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PROCURING INNOVATION

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ABSTRACT

Procuring Innovation*

To stay on top of global competition, firms and governments often need to acquire innovative goods and services, including ideas and research, from their strategic suppliers. A careful design of procurement policy is crucial to make potential suppliers generate and sell the most suitable innovation. Moreover, procurement by public agencies and large firms often set the incentives for the development of innovations economy-wide. In this paper, guided by recent micro- and macro-economic research, we discuss vices and virtues of the many ways to induce potential suppliers to create and sell innovations. We consider a menu of procurement methods and policies for best procuring new knowledge and innovative products, discussing their costs and benefits in different possible scenarios and suggesting criteria to choose among them. We explain how to optimize the degree of competition between suppliers, as well as other more practical indirect ways to stimulate innovation. We discuss the effects of standard setting activities by large, often public, procurers on innovation races. We evaluate how public and large private firm's procurement may induce innovation and growth at the national, industry or supply network level by affecting input market prices and the returns to human capital formation. Finally, we point out how risk management methods used in procurement should be modified when innovation is a central concern for a buyer.

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1 Introduction

Innovation is a key source of competitive advantage, both for firms and nations.[2] Though internal research and development (R&D) is widely acknowledged as a primary source of innovation, it is less often remarked that a firm can secure innovative products from its suppliers. Innovative procurement somewhat hides in the stage of the popular press, but practitioners know all too well that a careful designed procurement policy is often the key to success in the most innovative markets. The recent history of the Formula One championship nicely demonstrates how crucial the role of suppliers and procurement of innovative goods can be in determining a firm eventual success or failure.[3] In our "age of outsourcing", in which all non-core activities are increasingly being outsourced, firms must know how to best procure innovative inputs from strategic suppliers. This involves selecting the suppliers, choosing how to reward them, designing property rights for on-demand innovation, and ensuring that suppliers do not gain too much bargaining power creating hold-up problems.

On the other hand, public procurement can strongly impact firms' profitability in innovative industries. It is well known, for example, that the US government's defense procurement has been a major driving force for the development of such innovations as large passenger jets[4], semiconductors,[5] and the Internet.[6] These examples highlight that public procurement mechanisms can play a crucial role in stimulating or hampering private innovative activity.[7] Since governmental

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[2]This was forcefully recognized by the Lisbon European Council of March 2000 in setting the objective of making Europe a more competitive and, therefore, innovative economy.

[3] In 2005, the rules of Formula One races changed in that the same set of tires had to be used for an entire race. Japanese manufacturer Bridgestone, that supplied tires to Ferrari and other minor teams, apparently was much less able than its French rival Michelin in developing products coping with the new rules and, as a result, Michelin-supplied teams dominated the 2005 championship after five years of persistent leadership by Ferrari.

[4] The US military sector provided large amounts of funds to research on jet engines that greatly facilitated the development of commercial wide body jets. During the interwar period commercial aircraft have been developed and introduced more slowly in the absence of defence related and R&D and military procurement (see e.g. Ruttan, 2005).

[5] The microelectronics industry attracted a considerable amount of government investment effort (by the 1953 the Army Signal Corps was funding approximately 50% of transistor research at Bell Telephone Laboratory, see Holbrook, (1995). There is a consensus among industrial analysts that the USA government through its direct or indirect procurement polices stimulated an early market, promoting R&D investments and allowing firms to learn and decrease production cost.

[6] The Advanced Research Projects Agency (ARPA) of the American Department of Defence played a crucial role for the development of Internet. Since 1966 ARPA began to fund a multi-computer network that would have interconnected time-sharing computers. From that year ARPA continued to finance research in the field and in the late seventies procured to Western Union an updated version of the Automatic Digital Network – that was developed for exclusively military use (see Litan and Rivlin, 2001).

[7] A recent study by Cozzi and Impulitti (2004) suggests that the US Government dramatic shift in procurement choices in favour of high-tech sectors was a main determinant of the wave of innovation that the US economy in the 1980's and 1990's. For less technical discussions on the role of the US technology policy, and in particular of innovative procurement policy, see Branscomb and Florida (1998) and Hart (1998). The EU also recognized now the importance of

large-scale purchases can be oriented toward goods with different R&D contents, governments must take into account the effects of their procurement decisions on R&D investment in the private economy. Although the appropriate design of procurement contests may entail substantial gains in terms of static efficiency, any contribution it may give to faster technical progress will compound over time and potentially can result in benefits of a larger order of magnitude.

In this Chapter we draw from frontier economic research to offer practical answers to these crucial questions. In particular, we consider different ways to induce potential suppliers to produce and sell innovative products. Many of our arguments and practical conclusions are equally valid when the procurer is public or private, but some apply only to public or only to private procurers.

We will also try to answer important macroeconomic questions on how to use public procurement in order to stimulate aggregate R&D expenditure and to incentive the formation of human capital in the sector or country. Note that, at the private level, large firms are often the most important buyers for several specialized suppliers, which raises at the industry or district level questions that are similar to the analysis of the growth effect of public procurement.

Innovative knowledge is a particular good, and its procurement is possible but rather tricky, whether at the public or private level. Section 2 will deal with methods to procure such a special good as knowledge.

Other goods that buyers want to procure are often new or innovative. New knowledge must be created to produce these goods, and therefore the buyer must ensure that the suppliers have enough incentives to invest in the innovative knowledge that will eventually be incorporated in the goods it needs. In Section 3 we discuss what changes in the structure of optimal procurement contests are implied by this additional objective that must be pursued.

Procurement policy can have important indirect effects on innovative activity, e.g. by enlarging the market for new goods, by facilitating the adoption of new standards, by changing the input and output market structure and prevailing prices so as to make them conducive to faster innovation etc. Section 4 discusses the effects on innovation races of standard setting activities by large, often public, procurers. It also considers how to optimise the degree of competition between suppliers, and other more practical indirect ways to stimulate innovation. Section 5 discusses how public and

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procurement as an instrument to stimulate innovation, and among other actions commissioned an experts' report on the subject (EU Expert Group, 2005).

large private firm's procurement may induce innovation and growth at the national, industry or sully network level by affecting input market prices and the return to investments in human capital. Section 6 discusses how risk management methods used in procurement should be modified when innovation is a central concern for the buyer.

2 Procuring knowledge

Innovative knowledge can in principle be procured like any other good. To be sure, knowledge is "non-rival", once it has been created, it can be used by many people simultaneously at almost no cost: any number of people can simultaneously apply Pythagoras' theorem without "consuming" it. Similarly, once a new idea about what to produce (a new product) or about how to produce (a process innovation) has been invented and successfully tested it can be applied to the production of an indefinite number of products. For example, given the chemical formula for a new drug, a firm can implement it to manufacture an indefinite number of drugs; given a project for a new engine, it can be embedded in an indefinite number of cars, etc.

In the absence of intellectual property rights, secrecy, or other means of appropriation, innovative knowledge also tends to be "non-excludable", i.e. it is hard or impossible to control who has or is using a certain innovative knowledge. This means that knowledge tends to be what economists name a "public good,"[8] which however does not preclude the public procurement of innovative knowledge. Even private procurement of knowledge is possible, either for philanthropic reasons, in which case knowledge is put in the public domain as soon as it is acquired, or else when the buyer can somehow exclude others from the innovative knowledge he has procured from the original inventor or author and thus can profit from his monopoly. This section reviews the main tools for the procurement of knowledge and compares procurement with other means of fostering innovative activity, like intellectual property.

Society procures innovative knowledge in various ways. First, innovative knowledge is often publicly provided: for example, a considerable amount of basic research is conducted in public universities and laboratories. However, ideas tend to be widely distributed among individual researchers.[9] This implies that effective public provision of innovative knowledge can be very costly, since it requires that the government hires a large number of researchers in order to avoid the

[8] The notion that knowledge can be viewed as a public good dates back at least to Arrow (1962). For a critique of such a view, see Boldrin and Levine (2005).
[9] Menell and Scotchmer (2005).

risk that valuable ideas are not pursued. Although the costs can be somewhat reduced by using various incentive mechanisms to elicit adequate research effort, like performance-based research grants and promotions, public provision tends to be practical only if the number of potential innovators is limited, for instance because the expertise required to contribute innovative knowledge is difficult to achieve.

