currency Reports, Vol. 6, Ch. 7 for specific reporting requirements.

5 Currencies include Belgian franc, British pound, Canadian dollar, Danish krone, Dutch guilder, French franc, German mark, Greek drachma, Italian lira, Japanese yen, Norwegian krone, Portuguese escudo, Singapore dollar, South Korean won, Spanish peseta, and Turkish lira.

6 Only amounts resulting from actual currency fluctuation can be charged to the CMA. Differences due to changes in the cost, magnitude, or scope of requirements must be charged to the operating appropriation.

7 Defense funding has declined 23% in real terms (constant fiscal year 1998 dollars) since 1991 with a 31.5% real decline in the Operations and Maintenance appropriation versus a 49% decline in the Procurement appropriation (Cohen, 1997).
ties for cost reduction. Last, the DoD’s prevailing bias against foreign currency hedging maintains a high degree of uncertainty in the formulation and execution of overseas commitments. Current practice does not eliminate risk from foreign currency fluctuation, it merely defers its realization beyond the budgeting phase. In the next section, we develop a generic decision model to examine alternative methods of dealing with the DoD’s foreign currency exposure in light of these motivating factors.

3. Method

3.1. The model

The fundamental problem is to ensure that adequate domestic funds are allocated to offset future foreign currency needs. Fig. 1 illustrates ex ante alternatives and their ex post consequences in the context of a fiscal year.

Regardless of the alternative selected, costs are incurred before and after liquidated amounts are revealed. The ex ante costs relate primarily to cost-of-funds issues in the allocation (budgeting) phase. Committing the US dollar equivalent of a foreign-denominated obligation, $B_i$, precludes alternative uses of those funds over the relevant time frame. The result is a lost opportunity proportional to the budgeted amount, $\delta B_i$. Ex post costs arise from uncertainty over the actual exchange rates that will prevail in the payment (liquidation) phase. Depending on the relation between the rates of exchange applied ex ante and ex post, sufficient funds might or might not have been budgeted to cover the exposure.

In general, the relative value of an allocation policy can be determined by the relation between ex ante outlays (e.g. budgeted amounts and lost opportunities) and

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Fig. 1. The fundamental decision problem. For policy $i$, $B_i$ represents the domestic amount allocated to offset uncertain future liquidation $L_i$. $\delta$ is the relevant annual discount rate and $p$ is the probability that $B_i$ equals or exceeds $L_i$ at the time of payment.

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\footnote{In line with Office of Management and Budget discount rate policy (OMB, 1992), we use $\delta = 0.07$ throughout our analysis.}
ex post receipts (e.g. excess or insufficient budgeted amounts). Using negative signs to signal outlays and positive signs to denote receipts, the value of a specific policy \(i\) in Fig. 1 can be expressed:

\[
V_i = - (B_i + \delta B_i) + p(B_i - L_i) - (1 - p)(L_i - B_i) = - (\delta B_i + L_i)
\]  

(1)

For policy \(i\), \(B_i\) represents the domestic amount allocated to offset uncertain future liquidation \(L_i\). \(\delta\) is the relevant annual discount rate and \(p\) is the probability that \(B_i\) equals or exceeds \(L_i\) at the time of payment. The difference in respective values for a reference policy \(X\) and alternative policy \(Y\), can be expressed:

\[
V_X - V_Y = (\delta B_X + L_X) + (\delta B_Y + L_Y) = \delta(B_X - B_Y) + (L_X - L_Y)
\]  

(2)

In a situation where \(X\) is a status quo policy, \(V_X^Y\) quantifies the relative benefit of switching from \(X\) to \(Y\). Given values for the relevant discount rate, the budgeted amounts, and amounts due at liquidation, such a switch would be attractive whenever \(V_X^Y > 0\).

3.2. The DoD’s problem

We adapt the model of Fig. 1 to compare the DoD’s current budgeting approach against a simple hedging strategy. Given cost-of-funds issues and the DoD’s bias against speculation, we defer consideration of currency options and focus on the use of forward rate contracts. Forward contracts require no expectation about future currency values; nor do cost-of-funds issues arise, because moneys are not disbursed until the expiration date. Instead, interest rates on Eurocurrency deposits of similar maturity determine a premium or discount adjustment to the spot rate.

