5
Force Acquisition I, Demand: The Biggest Bang for a Buck?

There are two dimensions to force acquisition and they will be covered in separate chapters. The first is demand, what troops and equipment are wanted, examined in this chapter. The second is supply, the arms industry and the arms trade that provide the weapons, examined in the next chapter.

Entrepreneurs face a standard economic problem: how to acquire labour and capital (workforce and means of production) and choose a technology to produce a product that will thrive in the competition of the market. The military entrepreneur faces a similar problem: how to acquire labour and capital (armed forces and weapons) and choose a technology to produce military capability that will thrive in the competition of war. Military entrepreneurs can solve these problems in ways not always available to their commercial comrades. Joseph Kony, who established the Lord's Resistance Army in Uganda, which promised to rule by the Ten Commandments, recruited by abducting and indoctrinating children who were provided with AK47s. Child labour was traditionally used by civilian employers, and in some countries still is. But with some exceptions, such as naval midshipmen who usually started at an early age, children tended not to be used in the military because they did not have the required strength. With modern military technology this limitation is removed, so children can be used.

In more conventional circumstances, how many forces you get for your budget involves a range of microeconomic issues. It depends on the state of the labour market (national wage rates and unemployment); the nature of the product market (the efficiency of the defence industry in building the weapons and the cost of other inputs, such as fuel and food); the use of technology; and the efficiency of the public sector

(the size of the non-fighting bureaucracy and the effectiveness of the expenditure and acquisition process).

If the share of defence in GDP is constant, defence budgets grow with GDP, in the US and UK about 3 per cent a year on average, though it fluctuates from year to year. The wages of volunteer armed forces and defence civil servants also tend to grow at the same rate. Planners need to determine the capital intensity of their defence provision, the balance between spending on personnel and weapons. Given that they have decided on the size of the armed forces, this determines the share of the budget devoted to personnel and the remainder can be spent on operating the existing weapons and buying new weapons.

Weapons can be developed and produced within a country, developed and produced collaboratively by a group of countries, produced under license from the country that developed it, or imported. The fear that other countries might not re-supply spares and munitions in time of conflict prompts countries to prefer domestic supply from a 'defence industrial base' (DIB). However, the cost of developing major weapons systems is so great that few can afford to be self sufficient. We defer these issues to the next chapter and here emphasise the choices involved in acquiring troops and weapons and choosing the appropriate technology.

Labour

Throughout history, the supply of suitable labour, usually young men, has been a constant concern to the military. Troops may be forced to join or they may want to serve their country or to fight for a cause they believe in. The travel and adventure may seem attractive, and the military may offer better pay and more secure employment than the alternatives available to them, so the military often recruit in areas of poverty and high unemployment. The troops may acquire useful skills and education and the military may look after them better than their community and even provide a pension. Petty criminals were once given the choice of jail or army. The troops may be coerced into joining through press gangs or conscription. Even without coercion the decision may not be fully considered. In the past, recruiting sergeants would try to get potential candidates drunk enough to sign up; now the armed forces rely more on advertising. Historically, whereas the infantry could use relatively unskilled recruits, the navy needed skilled seamen. In the age of sail, not only were landlubbers useless, they could be a danger to everybody else on board and skilled sailors had usually been at sea from an early age. N.A.M. Rodger (1997, 2004) describes the recurrent

difficulties of the Royal Navy in recruitment and training. As always, it is the opportunity costs that are important. Conditions that are perceived by some as the appalling hardships of military service may be seen as others as quite pleasant relative to their previous circumstances.

A major question is the relative advantage of volunteers and conscripts. There is no unique answer; it depends on the size and type of the forces required, the ease of recruiting volunteers relative to the ease of evading conscription and the relative military effectiveness of volunteers and conscripts. The UK announced the abolition of conscription, national service, in 1957. The US abolished conscription, the draft, and moved to all volunteer forces (AVF) in the 1970s. Conscription still remains the norm in many countries and was almost universal among continental European countries during the Cold War. France announced the end of conscription in 2001, Italy in 2005, but Germany still retains conscription. Some countries rely on reserves. Switzerland has 18 weeks of compulsory service and then seven refresher training courses of 3 weeks until the age of 30. The Swiss also allow reservists to keep weapons at home; other states tend to be more hesitant about arming their citizens. Conscription has been controversial in Russia, with the military arguing for maintaining a large conscript army, mainly, some have suggested, to justify jobs for the large number of generals. The size of the Russian armed forces has reduced from about 3 million to about a million in 2008; the length of service for conscripts has been reduced from two years to one year and there are attempts to establish core forces of longer term volunteers.