The main alternative to public provision is intellectual property. Through intellectual property rights or trade secrecy, authors and inventors obtain a temporary monopoly over the commercial use of the innovative knowledge they have created. The prospect of reaping monopoly rents, albeit for a limited time period, stimulates innovative activity. Although intellectual property and trade secret protection can be viewed as special forms of procurement in which the monetary payment is replaced by the right to exercise monopoly power temporarily, the optimal design of intellectual property falls outside the scope of this book and will be dealt with only cursorily.

Another mechanism to foster innovative activity, and one that is most akin to standard procurement, is the granting of monetary prizes to innovators; any innovative knowledge elicited by the prospect of winning the prize is then put in the public domain. One can distinguish between ex-ante and ex-post prizes. *Ex-ante prizes* are posted in advance and can be claimed by the first to solve a well-defined problem, e.g. proving Fermat's conjecture. *Ex-post prizes* reward discoveries that may not even have been conceived of before they occurred to someone. Still, if ex-post prizes are systematically and consistently awarded when useful innovations occur, the prospect of winning such prizes may elicit substantial research effort. In both cases, the nature of the innovation must be clearly and objectively defined, either ex ante or ex post, so that the prize can be awarded if and only if the innovation is achieved.

Private firms can procure knowledge in much the same way as society does: they can conduct research in-house, obtain licenses from independent holders of intellectual property rights or trade secrets, and post prizes. Both ex-ante and ex-post prizes can be used by private firms: for example, pharmaceutical firms normally reward with bonuses to their researchers that find solutions to pre-specified health market needs[10], whereas IBM used to reward with a monetary prize any patent obtained by one of its employees. Clearly, posted prizes can be privately profitable only if the firm can appropriate the result of the research, e.g. through intellectual property. Although we will mostly focus on public procurement of knowledge, many conclusions reviewed in this section readily extend to the case of private procurement.

[10] See also Chapter 4 for a discussion on how bonuses can be designed to provide performance incentives.

2.1 Ex-ante prizes

Monetary prizes financed out of general fiscal revenue have sometimes been used to reward innovators. In particular, ex-ante prizes are posted in advance and can be claimed by anyone that is first to invent. They differ from ex-post prizes in that the latter are granted discretionally as a reward for achievements that could not be foreseen in advance. In both cases, the prospect of winning the prize will elicit some research effort. Famous examples of ex ante prizes include the 18th century "longitude" prize[11], "America's most energy-efficient refrigerator" prize,[12] and the X Prize for space technology.[13]

In some cases, innovations originally spurred by the prospect of a monetary prize turned out to be patented;[14] on other occasions, the government acquired newly granted patents in exchange for a monetary prize[15] (such patent-buy-outs resemble ex-post prizes and will be discussed more fully later).

2.1.1 Problems of ex-ante prizes

Ex-ante prizes are impractical unless the invention society wants to procure is easily describable, like e.g. "a vaccine against AIDS which is effective in at least 70% of the population," and it is verifiable whether the invention has been achieved or not, e.g. through monitored clinical tests.[16] Even assuming that these conditions are met, however, three shortcomings of prizes as compared to intellectual property – patents, in the vaccine example – come immediately to mind:

1. When the procurement of innovations is financed out of general fiscal revenue, some individuals may end up paying for something they do not use or value. In contrast, with patents no one pays more than he benefits from what he buys.

[11] In 1714, in order to create an instrument able to determine the longitude, the British Government designed a contest with a final fixed prize of £20,000 (equivalent to million of pounds today) for the winner. John Harrison presented the eventual solution: a clock that could withstand storms, changes in temperature, and salt air. He received an initial payment of 10,000 and the remaining sum of money after the first successful test. See the entertaining account in Sobel (2005).

[12] A prize incentive was proposed for developing new vaccines, new ICT and other technologies. In 1991, a $30 million prize was sponsored to build the "America's most energy-efficient refrigerator". Whirlpool won the contest but to receive payment Whirlpool had to sell 250,000 new refrigerators by 1997 (the prize was established in 1992). Only 200,000 units have been sol and, therefore, the prize was not paid. See Langreth (1994).

[13] The X-Foundation in 1996 posted a 10 million dollar prize for to the first private firm to carry three passengers to a sub-orbital height of 100km twice within a single to two-week period. Many teams representing several countries have entered the race. The prize was awarded in 2005 (see www.xprizefoundation.org).

[14] John Hyatt's invention of celluloid was spurred by the prospect of a monetary prize posted by a manufacturer of billiard balls, but Hyatt eventually decided to patent his innovation (Porter, 1994).

[15] As an example, Louis Daguerre, the inventor of photography, sold his rights on the invention to the French government in exchange for a pension. The French government then put the invention in the public domain.

[16] Regulatory agencies like the FDA in the US and EMEA in Europe routinely decide whether a new drug is effective and safe or not; this means that the achievement of this particular innovation in principle would be verifiable.

2. Individual countries must reach an international agreement to divide the burden of funding the prize amongst them. With patents, a similar problem might also arise (i.e. each country might be tempted to free ride on research incentives provided by others), but this problem has already been addressed and solved by various international treaties, like TRIPS (Presumably, with patents an agreement was simpler to reach precisely because with a fully harmonized patent system each country pays in proportion to what it benefits from the innovation.)
3. "The reward conferred by [patents] depends upon the invention being found useful, and the greater the usefulness, the greater the reward."[17] With incomplete information on the value of the innovation, in contrast, it is difficult to choose the "correct" prize, i.e. the prize that aligns the private incentive to invest with the social value of the innovation; consequently, a prize system is bound to over-incentive certain innovations and under-incentive others.

2.1.2 Advantages of ex-ante prizes

On the other hand, a prize system has two important advantages over a patent system. First and foremost, generally the deadweight loss from monopoly pricing of new goods is greater than the excess burden from an optimally designed tax system – and probably from most of the existing tax systems. For example, in the AIDS vaccine case, monopoly pricing of a patented vaccine might result in some people being excluded from the cure, with social costs that might amount to thousands if not millions of deaths. With prizes, the vaccine would be immediately priced at marginal cost and a much smaller number of people would be excluded. Second, typically the private value of a patented innovation falls short of its social value[18] and thus a patent system may provide insufficient incentives to invest in research, whereas in principle there is no upper bound on the size of a monetary prize.

2.1.3 Choosing between ex-ante prizes and intellectual property rights

Leaving aside distributional concerns, assuming that international agreements are easy to reach, and assuming that the optimal patent life is finite,[19] the comparison between patents and prizes boils

[17] See Mill (1848).

[18] There are various reasons why the private value is lower than the social value: limited protection, the fact that the patentee may not be able to extract all the surplus from consumers, technological spillovers, monopoly deadweight losses.

[19] This is not to suggest that with a finite optimal patent life there is no under-investment in research; quite to the contrary, an optimized patent system must lead to under-investment in research because increasing patent protection is socially costly and so it is desirable to stop raising the strength of patent protection before the socially optimal level of investment in R&D is reached. However, when the optimal patent life is finite, any under-investment in research is due

down to a comparison between the distortion created by asymmetric information on the one hand and those associated with monopoly pricing on the other hand. Note that, to the extent that potential innovators are uncertain about the value of the innovation, incomplete information will distort the decision to invest in research also under a patent system. The extra cost of a prize system is due to the asymmetry of information between the government (that sets the prize) and innovators, and vanishes when information is symmetric – even if it is incomplete. Therefore, in a world of symmetric information it would be preferable to reward innovators through monetary prizes. This conclusion continues to hold if informational asymmetry is limited and the monopoly deadweight loss (the social loss induced by the exercise of market power, with higher prices and reduced output) is large, e.g. the demand for the new good is very elastic. A patent system would be preferable if the asymmetry of information is substantial and/or demand is inelastic.[20]

Practical Conclusion 1

Procuring innovations through monetary prizes tends to be preferable to intellectual property when the innovation is easily describable in advance, the expected costs of monopoly prices are high, the occurrence of the innovation is verifiable, and there is little informational asymmetry on the value of the innovation.

When the procurer is a private firm, a similar trade-off may arise. Consider a private firm that is the sole potential user of an innovation that can uniquely be supplied by an independent inventor. The private firm can wait for the inventor to achieve and patent the innovation and then bargain for a license, or it can post a prize which it commits to pay to the successful inventor, retaining any intellectual property right might be granted on the innovation. Bargaining ex-post for a license is costly, however, and the licensing agreement may involve distortionary clauses such as unit royalties. On the other hand, the procurer may not know the value of the innovation that the independent inventor will eventually supply. Again, a trade-off arises and the procurement of innovative knowledge through a monetary prize posted ex-ante tends to be preferable if information is symmetric or informational asymmetry is limited.

to the monopoly deadweight losses created by the patent, and therefore are already encompassed in the first reason why prizes can be better than patents.

