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DEATH (MACHINES) AND TAXES

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Abstract: In the defense policy literature, it is widely believed that there is a pronounced bias towards the procurement of a less than optimal number of excessively sophisticated weapons. In this paper, we consider the possibility that this perceived bias is the result of the timing and informational structure of defense procurement decisions, and the inter-relationship of this structure with overall fiscal policy. Specifically, this paper presents a model that suggests that tax smoothing considerations of the type first articulated in Barro (1979) could lead social welfare maximizing decision makers to choose a higher level of weapon quality than would be optimal if government revenue could be raised without resort to distortionary taxation.

Keywords: Defense procurement; Weapon quality; Tax smoothing;

JEL classification: H57

INTRODUCTION

It is widely believed that the defense procurement processes followed by most countries result in the purchase of an inefficiently small number of excessively sophisticated weapons. This belief can be traced back to the ACEVAL/AIMVAL trials conducted by the US Air Force during the 1970s. In these trials, advanced F-15 fighters were pitted against "low tech" F-5 interceptors in simulated air combat engagements. The F-15s performed no better than the F-5s.[1]

Since ACEVAL/AIMVAL first raised the subject, a number of empirical studies have reported anecdotal or "case study" evidence in support of a systematic bias towards procurement of high quality weapons. Most notable amongst these studies are Gansler (1980), Stubbing (1986), and Lipow and Feinerman (2001).

While psychologists may chalk up this bias towards fancy weapons to a bad case of "missile envy," no less than three papers have considered the economic theory underpinning the "quantity/quality" trade-offs inherent in the defense procurement process. In Rogerson (1990), the military leadership is motivated by an idealistic commitment to maximizing the nation's combat capabilities. The government, however, is interested in maximizing a social welfare function of which military capability is only one argument, while program cost is another.

Rogerson assumes that the military controls the weapon development process, thus allowing it to dictate the level of quality incorporated into proposed weapon systems. The government, having

[1]A number of observers, including the authors of this paper, regard the AICVAl/AIMVAL results with great skepticism. All engagements were in daylight and good weather, negating the F-15's superior night/adverse weather capabilities. Ground radars guided the aircraft to each other, negating the value of the F-15s superior radar. Furthermore, all engagements were near USAF bases, eliminating the F-15s advantage in range. In short, the F-15 was unable to demonstrate its qualitative superiority because the structure of the trials forbade it from doing so.

been presented with a system whose quality cannot be altered, then determines the quantity it desires to purchase. When quality and quantity are poor (good) substitutes in the production of military capability, this framework gives the military an incentive to choose systems of higher (lower) than socially optimal quality.

Lipow and Feinerman (2001) consider a special case that mimics the institutional arrangements established in Israel. In their formulation, the military faces a fixed budget constraint but enjoys absolute control of budget allocation. The quality of military leadership is not directly observable. In order to enhance their reputations, officers engage in signaling behavior that results in a separating equilibrium in which more capable military leaders choose to purchase weapons of excessive quality while less capable leaders choose a socially optimal quality level.

In Feinerman and Lipow (2001), the authors argue that the choice of weapon quality must be made under conditions of uncertainty regarding the security environment that the military will face when the proposed weapon is actually fielded, while the choice of quantity is only taken following observation of the evolution of security threats. They find that for most credible classes of production functions, the inter-temporal and informational structure of the decision making process unambiguously leads to the choice of a higher level of weapon quality than would be the case under conditions of certainty or if the quality and quantity decisions were made simultaneously.

In this paper, we will argue that the efficiency of the tax system may also influence the socially optimal choice of weapons quality. In our formulation, social welfare is a function of military capability and the total social cost of financing the program, where total social cost includes both direct program costs as well as the welfare losses stemming from the taxation required to finance program costs. This differs from papers such as Rogerson (1990) and Feinerman and Lipow (2001) that only consider direct program costs.