At first sight conscripts appear cheaper than volunteers, since conscripts are paid much lower wages than would be required to recruit the same number of volunteers. But this is partly illusory, since there is a real opportunity cost, the lost output those conscripts would have produced had they not been in the military. Conscription is a tax which falls most heavily on young men. It is a tax that is relatively easy to collect, which is one of the attractions, though there are fixed costs in setting up effective conscription systems. During major wars there is usually no alternative, the wages required to attract large numbers of volunteers would be too high and those that volunteer may be taken away from work that is crucial to the war effort. During the early part of World War I, the UK was able to recruit volunteers very easily. The famous poster of Kitchener pointing out above the message 'Your Country Needs You' was very effective. But the recruitment disrupted the economy, volunteers left jobs that were crucial to the war effort, and eventually conscription was introduced. Conversely, when only small

forces are required and only a proportion of the age-cohort are conscripted, it can seem very inequitable on those that are chosen, even when chosen randomly, as in the US draft.

There is also a large cost in training. Learning about modern weapons and tactics can absorb a large part of a conscript's tour of duty, so despite very large flows through the military there is a relatively small force of experienced troops. Much smaller AVF forces can provide the same level of capability. As with weapons one must distinguish between the stocks, the number of trained personnel available, and the flows, the numbers recruited or leaving. Training times differ between infantry and fighter pilots, for instance. Training issues can often shape forces. From the 1500s guns displaced bows and arrows not because guns were militarily more effective. A skilled archer could fire more rapidly, with greater accuracy, over a greater range, with a greater penetrating power than a soldier with a gun, well into the 19th century. But becoming a skilled archer took a lifetime of training, whereas soldiers could learn to use a gun relatively quickly. In some societies the acquisition of military skills was part of ordinary life. John Keegan (1993) notes how nomadic pastoralists, moving with their herds of animals, learn to kill and select for killing as a matter of course. Their mobility, their ability to live off the land and their tactical skills of movement, gained through herding their flocks, could all be used against their enemies. This made pastoralists like the Huns and the Mongols dangerous neighbours for both Eastern and Western powers.

AVF forces may also be more highly motivated than unwilling conscripts. Conscription does provide a trained reserve that can be mobilised in time of war and this is important to countries like Israel. Maintaining operational reserves can be expensive in terms of lost output to the economy, since reserves have to regularly leave work to train. It can be politically difficult to use conscripts in some operations as the US found in Vietnam. Conscription may provide training and socialisation that contributes to society; but conscription may not be the most effective way of providing it. While some believe that young thugs would be straightened out by a spell in the military, it may only produce fitter, better-organised, more dangerous young thugs, able to handle weapons.

Some argue that conscription establishes closer links between society and the military and that it may be a constraint on military interventions in politics. However, most military coups have been conducted with conscript armies; largely because military coups are more prevalent in poor countries and poor countries tend to use conscription, not

having the tax capacity to pay for volunteer forces. Whether, when one allows for the level of development, conscription increases or decreases the risk of military coups is unclear because there are so many other factors at work. Thailand and Turkey, relatively high income countries with large conscript armies, have had military coups or threats of them in recent years, but that is not conclusive. The labour market issues overlap with the wider issues of the relationship between the armed forces and civil society, such as the role of the warrior ethos and the treatment of gays, women and ethnic minorities in the armed forces. For the military (as for teachers, doctors, nurses and police) the public sector is both the main buyer of their services and the main provider of them through training. The government has to decide how many to train now in the light of their expectation of the future demand for their services, which can be often difficult to foresee.

Most military organisations are strongly hierarchical and make a sharp distinction between officers and enlisted troops with further stratification among the enlisted troops: the non-commissioned officers (NCOs), having considerable power. Such clear stratification used to be common in companies and government organisations but has largely disappeared elsewhere. One possible function is to prevent promotion on ability. If promotion on ability operated freely, all the very capable people would be promoted to command jobs behind the lines and front line positions would be filled only by the young and inexperienced or the old and incapable. Having a barrier means that capable experienced NCOs are leading front-line units and advising the nominal commander, usually a very junior officer. In the age of 'the strategic corporal' where the decisions even of junior NCOs can have major repercussions, this is important. Of course, the barriers are not completely impermeable and some do rise from the ranks to become officers and attain senior positions. This tends to be more common in war. Within the military, promotion is largely internal and unlike commercial firms, recruitment to top posts from outside the organisation is rare. There are usually 'up or out' rules (get promoted or leave) and age limits on service so that even in an AVF people leave the military to go on to other jobs.

Recruitment and retention issues play a large role in an AVF and there is an economic literature on such military personnel issues, surveyed in Asch, Hosek and Warner (2007). In the US the military have provided education, most notably through the GI Bill after World War II, which made a major contribution to US human capital. The education benefits have attracted recruits to the US military. The US military has also been seen as a profession where African-Americans and Hispanics can

get ahead. While there may be externalities for society in military training, the recruitment and retention effects are probably more important: people will be more willing to join and stay in the military if they are acquiring skills that will enable them to get good jobs when they leave.

There are other possibilities than national conscripts or volunteers. One can hire mercenaries, like the Italian Condottieri, and some countries have extensively used foreign recruits, such as the UK Gurka troops from Nepal and the French Foreign Legion. In recent years private military companies have increasingly been used for logistics, security and other military tasks, though there has been controversy over their role. Governments that want to provide covert, deniable support to one side in a conflict, may release their military for a time to serve with a private military company that will actually provide the support.