[20] See Wright (1983). The monopoly deadweight loss may be small even if demand is elastic, provided that the patentee can engage in price discrimination.

Coming back to the case of public procurement, consider next self-selection mechanisms that combine prizes and intellectual property. One such mechanism is an optional patent system in which the supplier (that is better informed on the value of his innovation than the government) can choose between a patent and a monetary prize.[21] The reward obtained by a successful supplier will be constant if he chooses the prizes, but will increase with the value of the innovation if he opts for patent protection. Consequently, more valuable innovations will end up being patented, and only innovators holding less valuable innovations will claim the monetary prize. Such a sorting means that suppliers will retain some informational rents. Nevertheless, a properly designed optional system dominates a pure patent system and may be preferable to a pure prize system.[22]

An optional patent system can be further improved upon by allowing for the possibility that innovators are granted both a prize and a patent. In particular, the government could offer a menu comprising a monetary prize and, alternatively, a lower (and possibly negative) prize augmented by a patent of positive length. If optimally designed, this two-option menu is preferable to an optional patent system. Furthermore, it turns out that offering to innovators two options suffices to achieve a constrained optimum under weak regularity conditions.[23]

> **Practical Conclusion 2**
>
> *When the innovation is easily describable in advance and the occurrence of the innovation is verifiable, the supplier should offer a menu comprising two options: a monetary prize, and a lower prize coupled with patent protection.*

2.2 Ex-ante prizes with sequential innovations

So far, we have considered the case where each innovation is independent of the others. However, innovation is cumulative in nature: typically each innovation builds on the previous ones, and in

[21] Shavell and van Yperseele (2001). Note that when the procurer is a private firm, even if only a monetary prize is offered, the supplier retains the option to patent and therefore effectively faces an optional system. To rule out the option to patent, the procurer should require participants to the competition for the prize to assign in advance any intellectual property rights they may obtain to the procurer itself.

[22] To see this, consider a fully optimized patent system and take the lowest possible value of the innovation. Offering a menu with the same patent length and a prize slightly greater than the lowest private value of the innovation (i.e. the private value in the worst possible case, calculated on the basis of the optimal patent length) will raise the incentive to innovate and reduce the expected deadweight loss. Similarly, consider the optimal prize in a pure prize system. Now reduce the prize but offer a patent of positive length, in such a way that the expected deadweight loss remains constant. Such a move reduces the investment in relatively low-value innovations, and increases the investment in relatively high-value innovations; thus, this move tends to be welfare improving. There is no guarantee, however, that such a move will indeed be welfare improving, because the changes in equilibrium investments brought about by this move are discrete, not infinitesimal. The move will be welfare improving if there is enough uncertainty on the value of the innovation. See Shavell and van Ypersele (2001) for details.

[23] See Scotchmer (1999) and Chiesa and Denicolò (2005) for more on these more elaborate schemes.

turn constitutes the basis for subsequent developments. With cumulative innovation, intellectual property rights run into problems, which potentially enhance the desirability of ex-ante prizes.

In particular, the cumulative nature of technical progress has two important consequences. First, with sequential innovations the social value of an innovation now includes also the option value of investing for obtaining the subsequent improvements. Second, the occurrence of the next-generation innovation tends to kill the market for the current innovation. This means that when path-breaking innovators are protected by intellectual property, instead of being compensated for the option value they have created, they suffer from competition from second-generation innovators.

Basic innovations therefore need forward protection, because otherwise future innovators could compete away the original innovators' profits; and because the first innovator should be rewarded for opening the way to the subsequent improvements.[24] The patent system provides forward protection in two ways: first, any patent application must meet certain novelty requirements; second, even patentable improvements may constitute infringement on the original patent, depending on the first-generation patent's leading breadth. Both the novelty requirement and leading breadth, however, entail a social cost in that they impede the achievement of the second-generation improvements, which can be substantial and socially valuable.[25]

A prize system is in principle immune from these defects, because prizes can be calculated taking into account the option value of basic innovations, and because business stealing from second-generation innovators is not an issue when any innovative knowledge is immediately put in the public domain. However, ex-ante prizes must be properly designed in order to cope with the sequential nature of the innovative activity. For example, when it is important for cumulative innovation that individual innovations are disclosed early, so that other researchers can use them, it may be optimal to abandon the classic "winner-takes-all" design, select a group of innovators, and ensure that the prizes each of them wins is shared with the others in the group.[26]

[24] See Scotchmer (1991).

[25] In fact, the novelty requirement and leading breadth protect early innovators in different ways. The fact that an innovation must satisfy novelty requirements may block or impede second-generation improvements, thus lengthening the first-generation innovators' monopoly. On the other hand, by finding that an improvement infringes on a basic patent, the courts can force the patentees to bargain over profit shares, thus allowing the original innovator to capture some of the rents from the improvement. This means that the novelty requirement has a "blocking effect," and leading breadth a "sharing effect." The sharing effect of leading breadth, however, automatically entails also a blocking effect: if the second innovation is small and infringes, the profit left to the second innovator may be too low for investment to be profitable (R&D costs are sunk when bargaining between the patent holders takes place). This means that even leading breadth inevitably prevents some second-generation improvements. See Denicolò and Zanchettin (2002) for a more detailed discussion of these two effects of forward patent protection.

[26] See e.g. Lewis and Talley (2005).

2.3 Ex-post prizes

When the innovation is not easily and precisely describable, or cannot even be conceived of in advance, ex-ante prizes are unfeasible. However, if the occurrence of the innovation is verifiable ex-post, in principle a procurer could commit to offer ex-post prizes to successful innovators. In an ex-post framework, describing the innovation is no longer at issue, but the problem remains of guessing the value of the innovation and hence the appropriate prize.

2.3.1 Uncertainty and discretion

With ex-post prizes two distinct problems in fact arise: the uncertainty over the value of the innovation, which raises issues similar to those discussed in the preceding subsection, and the fact that the value of the innovation is typically unobservable. Generally speaking, in a public procurement case, once the innovation has been achieved the government has an incentive to renege on its promises, be it the award of a prize or an intellectual property right. Whereas with ex-ante prizes and intellectual property it is easy to observe whether or not the government has kept its promises, and so simple reputation mechanisms[27] can provide enough incentives for the government to stick to the commitment, with ex-post prizes the government is not committed to any particular size of the prize. As a consequence, if the value of the innovation is unobservable to third parties, reputation mechanisms do not work efficiently to induce the government to match its promises. Ex post, the government is therefore systematically tempted to under-reward innovators; such a temptation will be anticipated by potential innovators and results in under-investment in research.

The fact that the value of the innovation is not observable or verifiable also means that the procurer can set the prize quite discretionally, implying that innovators have an incentive to engage in opportunistic behaviour and lobbing. As a consequence, the whole system of ex-post prizes can be prone to corruption. These reasons explain why ex-post prizes are rarely observed in practice. The Nobel prizes, and other similar prizes, are in fact awarded at pre-specified dates, and are of a pre-specified size; thus, they resemble research contests (discussed later) more closely than ex-post prizes[28]. Examples of ex post prizes are medals, honor mentions, and similar recognitions that heads of state award every now and then to successful people.

[27] See also Chapter 4 on contracting issues, and Chapter 18 on feedback mechanisms for further discussions on the role reputation in procurement

[28] Even so, the Nobel Prize has, on occasion, “cheated”: in the early '30s the physics prize was not awarded for several years.

2.3.2 Kremer's mechanism and collusion

These problems with ex-post prizes could be overcome, however, if a mechanism to set the prize could be found that leaves little or no discretion to the procurer. A recently proposed patent-buy-out mechanism may achieve this goal and at the same time solve the problem of informational asymmetries that plague even ex-ante prizes.[29] The proposal is that suppliers initially rely on the protection conferred by intellectual property, but at a subsequent stage the government acquires the intellectual property rights it just granted, using an appropriately designed competitive procurement, and then puts the innovative knowledge in the public domain.

The fundamental premise of the Kremer patent-buy-out mechanism is that even if the government is poorly informed about the value of innovations, the patentee's competitors are typically better informed. To extract this information at a low social cost, the government implements a standard first-price sealed-bid tendering process for the patent, with the proviso that almost always the winner will not receive the patent, which will instead be acquired by the government, at the price determined by the tendering process. In order to preserve the incentives to bid correctly, however, in a small fraction of cases the winner of the competitive bidding should really get the patent and pay his bid.