Our approach to tax efficiency is strongly inspired by Barro (1978) and Lucas and Stokey (1982). Barro models the dead-weight loss of taxation as an increasing function of the tax rate. This allows him to derive an inter-temporal version of the Ramsey Rule (Ramsey, 1927) known as "tax smoothing" in which tax efficiency is maximized by maintaining a constant marginal tax level over time.

Lucas and Stokey (1982) extend Barro's approach into a stochastic world and demonstrate that tax smoothing holds not only over time but over states of nature. This implies that marginal tax rates should evolve as a random walk process driven by unexpected changes in spending and tax revenue.

The intuition behind our argument is quite straightforward. Wars result in an unexpected increase in government expenditures as well as an unexpected decline in tax revenue. An investment in weapon quality yields a high return when there is a war and a low return when there is peace. In other words, it yields a high pay-off precisely in the state of nature that would otherwise require that marginal tax rates be raised. Due to the increasing marginal cost associated with tax rates, a government concerned with lowering total expected social cost would invest more in weapon quality than would be the case if its objective is to minimize expected program cost.

This paper has four sections. In the second section, we present a model of defense procurement decision making. The model demonstrates that tax efficiency consideration do indeed influence the socially optimal level of weapons quality. An unambiguous bias towards greater weapon quality, however, requires additional assumptions regarding the production of military capability or the level of security threat. In the third section, we argue that, in practice, the conditions required for tax smoothing to lead to a bias towards greater weapon quality are almost always met. The fourth section concludes the paper.

THE MODEL

In this model, the government must procure a new weapon system. Following Feinerman and Lipow (2001), defense procurement is modeled as a two-period process. The quality level must be chosen during the first period. When the government chooses the quality level, it does not know what the national security situation will look like when the weapon actually enters production. It does, however, have certain beliefs regarding the likelihood of various different security scenarios.

Between the first and second period, decision makers observe the evolution of the security threat. This reflects the protracted lag between the decision to design and test a weapon and the decision to actually go ahead and deploy it. For example, America's recently deployed F-22 "Raptor" fighter aircraft required 22 years of development. By the time the Raptor was ready for production, the security threat for which it was originally designed – a full scale conventional war with the Soviet Union – had literally disappeared.

During the second period, the government chooses the quantity of weapons to be purchased. Clearly, if national security threats have subsided over the course of a weapon's development phase, the production run will be scaled back or even canceled. If, on the other hand, security conditions have eroded during the weapon development phase, production may exceed that foreseen when the weapon was first proposed.

To simplify the analysis and preserve its underlying intuition, we assume that the government's budget must always be balanced. In a related working paper, we show that when the government may record fiscal surpluses and deficits, there is no closed form analytical solution to the government's optimization problem. In terms of optimal weapon quality, the results of simulation analyses prove to be consistent with the results presented in this paper. What is lost by assuming budget balance is the capability to evaluate the role of precautionary surpluses and deficits as tools in minimizing the social cost of evolving security threats.

Let Q be the amount of "weapon quality" and let N represent the number of weapons procured as well as the manpower required to operate them. The units of Q and N are calibrated so that the cost of a unit in both cases is 1. In other words, Q measures the expenditure on weapon research and development (as well as long lead-time fixed costs associated with readying the weapon for production) while N represents the expenditure on variable costs associated with procurement and manning.

Let the function D(Q,N) represent the level of military capability produced by a particular combination of weapon quality and quantity. For simplicity and clarity, D will be modeled as a Cobb-Douglas function:

(1) $D(Q,N)=Q^qN^n$, where $q,n>0$.

In addition to simplifying the presentation and analysis, the choice of Cobb-Douglass technology accurately reflects the methods applied by government policy makers. As evidence, consider the routine exploitation of Cobb-Douglass production functions in the CGE simulations so widely used to analyze tax reforms and trade agreements.