Of initial interest is whether the DoD incurs an opportunity loss in maintaining a na"ive approach rather than employing a forward contract approach. The analysis is based upon Eqs. (1) and (2) using \(i \in \{N,F\}\), where \(N(F)\) designates the Na"ive Approach (Forward Contract Approach). We let \(T\) designate the number of periods in the budget cycle and assign each foreign country an index from \(1,2,\ldots, C\), where \(C\) is the number of foreign countries included in the analysis. The index 0 is reserved for the United States. We define \(S^j_k\) to be the sum of money in the currency of country \(j\) that the DoD must provide at the end of period \(k\). The total amount of money in foreign currency \(j\) to be paid out by the DoD during the course of the fiscal year is

\[
S^j = \sum_{k=1}^{T} S^j_k \text{ for } j > 0.
\]

Under the Na"ive Approach, the DoD estimates the total US dollar equivalent of its overseas commitments for the upcoming fiscal year by using the spot exchange rate at some point in the budget preparation cycle to determine its total ex ante commitment \(B_N\). The amount due at the time of liquidation is \(L_N\), which might be quite different from \(B_N\). These quantities are defined:

\footnote{Forward contracts are the only alternative expressly identified as possible, albeit with Comptroller permission.}
\[B_N = \sum_{j=1}^{C} \sum_{k=1}^{T} S_j r^k_j, \quad L_N = \sum_{j=1}^{C} \sum_{k=1}^{T} S_j r^k_j\]

Under the Forward Contract Approach, the DoD determines the total US dollar equivalent of its overseas commitments by applying forward rates to the estimated foreign amounts. Under this approach, the amount budgeted equals the amount liquidated:

\[B_F = L_F = \sum_{j=1}^{C} \sum_{k=1}^{T} S_j^k \left( r^k_j \left( 1 + \frac{k(i^0_j - i^0_B)}{T} \right) \right)\]

where \(i^0_j\) is the per annum Eurocurrency interest rate for country \(j\) at the time of budgeting. The bracketed term is the familiar covered-interest parity condition used in determining forward rates.

Substituting these expressions into Eqs. (1) and (2) yields:

\[V_N^F = \sum_{j=1}^{C} \sum_{k=1}^{T} S_j^k \left( r^k_j \left( 1 + \frac{k(1-\delta)(i^0_j - i^0_B)}{T} \right) - r^k_j \right)\]

(3)

3.3. Simulation of the DoD’s problem

The quantities in Eq. (3) are not known with certainty at the time of budgeting, so exact comparisons are only available ex post. However, given a distribution over \(V_N^F\), one can gain insight into the long-term relative performance of the two competing alternatives. Monte Carlo simulation was used to estimate this distribution using:

- daily exchange rates for the three currencies considered drawn from the Federal Reserve Bank of Chicago and are quoted in US dollars per unit of foreign currency. The data extend from 1985:1 to 1998:3 providing 3317 daily exchange rate observations.
- Eurocurrency interest rates drawn from The Economist. The data extend from 1985:1 to 1998:3 providing 646 weekly interest rate observations.
- United States Air Force monthly O&M commitments (\(S_j^k\)) from fiscal year 1993 to 1997, as reported by the Defense Finance and Accounting Service (DFAS)-Denver. These commitments are budgeted and liquidated in the same fiscal year \((T=12)\) where \(r^k_j\) is the spot rate of exchange for currency \(j\) at the time of budgeting and \(r^k_j\) is the spot rate of exchange for currency \(j\) at the time of liquidation at the end of period \(k\).

To assure the validity of our results, several steps are taken to preserve parameter relationships in the simulation model. First, rather than sample exchange and interest rates independently or by currency, we sampled all rates jointly across currencies to preserve cross-currency relationships\(^\text{10}\). Second, because interest rates affect the returns on assets denominated in their respective currencies, relative changes in those rates affect the supply and demand for those currencies. Therefore, the Eurocurrency interest rates used in the calculation of forward rates were those

\(^\text{10}\) Bremnes et al. (1997) find Eurocurrency interest rates for the G-5 to be cointegrated.
Table 1
Results of a 25 000 iteration simulation of \( V^F_N \) for the three major currencies considered, individually and in aggregate