While much of standard personnel economics associated with recruitment, training and retention apply to the military, motivating the willingness to kill and be killed raises somewhat different, non-economic, issues on which there is a large sociological literature.

Weapons procurement

Buying military products is hard and, as a result, military projects tend to be late, over-budget and fail to meet performance targets. The Government Accountability Office (GAO) in the US, the National Audit Office (NAO) in the UK and their counterparts in other countries regularly report on the progress or lack of progress of the development of major weapons systems. Regular reports are *Defense Acquisitions: Assessment of Selected Weapons Programs* by the GAO and *Ministry of Defence Major Projects Report* by the NAO. As usual there are pessimistic and optimistic perspectives. Pessimists are dismayed by the failures. Optimists are pleasantly surprised that the military have any working weapons, given the difficulties involved in meeting time, cost and performance targets.

As an example, the UK MoD ordered 14 Chinook helicopters in 1995. The Chinook is a widely used, heavy-lift helicopter, introduced in 1962 and produced by Boeing. Six standard Mk2a were delivered satisfactorily; the other eight were modified to Mk3 for special-forces operation. These eight cost some £259 million and MoD took delivery in 2001. Although Boeing met its contractual obligations, the MoD could not get access to the source code, to ensure that the avionics software met UK airworthiness standards. Despite a desperate need for helicopters, particularly in Afghanistan, the helicopters had still not flown on operations

by June 2008, when NAO (2008) reported. They may be available for use in 2011, though at considerable extra cost.

The UK problem of ageing air-to-air refuelling tankers was discussed above; the US has similar problems. In 2002 the Air Force offered a $23.5 billion leasing contract to Boeing for military refuelling tanker aircraft. It was then discovered that Darleen Druyun, the top Air Force acquisitions official for tankers, had held illegal job negotiations with Boeing while negotiating the contract. She and the Boeing finance director, Michael Sears, got prison sentences for violating conflict of interest laws. The competition was reopened and the European company European Aeronautics, Defence and Space (EADS), in conjunction with Northrop Grumman, won the contract for 179 tankers, based on the Airbus A330 aircraft, in February 2008. In June 2008, a GAO enquiry found flaws in the process choosing EADS and the competition was again reopened. In September 2008 the Pentagon postponed restarting the competition, to allow a 'cooling-off period', despite the urgent need for new tankers. By this stage the contract was worth about $35 billion.

Procurement means to purchase or acquire, but it tends to be used in a narrower sense: the purchase of a one-off or customised product or service, where there is usually asymmetric information between buyer and seller; risk and uncertainty; concerns about the quality of the product provided; an inability to write a complete contracts; and the possibility of renegotiation. Nearly all these problems arise when a family hires a builder and they are common in large IT systems, big infrastructure projects and pharmaceuticals. Failure in procurement is common to both public and private sector. Products that are bought regularly, in volume, from a large market raise different issues of supply chain management, just-in-time supply, transactions costs and logistics. The military can make mistakes even with low-tech commodity products. The UK army boot proved inadequate during the Falklands War of 1982 and the consequent trench foot caused more British casualties than Argentina (Frost, 1983).

Principal–agent or contracting problems are central. A principal, with certain objectives, employs an agent, with the necessary skills and information, to achieve the objectives. However, the agent's objectives are different from the principal's. The principal's problem is to construct a set of incentives to ensure that the interests of the principal and agent are aligned, so that the agent acts in the principal's interest. The principal can rarely observe the agent's actions, including the agent's effort, only the final outcome; so the principal cannot tell whether the agent was not trying or was merely unlucky. This sort of relationship is

common. It occurs when people hire lawyers or owners of a firm appoint managers and is prevalent in procurement.

As an example of the principal–agent problem, every UK procurement review from the 1960s to the present (Zuckerman, Downey, Learning from Experience, Smart Procurement) concluded that on the typical complex project the MoD should spend about 15 per cent of the development budget on early research prior to full development, to demonstrate the feasibility of the technology and conduct pilot programmes to reduce risks. This is almost never done and the amounts spent on de-risking tend to be small. While the value of such up-front research is recognised, there are strong incentives against doing it, since it may reveal major problems that would cause the project to be cancelled. Neither the military, wanting the project, nor industry, wanting the profits, want the project cancelled. They would rather proceed and hope that they can resolve the difficulties later, albeit at the expense of time, cost or performance. To the senior manager, trying to fit the project into the budget, the extra early research does not seem to produce anything, so money will be saved by cutting it. The early research looks particularly wasteful if its only function is to cause the project to be cancelled.

There is not just one principal and one agent in defence procurement; there are agency problems all through the system. Politicians employ civil servants and the military; the civil servants and military employ industry; the top-level decision makers employ specialists to implement the decisions, and so on. The incentives of the various groups differ substantially: military and civil servants want promotion; politicians want good publicity; bureaucrats want a quiet life; industry wants to make profits. There is nothing wrong with these objectives in themselves but they constrain the way the system operates.