The main problem with the Kremer patent-buy-out mechanism is that it is hardly collusion-proof. Although almost any competitive procurement is subject to the risk that bidders collude, typically some competition among bidders will remain unless all bidders participate in the cartel. The Kremer competitive tendering, in contrast, can be undermined by agreements involving only two bidders, even if the number of bidders is quite large; in addition, the collusive agreement is always self-enforcing, even if players discount the future heavily.

To see this, suppose that firms A and B enter a bilateral agreement whereby firm B systematically bids in excess of the value of A's patents, and A does the same when it comes to B's patents to be competitively procured. Even if there are many bidders and no other firm participates in the agreement, firm B's (over-valued) bids will determine the price that the government pays for A's patents, and in like manner A will determine the price that B gets for its own patents. In the rare event that B must really purchase A's patent, the patent can be re-sold to A; alternatively, B can wait for A to over-pay one of B's patents to be compensated. Because such bilateral agreements are easier to reach than multilateral agreements, are self-enforcing irrespective of the size of the discount factor (there is no temptation to deviate), and there can be several bilateral agreements in place, the government may very often end up paying an excessive price for the patents it buys out.

[29] This mechanism is known as Kremer's patent-buy-out mechanism after Kremer (1998).

Because of this weakness of the Kremer patent-buy-out mechanism, it would be prudent not to apply the mechanism systematically, especially in those industries – like e.g. the pharmaceutical industry – in which there is a relatively small set of players that remain active for a long time. However, the patent-buy-out mechanism possesses nice properties if bidders behave non-cooperatively, and thus it can be useful when collusive agreements can somehow be prevented – for example, if the mechanism is used quite rarely, the probability that the winning firm must acquire the patent is not negligible, and re-sale of the patent is prohibited.

Practical Conclusion 3

The Kremer patent-buy-out mechanism must be used with caution, making sure that it is not employed frequently in the same industry, choosing a sufficiently large probability that the winning supplier must acquire the patent, and prohibiting re-sale of the patents.

Table 1 summarizes the effects of ex-ante and ex-post prize system.

TABLE 1	**Ex-ante prizes**	**Ex-post prizes**	**Results**
Asymmetrically Informed Contractual Parties	• Difficulty on choosing the "correct" prize • Ex-ante prizes are impractical	• Uncertainty over the value of the innovation • The procurer can set the prize quite discretionally	• Ex-post prize is the only practicable prize system
Symmetrically Informed Contractual Parties	• No need for information over the value of the innovation • With ex-ante prizes and intellectual property it is easy to observe whether or not the procurer has kept its promises	• No need for information over the value of the innovation • The procurer has an incentive to renege the award of a prize	• Government is systematically tempted to under-reward innovators • Ex-ante prize system preferible

2.4 Research contests

Often the outcome of innovative activities is neither describable in advance nor verifiable ex post. [30] Because a minimal requirement for a prize system to be feasible is that the occurrence of the innovation is verifiable, in these circumstances the procurer must resort to other mechanisms to obtain innovative knowledge.

2.4.1 Contests are easy to implement

Research contests are informatively less demanding than both ex-ante and ex-post prizes, and thus often constitute a feasible option. In a research contest, the procurer sets both a prize and a time deadline, and pays the prize to whomever has made the largest progress when the deadline is

[30] The longitude prize example illustrates that verifiability is often an issue: it took several decades, the construction of several prototypes and several replication tests to the watchmaker that won the longitude prize to actually receive his prize, because the prize-awarding commission was composed of astronomers that were looking more for new *knowledge* useful to establish longitude with precision, that being non-rival could be freely used by a large number of navigators, rather than for an hard to replicate and expansive object physically incorporating the solution to the longitude problem (in fact, such a knowledge did materialize later on; see the discussion in Scotchmer 2004).

reached. There is no need of ascertaining whether a prescribed target has been reached or not; all that matters is that the prize is awarded to a contestant at the conclusion of the research contest. The incentive to award the prize may be provided by reputational mechanisms, or else the procurer's obligation may be enforced by the courts. In any event, the court needs not be called to decide whether the winner has been properly selected, since the procurer has little incentives to manipulate the outcome of the contest given that he must pay the prize to someone.[31]

The main difference between research contests and research prizes is that research contests end on a specified date, whereas an innovation race for a prize ends whenever the innovation is achieved. As a consequence, in a research contest the timing is fixed but the amount of innovative knowledge produced is variable, whereas in an innovation race the R&D output is fixed but the timing of innovation is variable.[32]

Because research contests are informatively parsimonious and easily implementable, they are used frequently both by private and public procurers. The prize can be a sum of money, a procurement contract, etc. Over the years, contests have played a major role in the procurement of many innovations. One of the most famous research contests was sponsored in 1829 by the Manchester and Liverpool Railway to choose an engine for the first passenger service between the two Liverpool and Manchester. Two different engines were proposed. One of them reached a speed record of 51.5 kilometres per hour but collapsed. So the Railway paid to the other proposal a prize of £500. However, both the engines had impressive performances and this spawned an explosion of innovation in locomotives.[33] Relative performance evaluation systems for laboratory researchers that pay yearly bonuses to the best performing research teams are other common forms of research contests.

2.4.2 Research vs. Sport contests

Research contests are remarkably similar to sport contests which have been analyzed in a large and burgeoning literature.[34] However, in a research contest the procurer is typically interested in maximizing the performance of the winning supplier, i.e. the innovative knowledge supplied by losers duplicates that supplied by the winner and thus is useless to the procurer, whereas in sport contests more complex objectives seem appropriate, like maximizing the suppliers' average

[31] Taylor (1995, p. 973).

[32] Under this respect, research prizes are similar to patent races. Although innovators have some latitude in determining when to apply for a patent, which they may be tempted to exploit strategically, such a latitude is limited by various legal rules and so for many practical purposes one can assume that intellectual property rights are awarded as soon as a pre-specified innovation is achieved.

[33] See Day.(1971) and Fullerton and McAfee (1999).

[34] See Smylianski (2002) for an excellent survey.

performance or guaranteeing that sport events are sufficiently levelled. These differences can have notable consequences on the optimal design of sport contests as compared to research contests, and mean that one must use caution in applying to research contests conclusions drawn from the rich experience that has been gained in the design of sport contests.

Designing a research contest requires several careful choices: How many suppliers should the procurer invite to participate in the contest? Should the prize be awarded entirely to the winner, or should it be divided amongst several suppliers (presumably, the best performers)? Should suppliers compete on equal footing, or should the procurer handicap the most able? Although there are no clear-cut answers to these questions, a few general principles emerge from the rich experience from sport contests and a rigorous economic analysis of these issues.

2.4.3 The optimal number of participants

In sport contests, the number of participants is often restricted. In the Olympic Games, only one team per country is admitted in team sports, and only three participants per country are admitted in individual sports. In most European countries, about twenty football teams are admitted to the national premier league. Less than two hundred cyclists participate in the Tour de France or the Giro d'Italia. Many similar examples readily come to mind; often, there are complicated rules to determine who should be invited to participate in such elite sport events.

Some of the reasons why participation in sport contests is restricted do not have an immediate counterpart in research contests. For example, participation in the Tour de France by two thousands cyclists would be impractical or even dangerous, whereas in a research contest adding one participant hardly impedes the performance of the others. In sport contests, selecting a restricted number of ablest athletes guarantees that the game is more levelled than with free participation, but the procurer of a research contest is rarely interested in the levelness of the contest per se.