<table>
<thead>
<tr>
<th></th>
<th>German mark</th>
<th>Japanese yen</th>
<th>British pound</th>
<th>Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E[V^F_N] )</td>
<td>16 332 301</td>
<td>2 926 223</td>
<td>8 659 820</td>
<td>27 918 344</td>
</tr>
<tr>
<td>( E[L_N] )</td>
<td>492 478 122</td>
<td>96 835 752</td>
<td>208 492 104</td>
<td>797 805 978</td>
</tr>
<tr>
<td>( \sigma_{V^F_N} )</td>
<td>78 784 192</td>
<td>11 383 944</td>
<td>29 670 620</td>
<td>100 688 564</td>
</tr>
<tr>
<td>( SE_{V^F_N} )</td>
<td>498 275</td>
<td>71 998</td>
<td>187 653</td>
<td>636 810</td>
</tr>
<tr>
<td>( P[V^F_N &gt; 0] )</td>
<td>61.66</td>
<td>60.46</td>
<td>64.52</td>
<td>63.58</td>
</tr>
<tr>
<td>( E[V^F_N]/E[L_N] )</td>
<td>52 304 017</td>
<td>9 916 552</td>
<td>22 438 432</td>
<td>78 137 407</td>
</tr>
<tr>
<td>( E[V^F_N]/E[L_N] )</td>
<td>3.32</td>
<td>3.02</td>
<td>4.15</td>
<td>3.50</td>
</tr>
<tr>
<td>( E[V^F_N]/E[L_N] )</td>
<td>10.62</td>
<td>10.24</td>
<td>10.76</td>
<td>9.79</td>
</tr>
</tbody>
</table>

* The symbols \( \sigma_{V^F_N} \) and \( SE_{V^F_N} \) designate the standard deviation of \( V^F_N \) and mean standard error for samples of size \( n = 25 000 \). High standard deviations relative to the mean are the consequence of data outliers.

eexisting on the date of budget rate selection. Finally, we preserved the temporal relationships within each currency by tying the realization of the spot rate of exchange at liquidation (\( r_L \)) to the selection of the spot rate of exchange at budgeting (\( r_B \)). A detailed explanation of our sampling procedure is presented in Appendix A.

We limit the scope of our analysis to the Air Force’s operations and maintenance (O&M) obligations in the three major currencies of exposure: the German mark, the Japanese yen, and the British pound. Although these three currencies comprise 64% of total Air Force overseas O&M obligations, Air Force overseas obligations represent just 20% of total DoD overseas O&M expenditures (DoD, 1998). Although this may represent a small component of total DoD overseas obligations, it is sufficient to highlight the distributional properties of \( V^F_N \).

4. Results

4.1. Interpretation of simulation results

Fig. 3 illustrates the long-term behavior of \( V^F_N \) for the three currencies considered, individually and in aggregate. Summary statistics are provided in Table 1. Three things are immediately apparent. First, the expected value of switching from the Naïve Approach to the Forward Approach (\( E[V^F_N] \)) is positive for each currency, indicating that on average the Air Force would benefit from changing its

\[ r_L \] made independently of \( r_B \) might result in the selection of \( r_B \) at a period of dollar strength (e.g. February 1985) and a realization on \( r_L \) during a period of dollar weakness (e.g. March 1995). The 51% decline in the trade-weighted value of the dollar over this 10-year period does not reflect exchange rate behavior over the shorter 11–22 month budget-to-liquidation cycle.
procedures for budget execution of its overseas O&M obligations. Second, the long-term probability that the Forward Contract Approach outperforms the Naïve Approach \( P[V_N^F > 0] \), exceeds 60% in all cases. Last, when the Forward Contract Approach outperforms the Naïve Approach \( (V_N^F > 0) \), it does so on average by 10% of total yearly expenditures expected under the Naïve Approach. In other words,

\[
E \left[ V_N^F \mid V_N^F > 0 \right] \approx \frac{E[L_N]}{10}.
\]

Because each simulation year represents one of 25 000 independent observations (see Appendix A), the simulation output can be partitioned into sets of size \( N \) to represent 25 000/\( N \) \( N \)-year time frames. In the case of \( N = 5 \), for instance, the simulation could be viewed as a single run over 25 000 1-year frames or 5000 5-year frames. Fig. 2 shows the likelihood the Forward Contract Approach is average optimal over time frames from 1 to 30 years. In aggregate, this likelihood of average optimality increases beyond 75% for time frames of 5 years and longer. Consideration of 5-year time frames is particularly relevant given the DoD’s 5-year planning horizon on O&M expenditures. For time frames in excess of 19 years, this likelihood increases beyond 90% in aggregate.