Solutions are proposed, reforms implemented but the problems remain, so the system cycles, alternating between approaches. There is a vast literature. Recent UK examples are: Chin (2004) in the aptly titled *British Weapons Acquisition Policy and the Futility of Reform*; Kincaid (2008), which reviews recent reforms; and DEG (2005), based on a course by the Defence Engineering Group at University College London which examines the process of defence acquisition. Procurement is hard because of the interaction of a range of elements, which is why reform programmes which try to fix one aspect in isolation rarely work. To capture this interaction we will look first at the questions that military procurement organisations have to address and then at the economic problems that make answering them so hard. The agency problem is

that there is no single organisational answer, since the organisation is made up of conflicting groups with different answers to each of these questions.

Procurement: The difficult questions

What do we want? Requirements are vague, change and evolve over time and differ between stakeholders. It may be difficult to get input about needs from final users, such as troops on the ground, until too late. The requirement changes over time as one resolves uncertainties in technology, through work on the project, and as the perceived threat changes. US and UK combat experience in Afghanistan and Iraq showed that the threat from improvised explosive devices (IED) was more serious than expected and equipment had to be adapted rapidly to take account of this new threat. There is a choice between presenting requirements as a set of 'cardinal points', the general objectives of the system, or very detailed requirements about how it should meet those objectives. There may be disagreements about other objectives, such as how to trade off getting best value for money with promoting competition or maintaining a DIB. In areas where the government is the only buyer, such as warships, its procurement determines national industrial structure by default. Trying to achieve multiple objectives, like trying to hit two targets with a single missile, can be a recipe for disaster and it may be better to do one thing (buy weapons) properly, than two things (buy weapons and promote an industrial policy) badly. In practice, determining what is wanted is complicated by industrial issues, political accountability, budgetary uncertainty, compatibility with other systems and compliance with complex regulations.

There are hard trade-offs between the elements of time, cost, performance and risk. An important one is between a standard and a customised solution. The standard Chinooks worked well; those customised for special-forces caused difficulties. There is often an apparent trade-off between efficiency and competition. Economies of scale and scope and learning curves make a single supplier look cheaper, but competition can force down prices. Both effects are difficult to quantify and there has been considerable controversy in the US about having a second engine supplier for the JSF F35 aircraft. Nobody but the US could even consider this choice, given the cost of the investment and information transfer required to second source jet engines.

There is an issue as to who should make the decision about what is wanted. Buyers know more about their demand; the sellers know more about the potential of technology and materials. Lack of clarity in

objectives may be worsened by poor communication or lack of knowledge. It is said that an 'intelligent customer' knows the right question to ask; an 'informed customer' understands the answer; and an 'expert customer' does not need to ask the question, already knowing the answer. The cost of becoming a better customer increases very steeply. To be an informed customer may require research labs; to be an expert customer may require being able to produce the product.

How do we get it? Equipment may be imported; produced under license from a design developed elsewhere; designed and produced in collaboration with other countries; or designed and produced domestically. Collaboration promises great benefits: fixed costs are shared, longer production runs bring the benefits of learning curves, economies of scale and inter-operability. The use of common equipment between countries aids maintenance, training and logistics. In practice, the compromises required to get agreement, the inefficiencies associated with work-sharing arrangements and the lack of centralised control and coordination mean that these potential benefits are rarely realised. Wood and Sorenson (2000) present a set of case studies on military collaboration. In the commercial field, Airbus had difficulty coordinating German and French elements in the development of the A380 jumbo and Boeing in coordinating its suppliers in the development of the 787 Dreamliner; both aircraft are about two years late and over-budget. Procurement problems are not confined to the military.

Military goods or services may be provided in various ways. Equipment may be government owned, used and produced in government arsenals or it may be produced in government-owned facilities operated by a private contractor. Equipment may be leased from the producers, as with Private Finance Initiative (PFI), and services may be provided by private military companies. Equipment may be specifically developed for the buyer or purchased as either commercial off-the-shelf (COTS) or military off-the shelf (MOTS). Commercial suppliers, such as Microsoft, may be unwilling to provide the guarantees or information that the public sector contracts traditionally required, such as access to source code. This may also be a problem with military suppliers, as in the Chinook case; either where there are issues of intellectual property rights (IPR) or where governments restricts access to foreigners by, for instance, 'black-boxing' code. This has been an issue between the US and UK over the F35. Availability of suppliers may vary over the cycle as contractors substitute between public and private work.

On what terms? Contracts vary between fixed-price and cost-plus. Fixed-price contracts usually follow a competitive tender won by the

lowest bidder. Cost-plus contracts are usually part of a partnership arrangement where a preferred supplier is paid cost of production plus a profit margin. There are many intermediate cases where any difference between initial estimate and final cost is shared by buyer and seller, perhaps with some inflation adjustment. The price bid in a competition and the cost of production are not fixed numbers; they will be determined by the form of the contract. The profit rate used in cost-plus contracts is usually the average rate of return in industry. This may not be appropriate, since the industry average embodies a risk premium (firms may not sell the product), whereas cost-plus contracts are safe. Cost-plus requires the buyer to be able to audit the costs of the supplier and this may be difficult, allowing the supplier to attribute unnecessary costs to a project. Under cost-plus, the contractor may have incentive to make components in-house, on which there is a profit margin, rather than buy-in, on which there is not.