There are two possible states of nature during the second period. The first is "war," and the second is "peace." The term war implies full scale conflict, or what is commonly known amongst military planners as the "worst case scenario." Thus, the probability that a new armored vehicle, for example, may engage in combat during a peace keeping mission may be very high, but has no impact on decision making.

The government correctly believes during the first period that the probability of war during the second period is p. In the event of peace, the level of military capability required is zero, while in the event of war the level required is D_0. This implies that N equals zero in the event of peace. In the event of war,

(2) $N = D_0^{1/n} Q^{-q/n} \equiv B Q^{-\gamma}$, where $B \equiv D_0^{1/n}$ and $\gamma \equiv (q/n)$.

Given the probability of war, what is the socially optimal level of weapon quality? Let $\beta<1$ be the time discount rate. Then the government's objective is to identify the level of Q that minimizes the expected costs

$$Q^{1+\tau}+\beta p(BQ^{-\gamma})^{1+\tau}$$

If $\tau=0$ then the taxes raised to finance R&D and procurement are non-distorting, in the sense that there is no excess burden associated with the tax system. The cost of a dollar of taxes is one dollar. When $\tau>0$, and c dollars are raised to finance R&D or procurement, the total cost, including excess burden, is $c^{1+\tau}$ dollars.

For Q to be optimal it must satisfy

$$(1+\tau)Q^{\tau}+(1+\tau)\beta p(BQ^{-\gamma})^{\tau}(-\gamma BQ^{-(1+\gamma)})=0.$$

This implies

$$(3)\ \ Q=\left(\beta p\gamma B^{1+\tau}\right)^{1/(1+\gamma)(1+\tau)}.$$

Before proceeding, note that

$$\frac{\partial Q}{\partial p}=\frac{1}{(1+\tau)(1+\gamma)}\left(\beta\gamma B^{1+\tau}\right)^{1/(1+\tau)(1+\gamma)}p^{1-(1+\tau)(1+\gamma)/(1+\tau)(1+\gamma)}>0,\ \text{for } \tau\geq 0.$$

This makes perfect sense: as the probability of war increases, and hence the chance that money will be spent on procurement and manpower, more of the burden is shifted to R&D. This, irrespective of whether or not the tax is distortionary.

How does increased distortion affect the allocation between Q and N? For an answer, differentiate Q with respect to τ in (3) to obtain

$$(4)\ \ \frac{\partial Q}{\partial \tau}=-\frac{1}{(1+\gamma)(1+\tau)}Q\frac{ln\beta+ln\,p+ln\gamma}{1+\tau}.$$

A necessary condition for (4) to be positive is

$$ln\beta+lnp+ln\gamma=ln\beta+lnp+lnq-ln(n)<0.$$

Or, more elegantly,

$$(5)\ \beta p < \frac{n}{q}.$$

The left hand side of (5) is always less than 1, since β is the time discount rate and p is a probability. Hence, for (5) to hold it is sufficient – but not necessary – that $n \geq q$: the production elasticity of N must at least equal the production elasticity of Q.

DISCUSSION

There are a number of theoretical and empirical reasons to suspect that the production elasticity of N will generally be greater than that of Q. One alternative is to consider the defense production function introduced in Lanchester (1916).[2]

Strictly speaking, one cannot compare Lanchester's elasticities with those of Eq. (1). The formulation exploited in this paper is not calibrated in the same type of units as Lanchester's, and as Hildebrandt (1999) points out, formulations like those used in this paper are best defined as "military utility functions" while Lanchester equations are a form of genuine "military production function" that measures objective measures of output such as the number of targets destroyed rather than the amount of "national security."

In spite of this, we feel that Lanchester's approach does indeed lend some support for the idea that *n* will exceed *q*. The reason is simple. Lanchester's analysis demonstrates that raw numbers matter a lot in determining victory on the battlefield, and there must be some connection between battlefield outcomes and a nation's military utility function.