Given the high probability that the Forward Contract Approach will outperform the Naïve Approach, it is natural to ask whether the commensurate savings will be significant. Switching from the Naïve to the Forward Contract Approach can be expected to reduce total annual expenditures by 3.3% (German mark), 3.0% (Japanese yen), and 4.2% (British pound) (Table 1). These savings are non-trivial. In aggregate over the three currencies examined, the Air Force’s estimated annual

![Fig. 2. Probability that the Forward Contract Approach is less costly on average than the Naïve Approach for time frames of 1 to 30 years.](image)

\[\text{For } T\text{-many time frames of } N \text{ years, the probability of average optimality is } \frac{1}{NT} \sum_{j=1}^{T} \sum_{i=1}^{N} \xi_{ij}, \text{ where } \xi_{ij} = 1 \text{ if the Forward Contract Approach is optimal in year } i \text{ in time frame } j, \text{ and zero otherwise.}\]
overseas O&M expenditures under the Naive Approach total $798 million; the total annual savings from switching to the Forward Contract Approach average 3.5% of this amount, or $27.9 million. Assuming that the Air Force’s portion of total DoD overseas O&M expenditures in these three currencies remains constant at 20%, extending the estimated 3.5% savings across services implies an annual overall reduction of $139.5 million.

4.2. Effect of the CMA

This section accounts for the opportunity cost of maintaining a continuous source of funds to offset adverse changes in exchange rates during the budget to liquidation period. In FY1998, reserve amounts held in the O&M CMAs totalled $449 million (DoD, 1998). The Air Force share of this total is estimated at approximately 20%, or $89.8 million. Based on their 64% share of overall Air Force O&M obligations, the three currencies considered account for $57 million. What effect might inclusion of these funds have on the analysis?

In general, the existence of a reserve account such as the CMA does not alter the structure of the problem, it merely increases the DoD’s ex ante costs. If $M_i$ is the magnitude of the reserve for policy $i$ and $\delta$ is the relevant cost of funds, an additional opportunity loss of $\delta M_i$ is realized in maintaining the account. We can modify Eqs. (1) and (2) directly to reflect this.

\[
\hat{V}_t = -(\delta B_t + M_i) + L_i
\]

\[
\hat{V}_X = \hat{V}_Y - \hat{V}_X = \delta(B_X - B_Y + M_X - M_Y) + (L_X - L_Y) = V'_X + \delta(M_X - M_Y)
\]

Because the CMA is necessary only to manage losses (gains) from under (over) budgeting in the Naive Approach, $M_F = 0$ and $M_N = M$. Thus, $\hat{V}_N = V'_N + \delta M$ and there is enticement to switch from the Naive Approach to the Forward Contract Approach whenever $V'_N > -\delta M$. Hence, for the Forward Contract Approach to be optimal, it must be that $V'_N > -\delta M$ (as opposed to $V'_N > 0$ without a reserve account). Subsequently, the probability that the Forward Contract Approach is optimal for any given year increases by

\[
\int_{-\delta M}^{0} f_{V'_N} dV'_N,
\]

where $f_{V'_N}$ is the density function of $V'_N$ (approximated in Fig. 3). Incorporating a $57$ million CMA into the simulation effectively lowers the Forward Contract Approach’s optimality hurdle from $0$ to $-4$ million (i.e. $57$ million discounted at 7%). In the aggregate, the probability that the Forward Contract Approach is optimal increases by 2.2 to 65.8% (with increases of 4.5% for the German mark, 13.9% for the Japanese yen, and 8.2% for the British pound).

\[\text{Although actual data were unavailable, estimates are based relative to the USAF share of total O&M obligations. This is consistent with the USAF share of the Military Construction CMA for which data are available.}\]
Fig. 3. Distributions of the $V_N^p$ functions for the German mark, Japanese yen, British pound, and the aggregate of the three currencies.
4.3. Foreign currency options

Lifting current prohibitions against currency derivatives would enable the DoD to use over-the-counter call options to remove the dominant source of uncertainty—exchange rate variability—without the loss of flexibility. For comparison with the Forward Contract Approach, we consider call options with an at-the-money forward strike price. Such options require no expectations on future exchange rates because the strike price is determined using the same covered-interest parity conditions as the Forward Contract Approach. An option approach also eliminates the need to maintain the CMA, thereby releasing the estimated $57 million for alternative uses.