Fixed-price and cost-plus each have advantages and disadvantages. With experience, decision-makers learn the disadvantages of the current system and are tempted to switch to the other, so the UK government has cycled between the two approaches over periods of 15 to 20 years. Contracting for quality raises difficulties. At the end of the project, the equipment will be evaluated with trials, exercises and simulations, before it is accepted. But it can only be rejected on the basis of criteria that are specified in advance, otherwise the supplier would not know what to provide, and that can be tested, otherwise one cannot judge whether it meets the criteria. In practice, important characteristics, such as performance in combat, cannot be tested. Contracts also have to cover allocation of IPR and responsibility for failure.

Competitions can be very expensive, both for buyers who have to evaluate many complex bids and for the suppliers who may invest millions in bidding. Partnerships, with bidding restricted to suppliers with established reputations, are safer and allow cost savings and quality improvements; but they restrict entry, reduce competition and limit the range of solutions proposed. Collusion among the bidders in a competition is always a danger and more transparency may increase the probability of collusion, allowing price-fixing cartels to detect cheating by members more easily. Although the market may appear competitive, it may be very dependent on a single specialist subcontractor who supplies all the competitors.

What will it cost? There are various measures of cost; from purchase price, the cost of acquisition, to through-life cost including operation. Estimation of costs, particularly through life costs, is difficult. There is an

optimism bias, by both buyer and seller, to get the programme approved. The operation of this bias in the UK is discussed in Kincaid (2008). There is also the 'winners curse': the firm that wins a competition tends to be the one that bid too low, unaware of the problems that the other bidders took into account. There is the tendency, discussed above, to spend too little on de-risking the project during the assessment phase. Problems can also result from the overlapping of production and development and integration between systems. In IT and defence, systems integrators often take responsibility for making all the elements work together, not always successfully. There are parametric cost estimation procedures. These use past information on how costs are related to characteristics of the system, such as cost per kilogramme of aircraft delivered, to provide estimates. They are approximate, but quite useful, particularly in identifying where some break in trend is assumed in the cost estimate.

When do we want it? Time may be of the essence. In combat, an expensive piece of equipment, which only just meets the requirement, but is now available, may be of much more value than a cheaper more effective alternative that will be available in the future. Military equipment cycles are long. In the UK, the cycle is known as CADMID: concept, assessment, demonstration, manufacture, in-service, disposal. Procurement covers the first four stages. The Eurofighter-Typhoon design dates from the early 1980s, it came into service in the mid-2000s and could be operating for another 30 years, a CADMID cycle of half a century. Commercial and public sector heritage IT systems can be 50 years old, as are the B52s that are the backbone of US bomber command. Buildings and infrastructure can last even longer. In-service and operating costs, which are influenced by reliability and maintenance, are a large element of through-life costs. Small investments in reliability early on can produce large savings later on. But these are often cut to keep the initial cost low.

Procurement tends to be divided between normal budgeted procurement and requirements needed rapidly in war. In the US the latter are called 'emergency supplemental funds' and in the UK 'urgent operational requirements' (UORs). Normal procurement processes are slow (average 7 years), formalised, taking account of many objectives, trying to build compatibility with the rest of the system to minimise maintenance costs and maximise interoperability and usually require research and development (R&D). UORs are fast (usually less than 6 months), informal, focus on a single objective, may be incompatible with the rest of the system (creating fleets within fleets) and largely use off-the-shelf components.

In the normal budget procurement, the distribution of expenditure on projects is highly skewed, dominated by the large projects, which can become black holes, absorbing money. It can then be difficult to get small valuable projects into a constrained budget dominated by the big projects. In 2006 the distribution in the US and the UK was very similar with the two largest projects accounting for half the expenditure, with each succeeding project, ranked by size, being about half the size of the previous one. Flexibility can be bought by writing contracts that make it easy to change specifications and cancel projects, but this can be expensive and involve penalties.

Given the uncertainties, moral hazards and large expenditures involved, it is tempting to construct elaborate 'rational' decision-making procedures. These tend to emphasise process rather than outcomes and it is not clear that they produce better decisions. Excessive regulations can cause more problems than they solve and those involved in procurement regularly complain that they are 'drowning in process', as Bill Kincaid (2008) reports. The best projects seem marked by unified authority, sharp trade-offs and flexibility, characteristics that formal processes do not provide. Projects are easier if there is a single objective. This may be a performance goal, as with the Manhattan Project to build the atomic bomb; a time goal, as with UORs; or a cost goal, where price is treated as an independent variable and specified in advance. The problem with most projects is that they have multiple goals, which have to be traded-off.