Other reasons to restrict participation, however, do extend to research contests. Consider a chrono race, where the performance of each athlete depends on his ability, effort and a random component, and where each participant is incompletely informed on the performance of his rivals while he is performing. In such a race, the marginal value of effort is the prize to the winner multiplied by the increase in the probability of winning the race associated with a unit increase in effort. Because the latter decreases with the number of participants, the incentive to exert effort will also decrease with the number of participants. As a consequence, if the procurer wants to maximize the best performance, he might benefit from restricting participation in the race to only the ablest athletes. By the same logic, in a research contest the incentive to invest of any one participant may decrease with the amount of research conducted by others. In this case, if the procurer wants to maximize the total amount of research (i.e. the expected quality of the winning innovation), he may want to limit the number of participants.[35]

However, two countervailing effects may undermine this restricted-participation result. Firstly, imagine a research contest with two suppliers, 1 and 2, and consider the effect of supplier 3's entry into the contest, starting from the two-supplier equilibrium. If supplier 3 wins with positive probability, its entry will reduce the value of the investments made by suppliers 1 and 2. However, it is the marginal value, and not the total value of research effort that determines the best responses of suppliers 1 and 2, and the marginal value may well go up. This is most clear when each competitor can observe the progresses made by its rivals. Suppose that firm 3 would win by a small margin if firms 1 and 2 did not change their effort levels after 3's entry. In this case, probably suppliers 1 and 2 would be willing to exert more effort after 3's entry. If, however, supplier 3 would win by a large margin, this may well induce suppliers 1 and 2 to reduce their efforts. Likewise, in sport contests more intense competition can make rivals perform harder when they are neck-and-neck, whereas it can even induce laggards to completely stop investing if one contestant has a very large advantage over the others.[36]

Secondly, innovative ideas are widely distributed among individual suppliers and inventors,[37] implying that more effort exerted by any one firm may not compensate for the exclusion of another supplier from the contest. Also, restricting participation in a research contest risks eliminating very promising lines of research. As a matter of fact, research contests rarely involve substantial entry fees, as procurers frequently are concerned that there is enough competition in research. For example, the DoD has often subsidized the suppliers selected to participate in research contests in order to ensure their financial stability.[38]

Assuming that restricting participation is, nevertheless, desirable, the number of participants can be restricted by the introduction of an entry fee rather than by fiat. Using entry fees has the advantage of allowing the procurer to extract some (or even all) of the rents that otherwise would be obtained by the participants, but may result in excessive entry or, even worse, in entry by only one firm – if

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[35] See Taylor (1995) and Fullerton and McAfee (1999). While Taylor shows that the optimal number of participants can be finite, Fullerton and McAfee arrive at the much stronger conclusion that entry into a research contest should be restricted to two participants. The explanation of these different results is that whereas Taylor implicitly assumes that firms are capacity constrained in their research activity (in his model, the research activity consists in making draws from a probability distribution, and firm can only make one draw per period), Fullerton and McAfee assume that each firm can conduct an arbitrarily large amount of research, with a constant marginal cost of research. Furthermore, Fullerton and McAfee assume that there is a fixed cost of conducting research, and limiting the number of participants in the contest prevents wasteful duplication of the fixed costs. The result that it is optimal to restrict participation to just two firms has also been found in the more structured framework analyzed by Che and Gale (2003).

[36] Similarly, the patent race literature has shown that reaction functions can slope either upward or downward, depending on the specific assumptions made (compare Loury (1979) and Lee and Wilde (1980)).

[37] Menell and Scotchmer (2005).

[38] Che and Gale (2003).

the procurer is not fully informed. To solve this problem, it is possible to run an entry competitive tendering procurement.[39] Like contests, competitive procurement have low informational requirements and, if properly designed, are likely to select the most efficient contestants. In addition, and like entry fees, they allow the procurer to collect some revenue.

2.4.4 The division of the prize

In a contest, should the prize be awarded entirely to the winner, or should it be divided between several contestants? In sport contests, the-winner-takes-all principle is the exception rather than the rule, although the size of the prize is rapidly decreasing in the rank order of the contestants. With intellectual property, in contrast, only the first inventor has a right on the innovation.

There are two main reasons why in sports contests typically the winner does not take all. First, if the contestants' ability is the main determinant of their performances, rewarding only the winner will likely induce the less able athletes to exert little effort. This is not appropriate if the procurer sponsoring the contest wants to maximize aggregate effort. Second, in a multi-stage race the winner-takes-all principle may result in most of the effort being exerted in the first stages; once the rank order of the participants starts being clear, and laggards have little chances to overcome the leader, efforts may decline dramatically, especially if the leader can monitor the performance of the laggards.

Practical Conclusion 4

In multi-stage research contests, it is important to ensure that there is effective competition even in later stages. This can be achieved by splitting the prize between the contestants.

2.4.5 Handicapping contestants

Strong chess players often concede a pawn, or even a rook, when they play against a weaker opponent. This makes the game more levelled and therefore more enjoyable to both players, who have stronger incentives to play carefully than if they competed on equal footing. The same principle holds true in research contests: if contestants are asymmetric, it is optimal to handicap the most efficient one.[40] The reason is again that contestants perform harder when they are neck-and-neck; if they differ in their ability, handicapping the most efficient contestants results in a more levelled race. Note that the procurer is not interested in levelness per se; rather, he wants suppliers to be neck-and-neck in order to elicit more effort. However, this instrument has to be used with

[39] See Fullerton and McAfee (1999).
[40] Che and Gale (2003).

much care: it is crucial not to handicap suppliers too much. One has to be sure that a more levelled competition is worthwhile despite the decrease in the average productivity of research it inevitably entails. Suppose, for example, that in the economy there were two firms like ACER and DELL competing with a large number of extremely backward competitors. Severely handicapping the most efficient contestants to level the battle field might be highly detrimental to aggregate innovative performance.

Practical Conclusion 5

When contestants differ in their ability, handicap the most efficient contestants in order to guarantee that the contest is more levelled if and only if the resulting level is not too low.

BOX 1 Ex-ante Prizes, ex-post Prices, and Research Contests

Ex-ante prizes are posted in advance and can be claimed by the first to solve a well-defined problem, like proving Fermat's conjecture. Ex-ante prizes are impractical unless the invention society wants to procure is easily describable, like e.g. "a vaccine against AIDS which is effective in at least 70% of the population," and it is verifiable whether the invention has been achieved or not, e.g. through monitored clinical tests. They differ from ex-post prizes in that the latter are granted discretionally as a reward for achievements that could not be foreseen in advance.

Ex-post prizes reward discoveries that may not even have been conceived of before they occurred to someone. If the occurrence of the innovation is verifiable ex-post, in principle the procurer could commit to offer ex-post prizes to successful innovators. In an ex-post framework, describing the innovation is no longer at issue, but the problem remains of guessing the value of the innovation and hence the appropriate prize.

Research contests are informatively less demanding than both ex-ante and ex-post prizes, and thus often constitute a feasible option. In a research contest, the procurer sets both a prize and a time deadline, and commits to pay the prize to whomever has made the largest progress when the deadline is reached. Thus, there is no need of ascertaining whether a prescribed innovation has been obtained or not; all that matters is that the pre-specified prize is awarded to one of the contestants at the conclusion of the research contest.

The main difference between research contests and research prizes is that research contests end on a specified date, whereas an innovation race ends whenever the innovation is achieved. As a consequence, in a research contest the amount of innovative knowledge produced is variable, whereas in an innovation race it is pre-specified.

3 Procuring innovative goods

We have already remarked that in a research contest the prize for the winner may be an amount of money, a procurement contract, the positive advertising associated with the mere fact of winning the contest etc. When the prize is pre-specified ex ante, any benefit associated with winning the contest can be given a monetary evaluation; the sum total of these benefits then represents the prize to the winner.

However, when the winner of the research contest is rewarded through a procurement contract for the supply of the innovative good or service, the procurer has another instrument that can be used to improve upon the outcome of the contest, namely the price of the good. Imagine a two-stage competition, in which in the first stage suppliers invest to obtain an innovative good of variable quality, and then in the second stage they bid for the right to sell the innovative good to a procurer. As compared to a simple research contest with a pre-specified prize there are two main differences. First, the prize is not specified in advance, but is determined as a result of the second-stage competitive bidding. Second, the highest quality innovator is not sure of getting the prize; the winner of the contest will instead be the supplier that bids the lowest price per unit of quality supplied.[41]

Since a recurrent theme of the preceding section was that allowing the procurer to set the prize ex-post leaves room for opportunistic behaviour, it may sound surprising that now the procurer does not want to commit to a pre-specified prize when commitment is possible. Note, however, that in the proposed mechanism the prize is the outcome of a competitive bidding, and thus it is not left to the procurer's discretion. This means that there is no room for opportunistic behaviour on the part of the procurer.

It is important to note that this ability to separate between good and bad innovations is achieved at a cost: the competitive bidding inevitably reduces the prize contingent on winning the race, thereby reducing the benefits from investing in R&D. If R&D responds to incentives, this may lower the innovative effort of all suppliers participating in the race. For this reasons, if the suppliers are

[41] In principle such competitive bidding-augmented research contests could be used even with monetary prizes: i.e., suppliers first invest in research and then bid the prize they ask for the innovative knowledge they have created. However, for the mechanism to work suppliers must disclose their innovative knowledge to the procurer, who could then have access to all of the knowledge by paying only the low prize asked by a low-performance supplier. This difficulty can be overcome if suppliers can somehow communicate to the procurer the quality of their research outcome without disclosing all of the knowledge. Typically, this is possible when production of the good requires some tacit knowledge that suppliers cannot or need not transmit to the procurer, in which case the procurer cannot directly use the innovative knowledge but must procure the innovative good from the contestants.

homogeneous, competitive bidding-augmented research contests promote R&D less than research contests with the same pre-specified price. However, with heterogeneous suppliers they may be preferable despite the negative incentive effect on R&D expenditure.