[2] The Lanchester defense production function is still widely used in the formal modeling of warfare. Amongst the recent applications of Lanchester's approach are Shustik (1983), Dupuy (1985), Danilek et. al. (2001), and Gordon (2003).

In Lanchester's formulation of the defense production function, two armies – red and blue, designated R and B - face each other in battle. The force that destroys the other before it itself is destroyed is the winner. Lanchester demonstrates that blue will defeat red if:

$$(6) \qquad Q_B[N_B]^2 > Q_R[N_R]^2,$$

where Q represents the probability that each weapon on the battlefield will hit and destroy an enemy weapon and N represents the number of weapons on the battlefield. Had Lanchester coached his model in the production-function mold, (6) would have meant that the production elasticity of quantity is twice that of quality. For the type of attritional combat envisaged by Lanchester this result is supported by considerable intuition. An increase in weapon accuracy increases the rate at which the enemy is destroyed. An increase in numbers, however, increases both the rate at which the enemy is destroyed and the number of targets that the enemy must itself destroy in order to win.

It is easy to show that Lanchester's result is a very special case of the much more general "military utility" function we assume in (1). What is required is to modify (1) by assuming that (i) quality is measured by weapon accuracy and lethality; (ii) the cost of producing Q and N exhibits constant returns to scale; (iii) all weapons are always within range of each other; (iv) hit/kill probabilities are unaffected by the number or quality of weapons fielded by the enemy, (v) victory in battle is determined through attritional "last man standing" processes; and that (vi) victory in battle is the only determinant of "military utility."

While some of these assumptions are harmless, others are quite problematic. The assumption that the production of Q and N exhibit constant returns seems benign. Given that it is not possible to raise weapon accuracy and lethality above a level of one (at which point each shot is certain to destroy an enemy unit), it is almost certain that the marginal cost of enhanced accuracy and lethality is an increasing function. As for quantity, it is quite likely that the marginal cost of producing more aircraft or tanks is a decreasing function.[3] Taken together, these relationships would further reinforce the higher elasticity of production for quantity relative to quality when measured in monetary terms.

A more serious problem stems from differences in the definition of weapon quality. This paper uses a wider and more general definition of weapon quality than that used by Lanchester (1916). For example, long lead time expenditures that result in an increase in a weapon's mechanical reliability, rate of fire, survivability, or range would be included as expenditures on weapon quality in our formulation since they are expenditures that must be made during the weapon's design phase. In terms of Lanchester's approach, however, such expenditures would influence not the accuracy and lethality of weapons but their number.

A third serious problem is that Lanchester assumes that the probability of hitting and destroying an enemy weapon is independent of the number of weapons that the enemy fields. This is not likely to be the case. Often, fire directed on one target hits another nearby target. This is particularly true in light infantry engagements. As a force grows larger, the probability that enemy fire will hit something goes up.[4] When this is the case, Lanchester's equation will over-estimate the value of fielding more weapons, since higher quantity will have the unintended and undesirable effect of increasing the effectiveness of the opponent's forces as measured by its probability of hitting and destroying your forces.

[3] For example, see Arrow (1962).
[4] Indeed, the probability that friendly fire will hit one's own forces goes up as well.

Finally, it is legitimate to question the validity of Lanchester's attritional perspective on warfare. While attrition certainly played an important role in strategic thinking during World War I, the fact is that few wars are won by completely destroying the enemy. Most battles are won by inducing the enemy to run away. It is not clear that Lanchester's equations are still relevant if superior morale – rather than greater numbers – is the key to victory.

In spite of all these caveats, we still feel that Lanchester's approach does indeed offer some support for the idea that the production elasticity of N will generally exceed the production elasticity of Q, and that as a result, tax smoothing considerations will lead to higher long lead- time military expenditures.