Economic problems

Risk aversion is important, because of the size of the project and the consequences of failure. There are military, political and financial risks. The public sector may be risk averse because of the political fall-out from failures. The firm may be risk averse because the project is large relative to the firm. Rolls Royce went bankrupt with the RB211 fixed-price civil engine project and had to be nationalised in 1971. Suppose firms are risk averse and eventual cost is subject to uncertainty about technology. The MoD, pooling over a number of projects is better able to absorb this risk, so should be risk neutral, acting as an insurer. Insuring the producer with a cost-plus contract reduces the risk premium that MoD has to pay and uninsured, fixed-price, contracts may not be credible if enforcement would drive the firm into bankruptcy leaving MoD without the project. Bailing out firms, like bailing out banks in a financial crisis, is likely to be optimal for MoD and this will be anticipated by firms making the bids, creating moral hazard. Whatever the contract says renegotiation

cannot be credibly precluded. Given that the uncertainty on military contracts is large, so is the risk premium that suppliers have to build into fixed-price bids.

Moral hazard problems arise because costs and quality are determined by the effort of the seller, which the buyer cannot monitor. Greater insurance, by cost-plus contracts, gives the seller less incentive to reduce costs. Under fixed-price contracts, the firm has incentives to minimise costs. However, if quality cannot be easily monitored fixed price gives it incentives to economise on quality. Changes to the contract can be very expensive on fixed-price project, because the firm can use the leverage from the existing contract. Corruption and bribery also raise issues of moral hazard.

Adverse selection arises under competitive bidding because the buyer cannot discover information private to the selling firm and may select the wrong supplier. The firm that makes the lowest bid may not be the lowest cost producer, but merely the firm that is most ignorant of the difficulties involved and thus subject to the winners curse. With large number of competitors, bidders should build a premium into their bids to protect them from the winners curse. If costs are higher than the winning firm's bid, this would just be a transfer from firm to buyer. But a large transfer may not be credible and the buyer may have to bail out the firm to get the project completed. Since firms know this, they have incentives to bid low to get the buyer to commit to the project, knowing that once committed the buyer will have to complete. Because of the conspiracy of optimism, the buyer may be happy to collude in this, to get the project onto the budget. Selling to the government may open up other markets or act as a signal of the quality of the product. Thus it may be worth a firm under-pricing to the government to get the contract, if it can exploit the subsequent monopoly elsewhere, for instance in exports. Firms may bid low on early stages to get the contract, then use learning curves and acquired tacit knowledge to establish a monopoly position, which they can exploit later. US defence firms tend to bid low on development and make their money on production.

Monopoly is common and while a single supplier can have great power this power is reduced if the monopolist is facing a single buyer, a monopsonist, as is usual in the defence market. The relative bargaining strength of monopolist and monopsonist will depend on factors such as the cost to each of not coming to an agreement. Information rents can be extracted under fixed-price contracts by monopolists with private information about costs who can bid high and still get the contract. With cost-plus the monopolist has to reveal their costs. Even where

there is not a global monopoly, a single national supplier may gain monopoly power from the political unacceptability of buying abroad.

Incomplete contracts and renegotiation are common because not every contingency can be specified in the original contract and changes in technology and buyer needs mean the contract may have to be rewritten. Cost-plus contracts can accommodate design changes easily; renegotiating fixed-price contracts gives the firm great bargaining power, since it has the option of insisting on the original contract. Failure by the firm to meet a fixed-price contract also prompts renegotiation. In 1997 the UK MoD signed contracts with GEC-Marconi to build a set of Astute class, hunter-killer submarines in the Barrow shipyards for delivery in 2005 on a fixed-price contract. GEC was taken over by BAE and there were big cost overruns on the submarines. In 2003 BAE and MoD had to renegotiate the contract and BAE had to write down its profits by £750 million because of the penalty. BAE said that it would never accept fixed-price contracts again. In 2008 the first of the class was still running late relative to the renegotiated schedule and was planned to enter service in 2009. The budget increased from an initial £2.58 billion to an estimated £3.79 billion in 2008. EADS faces similar issues with the A400M military transport aircraft that it is producing for Germany, France and the UK, under a fixed-price contract. It has incurred about €2 billion in extra development costs primarily because of problems with the propulsion system and the in-service date is delayed. Media reports in 2008 indicate that EADS hopes to be able to renegotiate the contract.

Technology

Technology can be crucial in combat. The Maxim gun, which could fire at 600 rounds per minute, was a major improvement on the earlier hand-cranked multi-barrelled Gatling gun. In the battle of Omdurman in Sudan in 1898, the British killed 10,000 Dervishes for the loss of 48 of their troops. The machine gun also transformed warfare in World War I, when advancing troops were mown down. In many cases the technology is introduced before armies know how to use it and there is a long period of painful learning and military reorganisation before the technology is successfully integrated into military doctrine. This was the case with self-loading rifles, tanks and nuclear weapons. Thus there was always a substantial evolution in any revolution in military technology. In the 1990s, it was proposed that there was a new 'revolution in military affairs' which would follow from the networking of sensors,

command, control, communication and weapons into an integrated system. As yet, the reality of 21st warfare has not conformed to that model.