Why can competitive bidding-augmented research contests be preferable to research contests with pre-specified prizes? There are at least three answers to this question.[42]

1. One advantage of competitive biddings is that they require little information: when suppliers are symmetric, the procurer needs no information at all concerning supplier' costs to properly design the contest. In a standard research contest, in contrast, the procurer needs some information on the technology of research to optimally determine the prize. (When suppliers differ in their ability, and it is desirable to handicap the most efficient contestants, some information about firms' ability is nevertheless required.)
2. With heterogeneous suppliers, the efficiency gap between the most efficient contestant and the second most efficient contestant can be so large that the outcome of the contest is largely independent of research efforts, which reduces the incentives to invest of all suppliers. Letting less efficient suppliers bid for a lower price in case they produce a low-quality innovation enhances the competitive pressure on the efficient firm, and makes the contest more similar to a neck-and-neck race. (This is also the intuitive reason why, with heterogeneous firms, the most efficient firms should be handicapped.)
3. Competitive bidding-augmented research contests allow to achieve a better alignment of the social and private incentives to invest in the innovative activity

Let us summarize our results in Table 19.2 and in the following Practical Conclusion.

Practical Conclusion 6

When suppliers can communicate to the procurer the quality of their research outcome without disclosing all of the innovative knowledge, it is desirable to employ competitive bidding-augmented research contest in which suppliers first invest in research, and then bid a price for the innovative good that the procurer wants to procure.

[42] See Che and Gale (2003) and Fullerton et al. (2002).

TABLE 19.2	**Competitive bidding-augmented Research Contest**	**Standard Research Contest (Pre-specified Prize)**	**Results**
Asymmetrically Informed Contractual Parties	• Little information needed	• The procurer needs much more information on the technology of research to optimally determine the prize	• Competitive bidding-augmented research contest reduces the effect of asymmetric information • Competitive bidding-augmented research contest is preferable
Symmetrically Informed Contractual Parties	• No need for information concerning suppliers' costs to properly design the contest • Competitive bidding-augmented research contests discourage research activity	• No need for information concerning suppliers' costs to properly design the contest	• Standard research contest is preferable
Heterogeneous Bidders	• Possibility of very large efficiency gaps among suppliers • Competitive bidding-augmented research contest makes the contest more similar to a neck-to-neck race • Better alignment of the social and private incentives to invest in the innovative activity	• Possibility of very large efficiency gap among suppliers • The incentives to invest of all suppliers are reduced	• In a standard research contest, the outcome from the contest is largely independent of research efforts, whereas in competitive bidding-augmented research contest suppliers compete neck-to-neck • Competitive bidding-augmented research contest is preferable
Homogenous Suppliers	• In case of asymmetrically informed contractual parties, the competitive bidding-augmented Research Contest reduces the effect of asymmetric information • When the contractual parties are symmetrically informed, the competitive bidding-augmented Research Contest reduces suppliers' innovative activity	• In case of asymmetrically informed contractual parties, the procurer needs some information on the technology of research to optimally determine the prize	• Standard research contest is preferable

4. Using procurement to stimulate innovation

Procurement design can have indirect effects on innovative activity by enlarging the market for new goods, by facilitating the adoption of new standards[43], or by changing the market structure so as to make it more conducive to faster innovation. In this section we analyze these more indirect ways in which procurement can stimulate innovation.

4.1. Procurement and standards setting

Many innovative goods and services exhibit network effects: each user's value increases when the number of other users increases as well. Sometimes, these effects result from "physical" networks, such as a telephone network (the value of a phone is greater the greater number of people I can call). In most cases, however, we are faced with "virtual network" effects. For example, the more users buy the Windows operating system, the more complementary products and services (e.g., software) will be available for Windows users.

Strong network effects can potentially lead to market failures that public procurement can help alleviate.[44] Two particularly important forms of market failure in markets for innovative goods that exhibit network effects are excess inertia and inefficient lock-in. Excess inertia refers to the situation when a new, superior technology fails to displace an older, inferior one due to network effects. Inefficient lock-in refers to the situation when market dynamics lead to the adoption of an inferior version of a new technology or standard.

The mechanism behind excess inertia is that users of the old technology or standard fear that they will be among the few to switch to the new one. If network effects are very strong, a new technology with few followers is worse than an old one with a good solid installed base, especially when there are costs in switching to a new technology or standard. Historical examples of excess inertia include the aborted attempt at switching from AM to FM radio broadcasting in the 1950s; and the failed launch of quadraphonic sound technology in the 1970s.

[43] Chapter 3 discusses how centralized procurement is able to magnify network effects and the adoption of common standards.

[44] A few economics scholars, however, passionately disagree with such a statement. See for example Liebowitz and Margolis (1990).

Inefficient lock-in typically results from the self-reinforcing (or "snow ball") dynamics of network effects. A classic example is that of video-cassette recorders (VCRs). Many industry experts agree that Sony's Betamax system was superior to JVC's VHS (in fact, until the advent of digital recording technology, Betamax remained the technology of choice for TV professionals). However, the VHS standard found itself on the right side of the wave when, during the 1980s, video rental stores and consumers needed to coordinate on one standard. Once most video stores were carrying mostly VHS tapes, even users who would otherwise prefer the Betamax system caved it and opted for the JVC sponsored standard.

Whenever there is a market failure, there is a potential for welfare-improving public policy intervention. In the context of network effects, this can take on various forms. Governments can mandate a standard or a technology. For example, several governments have decreed deadlines for switching to digital television broadcasting. Alternatively, governments may subsidize investments in a particular standard or technology. In this section, we are particularly interested in public policy through procurement.

When public administrations purchase sizeable amounts of innovative goods and services, choosing a new technology or choosing a particular version / standard of a new technology may have significant effects in the eventual outcome of the technology adoption process.

The adoption of a new technology by the public sector as a whole may also stimulate private demand through the reduction of the risk of isolation. More generally, by adopting new technologies the public sector can play a key role in coordinating the demand and avoiding lock-in. By increasing the installed base of the good that it purchases, the public sector's action increases the value of that good, thus inducing greater adoption by other users. Moreover, a choice made by such a large agent as a government agency may act as an important focal point of coordination whenever there are several options available.

There are a variety of examples where government procurement had an influence in the direction of the standard setting processes. Nuclear power reactors is one such example. By the late 1950s, there were about a dozen relevant alternative technologies. According to Cowan (1990), "light water is considered inferior to other technologies, yet it [currently] dominates the market for nuclear reactors." The reason for this inefficient lock-in can be traced back to a major procurement effort by the U.S. Navy in the 1950s.

Wide body aircraft provides an instance of an indirect network industry. An airline (the typical buyer) has an incentive to buy the same type of aircraft as other buyers. Otherwise, maintenance and other complementary services may become prohibitively costly. During the mid 1970s, the McDonnell Douglas DC-10 was in serious danger of being taken over by the Boeing 747 (and, to some extent, the Lockheed 1011). However, when the U.S. Air Force ordered sixty units of the KC-10 (the military version of the DC-10), the programme was given a new life and was able to compete for a few more years.[45]

A final example is given by computer operating systems, which, as shown above, are subject to strong "virtual network" effects. The Brazilian government has recently decided to expand the use of free source software in the public sector. In September 2004, an agreement with IBM led to the establishment of a knowledge and technology centre to promote and develop open source and Linux solutions in Brazil. Brazil is just the latest of a long list of government agencies that are actively promoting Linux through their procurement decisions. Others include, in the U.S., the Air Force, the Federal Aviation Administration, the Postal Service, and the Departments of Defense, Agriculture and Energy; in Europe, the European Commission, various government offices in Germany, and France's Ministries of Culture, Defense and Education; and China's Post Office.[46]

In sum, the public sector is likely to be a large buyer in whatever market it establishes a procurement process.[47] And to that extent its choice of supplier, in particular its choice of standard, is bound to have an effect on market outcomes. What guidelines should the public sector follow to account for this potential influence?