With a currency option, the DoD purchases the right to buy a given currency (e.g. German marks, Japanese yen, and British pounds) at a specified future date at a specified rate (strike price) in exchange for the payment of an up-front premium. The premium secures the flexibility to decide ex post whether to apply the budget rate (i.e. the strike price) or the then-current spot rate against payment of the DoD’s obligations. The cost of the premium depends on the time-to-maturity of the contract, interest rates, currency volatility, and the relation of the strike price to the spot rate at the time of budgeting.

The premium or discount on the forward rate determines whether the option strike price is in-the-money or out-of-the-money, and subsequently affects the option premium. For example, suppose the Air Force has an exposure of one million German marks payable in 12 months. With a spot rate of 0.5000 and a forward rate of 0.4950, the call option strike price will be in-the-money by 0.0050 points. Strike prices further below the spot rate will increase the option premium as will longer maturities. At expiration, the DoD can choose whether to exercise its right to buy the German marks at 0.4950 or permit the option to lapse and buy at the current spot rate. The option is exercised when \( B_{\text{Option}} = L_{\text{Option}} < L_N \).

The purchase of a currency option essentially enables the DoD to defer its choice of Naïve or Forward Contract Approach until after exchange rate uncertainty is resolved. However, any reduction in final outlays attributable to a currency option must be offset by the ex ante option premium. On average, as long as this premium does not exceed the expected savings from the option, it would benefit DoD to consider the call option. Consequently, upper bounds on premiums can be estimated by calculating the expected value of perfect information on currency exchange rates.

The expected value of perfect information (EVPI) (Howard, 1966, 1967) is based on the idea of deferring a decision until after uncertainties are resolved\(^{14}\). For any uncertainty set \( \Pi \), the decision is deferred until the values obtained by all \( \pi \in \Pi \) are observed. Averaging over all possible realizations of \( \Pi \) results in the expected value of perfect information on \( \Pi \), \( EVPI(\Pi) \). Mathematically, this is expressed:

\(^{14}\) Good general discussions of EVPI may be found in Raiffa and Schlaifer (1961), Gould (1974), and Howard (1988).
\[ EVPI(\Pi) = E_0[\max_i \{E[V_i - V_0 | \Pi]\}] \]

where \( V_0 \) is the average optimal alternative (i.e. \( E[V_0] \geq E[V_i] \) for all \( i \)). Because EVPI can be interpreted as an expected improvement over a base preferred alternative, we can use the Naïve Approach as the DoD’s base preferred alternative, let \( \Pi \) be the set of all relevant foreign currency exchange rates, and write:

\[ EVPI(\Pi) = E_0[\max \{ E[V_\Pi^k] | \Pi \}, 0] \] (4)

For a specific currency, \( EVPI(\pi) \) represents the average savings, if any, the DoD could expect (relative to the payoff of the Naïve Approach) if all uncertainty regarding that currency rate was resolved prior to deciding whether to opt for a Forward Contract Approach or stay with the Naïve Approach\(^{15}\).

We defined \( \Pi = \{r_k, r_j^L\} \) for all \( k \) and all \( j > 0 \), then performed an EVPI analysis using Eq. (4). Expressed as percentage savings over \( E[L_\pi] \), \( EVPI(\pi) \) is 6.46% (German mark), 6.28% (Japanese yen), 7.83% (British pound), and \( EVPI(\Pi) = 6.36% \). However, because the Forward Contract Approach outperforms the Naïve Approach on average, only marginal improvements over the former are relevant in determining an acceptable option premium. For example, the Forward Contract Approach outperforms the Naïve Approach for the German mark by 3.32% on average (Table 1). Because \( EVPI(\pi) = 6.46% \) for the German mark, perfect foresight yields a 3.14% marginal improvement over the Forward Contract Approach. Given that \( E[L_\pi] = \$492 \) million for the German mark, annual premiums for German mark options should not exceed \( \$492 \times 0.0314 = \$15.5 \) million. Marginal improvements for the remaining currencies are 3.26% (Japanese yen), 3.68% (British pound) and 2.86% (aggregate). Similarly, premium bounds for the Japanese yen and the British pound are \$3.2 million and \$7.7 million, respectively. For concurrent options on all three currencies, total premiums should not exceed 2.86% of \$798 million, or \$22.8 million. Since obtainable information is less than perfect, these figures represent theoretical upper limits on expenditures for option premiums\(^{16}\).