Many issues in the technology literature are common to both military and civilian applications. It is often useful to distinguish invention, the idea; innovation, turning the idea into a useful application; and diffusion, the spread of the technology. In 1620 Francis Bacon identified the three innovations that created the modern world: gunpowder, ocean navigation and printing. All were Chinese inventions; the magnetic compass in the case of ocean navigation. But it was in Europe that the process of innovation, diffusion and adaptation made each of them disruptive technologies that transformed society. Evolutionary innovations continue an established technological trajectory; disruptive innovations change how a technology is organised and applied. Some military technologies concentrate power, like the expensive armour and horses required by the mediaeval knight; others disperse power, like relatively cheap guns that can be used by anyone. Innovations can be in the product, like a new type of tank; or in the process, like a new way of producing armour; or in organisation, like Blitzkrieg, a new way of combining technologies. Military technologies are sometimes divided into offensive or defensive, but this does not seem a useful distinction. Attack is often the best form of defence and certain defensive technologies, like castles and anti-ballistic missiles (ABM), are perceived as offensive. The 1972 ABM treaty restricting their use, from which the US withdrew in 2002, was seen as reducing the incentives to strike first.

Given a fixed budget, there is a choice between the quality and quantity of weapons: a few, technologically advanced, highly capable, units; or many, less capable, units. The balance between quality and quantity will be chosen to maximise force effectiveness, which depends both on the number of units and the capability of each. This quantity–quality balance is often described by Lanchester Laws, after Frederick Lanchester who in 1916 developed mathematical models of the relative power of opposing forces. The choice of the number of units also has implications for the number of armed forces required to operate and maintain them. It may be possible to maintain a Hi-Low mix as the US did by combining small numbers of the expensive F15 aircraft with large numbers of the cheaper F16. The F16 being a relatively cheap aircraft was also very successful in export markets and over 4000 have been produced. There may also be choices between investing in new systems and upgrading old systems. Upgrading, by technology insertion, may be attractive when military effectiveness depends not on the

characteristics of the platform – aircraft, ship or tank – but on what it carries – sensors, weapons or electronics – which can be upgraded within the old platform.

Chapter 4 discussed the vicious circles that tend to drive up weapons systems prices: the technological arms race in relative performance against an opponent; the reduced numbers of units in each generation; and the longer gaps between generations. Technology escalation differs over time and weapons. Military technology remained largely stagnant from about 1700 to about 1850 before starting to escalate again. Assault rifles have remained very similar since the AK47 was developed in 1945. Innovations, such as night vision equipment, have increased the effectiveness of the rifles, but the AK47 remains the market leader. Despite the lack of a catchy name or multinational marketing, the AK47 has become an iconic brand; it appears on the Mozambique national flag. Mikhail Kalashnikov with Elena Joly (2006) provides a personal account of the development of the rifle, which was designed to be simple – even child soldiers can use it – reliable and easy to repair. It is widely produced, partly because the Soviets did not patent it, though the quality varies between producers. The Taliban are said to pay more for an Iranian AK47 than a Pakistani one. Its wide use makes it familiar, reducing training costs, and makes ammunition abundant. Availability of ammunition is often more of a constraint than availability of weapons. Wide use also creates barriers to entry, making it difficult for competing brands to establish themselves. Quality has many dimensions and the AK47 does have disadvantages relative to competitors, including low range and accuracy and a lack of user safety features.

Phillip Killicoat (2007) analyses the market for assault rifles. Small arms are estimated to be responsible for between 200,000 and 400,000 deaths a year, between 10 and 25 per cent of these occurring in conflict settings. Of the approximately 500 million firearms available worldwide, approximately 100 million belong to the Kalashnikov family, three quarters of which are AK47s. He has 335 observations, from 117 countries, on AK47 prices, over the period 1986–2005. The average price is in the range $450–$550, with prices in Africa being about $200 lower and prices in Western Europe being about $400 higher. He attributes the low African prices to porous borders that allow more trade and more efficient markets; though in this context, many would see an efficient market as a bad thing. A legacy of conflict in the country and higher military spending by neighbouring countries both seem to increase available supply and reduce the price of AK47s. A number of other possible determinants of price do not seem important. The collapse of the Soviet Union, which

was thought to have increased supply, does not seem to have reduced prices.

There are two dimensions to the quantity–quality trade-off; in design and in production. Arms manufacturers get paid for the numbers produced. To meet their production targets at minimum cost, they have incentives to take short cuts that compromise the quality of their products. Military buyers try to prevent this by monitoring the quality of the products, rejecting those that do not meet specified standards. Quality has two aspects: how the product performs in battle and how it meets the technical criteria specified in the contract. It is only the latter that can be monitored and used as a basis for rejection, though the military hope that the technical criteria will be related to battle performance. During war the choice is harder: do the military accept sub-standard weapons or reject them, getting fewer or no weapons?