Defense budget data offers another reason to suspect that the production elasticity of N usually exceeds that of Q. If this was not the case, a relatively large share of defense spending would be devoted to weapons research and development, while only a small share would be allocated to procurement, training, and manpower. Yet published data on defense spending (to the extent that it can be regarded as reliable[5]) suggests that R&D costs typically account for 10% or less of total military spending, while manpower, training, and operations costs generally exceed 70% of total spending.

To be sure, both Lanchester's equations and defense budget data are simply insufficient to rule out situations in which the production elasticity of Q exceeds that of N. We believe, however, that the

[5] Not only are statistics on defense spending notoriously unreliable, but the budget categories identified as being for research, procurement, training, and manpower do not always correspond to the usage applied in the paper. For example, the salary of a research project's "program manager" may be counted as a manpower cost, although in reality this expense represents an investment in weapon quality. Meanwhile, research expenditures could include investments in R&D infrastructure or could even be masking the funding of intelligence agencies and special operations units.

inequality in (5) will still hold under most circumstances. Say, for example, that the production elasticity of quality is twice that of quantity – something that seems unlikely. Assuming a 4% annual discount rate, a reasonable value for β would be 0.7, reflecting the 10 years required to design a modern weapon. This means that (5) would hold if there was a probability of a full scale war below 70% for the period between 10 and 30 years in the future.

Now, the perception that there is a 70% probability of full scale war between 10 and 30 years in the future is a staggering level of security threat. Most countries that are currently in a legal state of war – countries such as Israel, South Korea, and Taiwan – do not foresee the likelihood of full scale combat during the next 30 years as being anywhere near that high. As for the Europeans and the Japanese, they regard real war as a distant and bad memory. Hence, it is extremely likely that tax system inefficiencies result in higher levels of weapon quality even when the elasticity of production for Q vastly exceeds that of N.

CONCLUSION

A credible case can be made that the inefficiencies inherent in taxation lead to the procurement of more sophisticated weapons than would otherwise be the case. This has several implications for researchers and policy makers. First, our results cast additional doubt on published evidence of a systematic bias towards excessive weapon quality. None of the empirical studies cited above took tax efficiency considerations into account. Failure to consider the role of tax efficiency in the procurement process biases the results of these studies towards what we believe to be incorrect conclusions.

Second, our results undermine the logic behind "sustainable" development theories that claim that LDCs are biased towards the adoption of "inappropriate" capital intensive technologies. Many poor countries do indeed field weapons as or even more sophisticated than those in service with OECD militaries. Hence, it is tempting to conclude that LDC military procurement decisions are evidence in support of sustainable development's "inappropriate technology" hypothesis.

Why do our results challenge the sustainable development paradigm? Without doubt, countries with low capital/labor ratios would prefer to purchase larger numbers of simpler weapons. On the other hand, our results suggest that countries with relatively primitive and inefficient tax systems would prefer to develop more sophisticated weapons.[6] Since most LDCs have inefficient tax systems, it is entirely conceivable that they gain more from the tax smoothing benefits of higher weapon quality than they lose due to the costs associated with spending their relatively scarce capital. In other words, "high tech" may be the appropriate technology for the defense needs of developing countries.

Finally, this paper is to the best of our knowledge the first example in the literature of a situation in which tax smoothing considerations influence and alter public investment decisions.[7] Our formulation suggests that when tax smoothing is taken into account, conversion to a more efficient tax system should lead to reduced defense expenditures. Hence, more efficient taxation not only reduces the welfare cost of raising a given level of revenue. It may lower the required level of revenue as well. Failure to take this effect into account could lead to a significant under-estimate of the aggregate welfare gains produced by a well designed tax reform.

[6] It may be argued that our results do not hold for LDCs since few of these countries design or manufacture their own weapons. This is not the case. Many LDCs actually do produce much of their own weaponry, including Brazil, China, Egypt, India, Iran, Israel, Russia, South Africa, South Korea, and Turkey.
[7] Following publication of Bohn (1990), a vibrant literature has developed regarding the use of government debt management as a tool in facilitating tax smoothing.

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