5. Summary and conclusion

The preceding analysis employed Monte Carlo simulation to investigate the DoD’s approach to managing its foreign currency exposure. The evaluation was made relative to an alternative based on forward currency contracts. Analytic results were extended to encompass foreign currency options. Three results appear. First, for a 1-year time frame, the Forward Contract Approach outperforms the

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\(^{15}\) Although measuring improvement from a base optimal or status quo alternative is technically not the same as calculating a true EVPI, we use the term EVPI to represent expected savings given a pre-decision resolution of uncertainty.

\(^{16}\) As of time of writing, the premium on a 1-year at-the-money call forward option on German marks was 3.505%.
Naïve Approach 63.6% of the time by an average of 3.5% of the total amount liquidated under the Naïve Approach. Second, if the Naïve Approach were abandoned in favor of the Forward Contract Approach (or an option approach), the foreign currency fluctuation account (CMAs) would be superfluous and reserve amounts could be used elsewhere. Last, while an option approach outperforms the Forward Contract Approach on average, the marginal benefit must be adjusted to account for ex ante premium amounts.

This study reveals a paradox in the DoD’s current approach to its foreign currency exposure. In attempting to prevent speculation by restricting the use of hedging alternatives, the DoD has settled on a policy which is itself speculative. Under the Naïve Approach, the DoD effectively gambles that no significant change in exchange rates will occur during budget execution. Meanwhile, in maintaining a separate fund to offset expected losses consequent to exchange rate fluctuation, the government—if not the DoD itself—relinquishes its ability to use those moneys for other purposes, thereby incurring an additional opportunity loss.

Our findings indicate that the DoD would benefit, as it has in other areas, by applying market-based procedures to deal with its foreign currency exposure.

Acknowledgements

The authors would like to thank Kent Wall for insightful suggestions during the development of the sampling procedure and an anonymous referee for valuable comments on an earlier draft.

Appendix A

The following describes our method for generating the exchange and interest rate parameter values for each simulation year. Table 2 shows the first 10 rows of the underlying $3316 \times 7$ data matrix $D$ (non-shaded area). Each row $i$ corresponds to a date; each column $j$, a daily exchange rate ($0 \leq j \leq 2$) or a Eurocurrency interest rate for appropriate week ($3 \leq j \leq 6$). For example, in Table 2, $d_{2,1}$ is the exchange rate for the Japanese yen on January 4, 1985 and $d_{6,6}$ is the Eurocurrency interest rate for the British pound effective for the week containing January 15, 1985.

The data in $D$ were obtained from the following:
- Daily exchange rates for the three currencies considered were drawn from the Federal Reserve Bank of Chicago and are quoted in US dollars per unit of foreign currency. The data extend from 1985:1 to 1998:3 providing 3317 daily exchange rate observations.
- Eurocurrency interest rates are drawn from The Economist. The data extend from 1985:1 to 1998:3 providing 646 weekly observations.
Table 2
The first 10 rows of the data set $\mathbf{D}$

<table>
<thead>
<tr>
<th>Date</th>
<th>Exchange rates</th>
<th>Eurocurrency interest rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>German mark</td>
<td>Japanese yen</td>
</tr>
<tr>
<td>1/2/85</td>
<td>0.315159</td>
<td>0.003971</td>
</tr>
<tr>
<td>1/3/85</td>
<td>0.316206</td>
<td>0.003961</td>
</tr>
<tr>
<td>1/4/85</td>
<td>0.315657</td>
<td>0.003949</td>
</tr>
<tr>
<td>1/7/85</td>
<td>0.314713</td>
<td>0.003907</td>
</tr>
<tr>
<td>1/8/85</td>
<td>0.317007</td>
<td>0.003941</td>
</tr>
<tr>
<td>1/9/85</td>
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<tr>
<td>1/10/85</td>
<td>0.318421</td>
<td>0.003942</td>
</tr>
<tr>
<td>1/11/85</td>
<td>0.316957</td>
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</tr>
<tr>
<td>1/14/85</td>
<td>0.313185</td>
<td>0.003915</td>
</tr>
<tr>
<td>1/15/85</td>
<td>0.313922</td>
<td>0.003926</td>
</tr>
</tbody>
</table>
Each column vector of $\mathbf{D}$ represents a nonstationary time series; specifically, a unit root process (random walk) with zero drift. Accordingly, we created the $3316 \times 7$ first difference matrix $\mathbf{D} = [d_{i,j}]$ by defining $d_{i,j} = d_{i,j} - d_{i-1,j}$ for all $i, j$ and employed algorithm A (below) to generate a simulation year with time series properties consistent with those of $\mathbf{D}$.