Even autocratic command economies, where draconian penalties can be imposed for non-compliance, face this dilemma. Using recently released files, Markevich and Harrison (2006) examine how the Soviet Union, under Stalin, responded to this choice. Soviet manufacturers of particular types of weapons were largely monopolists. Their prime objective was to meet the production quotas specified in the plan and had strong incentives to cut quality to meet quotas. The military responded by putting military agents, often quite senior officers, in the factories. These agents had the power to accept or reject the weapons produced. But, since the military needed weapons, particularly once the war started, the agents could not reject everything that was sub-standard or they would get no weapons at all. The compromise that resulted was that a lot of low quality output was produced and sent into service; but the danger of rejection resulted in average quality being higher than it would have been otherwise and higher than the quality of products supplied to civilian buyers. Interestingly, the authors find no evidence that the arms producers bribed military agents to accept sub-standard product. As the authors point out, no evidence of bribery is not evidence of no bribery; the files dealing with bribery may not have been released. However, it is plausible that bribery was uncommon; being a military agent was an attractive job, certainly relative to serving on the front, and the risk of losing it could have outweighed the benefit of the bribe.

The value to civilian society of spin-offs from military technology is discussed in Chapter 8; here the issue is how the military gets the technology it needs. Increasingly, the military gets the technology from commercial sources, spin-in. This COTS procurement can cause

problems because of the difference between military and commercial time-scales. An average military procurement takes 7 years; so by the time the weapon system enters service, not only are the electronic components in it obsolescent, they are often no longer even being produced. Since military systems may be in service for 30 years or more, obtaining spares and replacements can be difficult. The US DoD has established a facility to produce obsolete electronic chips, no longer in commercial production but still in military use.

Some have seen a technological imperative which drives the elaboration of weapons along a particular trajectory. The interactions seem more complex. A detailed account of the interactions in the development of guidance systems for submarine-launched ballistic-missiles is described in *Inventing Accuracy* (MacKenzie 1990). The driving force here was inter-service rivalry: the navy wanted their own nuclear delivery systems. Submarine-based missiles had many advantages, such as being less vulnerable to first strike attack, but their main disadvantage was lack of accuracy. This arose because of the difficulty of pinpointing the position from which the submarine fired its missiles. The problem was solved by breaking from the established technological trajectory of guidance systems and introducing the quite different stellar guidance methods. Near the top of its trajectory a little window would open and the missile would use the stars to check its position. This was also culturally more acceptable to the navy, where there was a tradition of using starts to establish position, than it was to the more traditional guidance community.

Guidance has been transformed by the Global Positioning System (GPS), a military satellite-based system. This has enabled 'dumb' bombs to be transformed into 'smart' or precision-guided weapons. During the 1991 Gulf War, 9 per cent of the ordnance dropped by the US was smart. In Kosovo in 1999, the figure had risen to 29 per cent, though cloud cover hindered employment of laser-guided munitions. In the invasion of Afghanistan in 2001, between 60 and 70 per cent were smart, a large proportion of which were dumb bombs with strap-on guidance kits. In the 2003 invasion of Iraq, over 90 per cent were smart. The two main strap-on kits (the GPS-guided joint direct attack munition (JDAM) and the wind corrected munition dispensers (WCMD)) were cheap in military terms because they used more commercial development programmes and components. It was estimated that under a traditional acquisition programme each JDAM would cost $68,000. A mandated maximum price was used and the final cost was about $18,000, though with volume, competition and dual sourcing this fell to about $12,000.

Since there were a large number of dumb bombs to be fitted with guidance kits, these could be produced in volume.

Innovation involves integrating technology into culture and this can be difficult. The problems with replacing cavalry by tanks are an example, but then tanks themselves became cultural symbols. Tanks are usually evaluated on three performance characteristics: protection, firepower and manoeuvrability. In a US competition for new tank designs during the Cold War, the US Defence Advanced Research Projects Agency (DARPA) entered a dune buggy fitted with a missile. On the specified performance criteria it won. It had high protection because it was small and not easily visible by sight or radar; the missile gave it effective firepower against tanks; and it was fast and manoeuvrable. But despite winning the competition on the specified performance criteria, it was not adopted by the army, because it was not a tank; though it was used by special forces. The army's instinctive preference, irrespective of the specified performance criteria, was for something that looked like a tank: a powerful macho machine with lots of armour and a big gun. While this preference may be criticised, the performance criteria did reflect a specific scenario: tank-on-tank battles in fairly open country. The lack of armour would make the dune buggy little use in urban warfare against concealed insurgents using IED, where a traditional tank has advantages. Preferences about technologies can matter and unfashionable technologies can have difficulty in being accepted without powerful product champions. An example of an aircraft that met resistance is the A10 Thunderbolt II. US experience in Vietnam showed the limitations of both fast jets and helicopters in providing close air support to infantry. The solution was a slow, heavily armoured, aircraft designed for endurance and survivability. Although very popular with ground troops, initially it was not welcomed by the US air force. Their view, that a slow ugly jet was not the sort of weapon they wished to be seen flying in, is reflected in its usual name: the Warthog or Hog.