Cabral and Kretschmer[48] analyse the situation when two different versions of a given technology battle for market dominance – what some refer to as "standards competition" or "standards war." Two polar cases are considered. At one extreme, the life cycle of the innovative standard is expected to be relatively long. This implies that the cost of a mistake in the standard-selection process is likely to be very high. It follows that a long experimentation phase is optimal, as the

[45] Eventually, a series of crashes considerably reduced public confidence in the DC-10, which was discontinued in 1980. In retrospect, the DC-10 panic was blown out of proportion. By the end of the century, the statistics on the rate of hull losses per million departures show 1.90 for the 747 (early models); 0.77 for the L-1011; and 2.57 for the DC-10 (see *The Wall Street Journal*, September 19, 2000, p. A18). Though certainly the highest among the three, the DC-10 number hardly justifies the public's reaction.
[46] Sources: http://www.ZDNet.com on 04/06/2002; http://www.usatoday.com on 30/05/2002.
[47] For more examples, see Cabral and Kretschmer (*forthcoming*).
[48] Cabral and Kretschmer (2004).

higher experimentation costs are outweighed by the reduced likelihood of selecting a worse standard. The study refers to this as the "patient planner" case and show that the best policy is to support the lagging technology (a bit like what the U.S. Force did in the widebady aircraft race during the 1970s and many governments are currently doing in the operating systems race).

At the opposite extreme, when the life cycle of the innovative standard/technology is expected to be short, the costs of a protracted standards war are not justified by the benefits of a better selection. This is the "impatient planner" case. The optimal policy is then to intervene early and in support of the already leading standard.

This analysis ignores the issue of investment in technology improvement: the underlying assumption was that two technology designs are available and that the goal is to standardize on the optimal one. However, many (most?) situations present us with evolving technologies. The goal is then not only to select an appropriate technology but also to create incentives for investment in its improvement. If the potential for technology improvement is significant enough, then there may be benefits from delaying the standardization process.[49] The intuition, in broad strokes, is that early standardization may lead to a sort of "tragedy of the commons," whereby the key players have lower incentives to invest in technology improvement than they would if a standards war ware still being waged.

Practical Conclusion 7

- *If the life cycle of the innovative standard is expected to be relatively long and the potential for technology improvement is significant enough, favor a long experimentation phase by supporting lagging technologies.*
- *Otherwise, intervene early and in support of the already leading standard.*

4.2 Procurement, competition, and innovation

Procurement can be designed in such a way as to create more or less competition among potential suppliers. For example, contracts can be awarded through negotiations, beauty contests, or many different types of competitive mechanisms and tendering processes. The degree of competition

[49] See Cabral and Salant (2006).

induced by the chosen procurement design may affect suppliers' incentives to invest in R&D and innovate.

The relationship between the degree of competition in a market and the firms' incentive to innovate is a complex issue. Traditional economic analysis suggests that there exists a positive correlation between innovation and market power: tougher competition erodes the innovator's prospective monopoly rents, and is therefore detrimental to his incentives to invest in research for innovation.[50]

However, in oligopolistic industries the relation between competition and incentives to innovate is generally non monotone. Although diverse results have been found in the literature, based on different assumptions on the nature of technical progress (tournament or non-tournament) and on who conducts the research (incumbents or outside firms), two robust effects emerge. On the one hand, almost any definition of competition involves the idea that more intense competition reduces the equilibrium price, thus exerting downward pressure on the innovator's prospective rents and incentives to invest. On the other hand, in more highly competitive industries the technological leader has a larger market share, implying that competition tends to be good for innovation. The market share effect may or may not outweigh the negative effect of more intense competition on the equilibrium price.

To get a flavour of the subtle issues involved, consider one commonly accepted measure of the degree of competition, namely the number of incumbent firms. An increase in the number of competitors for a given total market size, will tend to[51]:

- Decrease price and individual firm output. This effect will tend to reduce R&D effort because a unit cost reduction will benefit a diminished output (size effect).

- Increase the amount of business a firm can steal from competitors through cost saving innovation (due to the elasticity effect). This increase competition effect will tend instead to increase R&D effort, because a unit reduction in costs will allow the firm to increase its output more than with weak competition.

The existence of opposing effects means that the overall impact of more intense competition on the incentive to innovate is generally ambiguous, perhaps making the relationship between the intensity

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[50] See the classical contributions of Schumpeter (1942). This argument is not uncontested though. See e.g. Arrow (1962).

[51] See e.g. Vives (2004). For a given total market size, competition - in terms of a larger number of competitors - affects the effective market of a firm, that is: its residual demand (a "level" or "size" effect) and the elasticity of the residual demand faced by the firm (an "elasticity" effect).

of competition and innovation non-monotone. Some recent studies find that the relationship between competition and innovation has, indeed, an inverted-U shape: ceteris paribus, the market share effect (whereby competition stimulates innovation) tends to dominate at lower levels of competition, whereas the "Schumpeterian" effect (competition erodes expected profits from the innovation hence the incentives to invest in R&D) tends to dominate at high levels of competition.[52]

When procurement can be designed to induce more or less competition among suppliers, in light of the discussion above, we can conclude that:

Practical Conclusion 8

- *If in the past procurement was not very competitive, fostering competition in procurement tends to increase suppliers' innovation.*
- *If procurement is already highly competitive, and the leading supplier has a strong advantage on followers, a further increase in competition may reduce suppliers' incentives to innovate.*

4.3 Procurement and the demand for innovative goods

The larger the market for an innovative good, the stronger the incentive to invest in it. Recent empirical research on the effect of market size on drug entry and pharmaceutical innovation clearly shows that there is a strong response in terms of emergence of innovative drugs to market size.[53] For example, only a handful of the 1,400 new drugs approved over the last forty years target so-called "tropical" diseases like malaria or tuberculosis, although such diseases are responsible for the death of millions of people every year. [54]

.By affecting the size of the market, procurement design can therefore significantly impact the development of innovative products. Centralized procurement of large bundled contracts for innovative products or services provide the prospect of a sufficiently large and certain demand to recover large investments in R&D. Moreover, the larger the demand a producer can satisfy with his innovation, the more intensively economies of scale can be exploited (this effect relates to the

[52] See for instance Aghion et al. (2005). However, consistently with Shumpeter (1942), Aiginger and Falk (2005) find that R&D intensity is higher where the competition is lower.

[53] Linn and Acemoglu (2004), for example, find that a 1% increase in potential market for a drug category leads to a 6% increase in the total number of drugs entering the US market; that a 1% increase in potential market size leads to approximately a 4% increase in the entry of new non-generic drugs; and that a 1% increase in potential market size is associated with a 4-6% increases in the entry of new molecular products.

[54] Kremer's proposal of creating a market for vaccines is based on the recognition that market size matters for innovation, and public policy can contribute to increasing the size of the market for innovative goods.

industry cost structure).[55] These effects suggest that split-award procurement contracts can be bad for innovation.

However, when the research contest is bundled with a procurement contract for the supply of the innovative good, a large bundled contract makes it harder for small firms to participate in the contest. This is unfortunate as ideas tend to be widely distributed among individual firms, and important innovations are often achieved by small and medium enterprises (SME) and start-ups. When SME conduct most of the research, large bundles make the participation of SME's in the research contest more difficult and so may in fact reduce overall innovation. Using large bundled contracts where the winner takes all, that is to say, gives large, mature incumbents a competitive advantage and makes entry by small innovative firms more difficult. In the long run, it may also induce excessive exit from the market. Apart from the effect on competition (dealt with in Chapter 7 and 17 of this volume), this may:

- Reduce the "diversity" of research paths thereby lowering the aggregate probability of success. A well-diversified research portfolio is important, as is also recognized by venture capitals who often finance several start-ups working on similar projects, in order to maintain high technological variety and improve their selection of the best one.[56]

- Reduce the competitive pressure on the incumbent(s), which may induce him to seat on the laurels of his past success, and cut the investments for future innovation.

- Increase the distance between the technological leader and the follower. This reduces "neck-and-neck" competition –which is bad for innovation, as both the laggard's reward to catching up with the technological leader and the latter's incentive to escape competition may fall.

These problems are exacerbated when firm size or experience are among the criteria of admission to procurement contests, as is often the case for a variety of reasons.

[55] This one of the reasons behind the European project of a common market.