A.1. Algorithm A: generate simulation year

BEGIN
FOR EACH YEAR
   Step 1. Generate $440 \times 7$ matrix $\mathbf{X} = [x_{i,j}]$ by sampling uniformly over the rows of $\mathbf{D}$ (with replacement). If row $k$ is randomly selected on iteration $m$, then $x_{m,j} = d_{k,j}$ for all $j$.
   Step 2. Generate random time index $i_0 \in \{0,1,\cdots,3316\}$. Define initial $1 \times 7$ vector $\mathbf{a} = [a_j]$ such that $a_j = d_{i_0,j}$ for all $j$.
   Step 3. Generate $440 \times 3$ matrix $\mathbf{Y} = [y_{i,j}]$ such that for $0 \leq \beta \leq 439$
   
   \[
   y_{\beta,j} = \begin{cases} 
   x_j & \text{if } \beta = 0 \\
   x_j + \sum_{k=1}^{\beta} -1/2x_{k,j} & \text{if } \beta > 0
   \end{cases}
   \]

   Step 4. \text{<GENERATE EXCHANGE RATES>}
NEXT YEAR
END

The time frame of 440 days in algorithm A is based on (1) an average of 20 days per month observed in $\mathbf{D}$ (due to holidays, leap years, weekends, etc.), and (2) the procedure used to set the Air Force’s O&M budget. The process begins when the DoD applies its spot exchange rates to Air Force monthly commitment projections in order to determine the O&M budget for the next fiscal year. The Air Force’s first monthly payment is made 11 months later, with remaining monthly amounts due over the next 11 months. To mimic this process, we generated initial spot rates as well as those in effect at the times of liquidation: this meant using time series of 22 months at 20 days per month, or 440 days.

Monthly O&M commitments in currency $c$ ($S^c_k$) were generated randomly from the historical account of the Air Force’s monthly (i.e. $T = 12$) O&M commitments over fiscal years 1993–1997, as reported by the Defense Finance and Accounting Service (DFAS)-Denver. These commitments are budgeted and liquidated in the same fiscal year. While this data set may seem sparse, it is rich from a simulation standpoint: each set of 60 observations (i.e. 5 years of monthly data for each currency) can be used to generate $2.18E+21$ distinct sequences of annual expenditures.

The exchange rates in effect at the time of liquidation ($r^L_k$) embedded in algorithm A were determined using algorithm B.
A.2. Algorithm B: generate exchange rates

BEGIN
Step 1. Let $r_B^c$ be the budgetary spot rate for currency $c \in \{1, 2, 3\}$. Let $i_B^c$ be the Eurocurrency interest rate for country $c \in \{0, 1, 2, 3\}$ ($c = 0$ is the US) at the time of budgeting. Then given $Y = [y_{i,j}]$ from A,

$$r_B^c = y_{0,c-1} \text{ for } 1 \leq c \leq 3$$

$$i_B^c = y_{0,c+3} \text{ for } 0 \leq c \leq 3$$

Step 2. Let $r_k^c$ be the liquidation exchange rate for month $k$ of the budgeted fiscal year (i.e. simulation year). Then, for each currency $c \in \{1, 2, 3\}$

For $k = 1$ to 12

$$r_k^c = y_{20(k-1) + 220,c-1}$$

Next $k$

END

Using this method, we were able to directly compare the costs associated with a Naïve and Forward Contract Approach over an ensemble of 25,000 simulation years, each of which maintained the sequential relationships existent in the underlying data matrix $D$.

References