[56] Venture capitalists typically finance pools of similar R&D-intensive projects precisely to maintain sufficient "technological diversity", being then careful to implement cross-fertilization of ideas transferring useful knowledge from one project to the other (See Gompers and Lerner, 1999). Analogously, Allen and Gale (1999) forcefully argue that the main advantage of a large stock market in terms of R&D project financing is the diversity of ideas among the many independent investors.

Licensing agreements can provide a solution to this problem. In principle, an innovator that does not participate in a procurement contest can nevertheless have an incentive to innovate if he can license the innovation to one or all of the participating firms. If the market for licenses was perfect, the incentive to innovate would be independent of procurement design. However, a variety of transaction costs impede licensing agreements. To begin with, innovative technological knowledge can be difficult to codify and transmit to others. In addition, royalty licensing is possible only if the output is verifiable; when individual output is not verifiable, only fixed-fee licensing is feasible, but fixed-fee licensing is profitable only if the size of innovations is sufficiently small. Moreover, incomplete information over the size of the innovation can lead parties to introduce inefficient terms in the licensing agreement. These transaction costs may likely result in an equilibrium outcome in which licensing does not allow the innovator to appropriate the value of his innovation fully. In these circumstances, procurement design matters.

When licensing agreements are difficult to reach, the sonsor may therefore want to split supply in smaller lots in order to allow small innovative firms to participate, even if this may dilute the incentive to innovate. The same outcome can be achieved through co-sourcing, dual-sourcing etc. Also, the procurer may want to delay the selection of the winner to preserve diversity and maintain firms in a neck-to-neck competitive situation.

Another strategy that has been adopted to increase the share of R&D government contracts awarded to SMEs consists in reserving for them a part of these contracts. In 2001, for instance, the English Department of Trade and Industry launched a programme called Small Business Research Initiative (SBRI). The objective of the programme was to purchase at least 2.5% of their R&D from SMEs by 2004/5. Up to know over 230 companies have registered and received information about contracts suited to their capabilities.

However, this strategy reduces the size of the market captured by the winner, and therefore dilutes the incentives to innovate. The trade-off is therefore between admitting small innovative firm participation, having more than one contractors and technology variety in use, and enhanced competition, all of which may require multiple smaller lots; and the lower the economies of scale exploited, and larger cost duplication incurred with small lots, which push to bundle supply (since production is or may be split among more firms).

The optimal size of supply contracts and number of contractors selected are therefore difficult to choose, as they depend on several economic variables which are hard to estimate (see Chapter 7). Given our limited knowledge of the strength of the various forces at play, one way out is to let competing firms endogenously determine the optimal demand size. This can be achieved by splitting competitive procurements in many small lots, but allowing for "package bidding." Package bidding means that bidders can condition their bids on the number, and possibly the type, of the lots awarded (Chapter 8 offers an overview of package bidding in procurement). The small size of lots allow small and perhaps more innovative firms to participate in the contest, but large suppliers can exploit economies of scale in R&D and production if these are substantial. Again, competitive tendering is an informatively parsimonious mechanism in that it allows the procurer to rely on the information held by suppliers to achieve the efficient solution.

Practical Conclusion 9

When procuring innovation, if the relative importance of having small diverse innovators versus exploiting scale economies in R&D is not clear, unbundle total supply in more and smaller lots, and allow for package bidding.

4.4 Other procurement practices that stimulate innovation

So far, we have discussed how to stimulate innovation and R&D through different procurement tools. In this paragraph we describe some procurement initiatives promoted by governments or purchasing agencies in order to stimulate innovation. Procurement experiences and best practices taken into consideration show that some of the most important European and American centralised procurement units share common guidelines in order to promote innovation and stimulate suppliers in investing in R&D.

4.4.1 Involvement of suppliers in the procurement process

Suppliers have sometimes been involved at the beginning of the procurement process in order to facilitate creativity through the interaction between tendering designers and suppliers, to define shape requirements, provide feedback on feasibility and affordability, and gear them up to be able to respond to future procurements.[57] The UK Department of Trade and Industry) (DTI) has applied this practice in the construction industry. The DTI and the National Health Service (NHS) have implemented the ProCure21, a healthcare facilities construction project. The objective of ProCure21 is to encourage a long-run cooperation between procurer and constructors in order to match users' needs. The programme aims at improving quality and safety, reducing costs and delivery date.

The new EU Directive (2004) on the procurement of good and services introduces a new procurement procedure called "competitive dialogue", to be used for public contracts considered "particularly complex". Thanks to this procedure the public authority can dialogue with pre-qualified tenderers for setting up « the » solution (which can be a combination of solutions). The aim of the dialogue shall be to identify and define the means best suited to satisfying the Authority needs. They may discuss all aspects of the contract with the chosen candidates during this dialogue. Contracting authorities may not reveal to the other participants solutions proposed or other confidential information communicated by a candidate participating in the dialogue without his/her agreement. Finally, there is a tendering process limited to at least three participants without further negotiation based on the requirements issued from the dialogue

4.4.2 Requesting "functionalities" rather than pre-specified solutions

Output or outcome specifications should be well-constructed in order to stimulate suppliers in proposing innovative solutions. A well-defined outcome can go a long way towards challenging suppliers to generate ideas. A well-constructed output specification identifies the outputs from, rather than the inputs to, a requirement. An outcome specification takes this one step further and only specifies the end result to be achieved. It is equivalent to specifying the problem and inviting proposed solutions.

In allowing suppliers freedom to submit innovative bids, procurers should specify compliance with standards where appropriate, for example to ensure compatibility[58]. In order to stimulate innovative solutions (process, integration, production, or delivery), requirements as well as evaluation criteria have to be based on a set of functionalities that the contractor must provide, regardless of the technology used to implement them (making intelligent use of standards).

Of course a good management of the tendering process must ensure suppliers sufficient time and opportunity to develop innovative proposals. Often, tenders have to be submitted in a very short

[57] See EU Expert Group (2005).

[58] The experience of Consip shows that even the procurement of mature technological products may promote firms' investments in R&D. See also EU Expert Group (2005).

time, and this does not allow suppliers to find innovative solutions. The duration of the procurement process should be fine-tuned with the role played by innovative solutions.

5 Other effects of large buyers on innovation

When the amount of innovative goods needed by a big procurer is large, as in the case of repeated government procurement or big firms' procurement, it can have important indirect effects on the markets of the inputs needed for the R&D activities: it can impact the wages of scientists and technicians as well as other specialized knowledge workers, and, by inducing intersector reallocations of labour and changes in the educational choices of young students, it can affect the flow of new skilled workers in the district, industry, or economy at large. In this Section we draw on theoretical and empirical analyses on innovation and growth to derive practical recommendations with a more macroscopic and long term vision than in most of the chapter. There are several similarities between the larger buyers in the economy, and the distinction between "public" and "private" is often semantics. Though, in order to facilitate the reader, we will keep the corresponding practical conclusions formally separated in two different sections – 5.1 on public procurement and 5.2 on private procurement.[59]

5.1 Public Procurement and Innovation

Firms invest in R&D and innovation as long as it is profitable to do it. Given the probability of innovating per unit R&D investment and the cost of the R&D inputs, the expected value of such profits are the main driving forces of innovative activity. Since government expenditure can affect profits in a massive way, it has the potential to indirectly affect the total amount of private R&D expenditure at the macroeconomic level as well as its direction by merely changing the amount of public procurement and the sectors in which it is directed.

In some cases, the innovative sectors can easily raise capital from private investors (stock markets, banks, venture capitalists, etc.) to finance R&D expenditure. In other cases, firms find it difficult to get money from external sources and need to rely on internally generated funds (cash flows). To evaluate the effect of public procurement on R&D it is important to distinguish between these two

[59] Those interested in t\he efficient management of big firm procurement will find it useful, after glancing section 6.2, to read section 6.1 for a better understanding of the logic underlying the practical conclusions appearing in section 6.2.

cases: financially unconstrained and financially constrained R&D firms. In industries where innovative firms are severely financially constrained, R&D investments may not respond positively to the incentive of higher future profits, because of the difficulty in increasing internal funds, though of course they will negatively react to the expectation of lower future profits. Instead, their R&D normally reacts positively to an increase in current profits, because it immediately allows more internally generated funding.

Conversely, in industries where innovative firms are not financially constrained, R&D investments will respond positively to the prospect of higher future profits, because they do not need to increase internal funds, and they will negatively react to the expectation of lower future profits. Instead, their R&D normally does not react at all to an increase in current profits.

Notice that, by increasing current profits through public procurement, the government would support the innovative activity of the firms ("incumbents") that are already manufacturing the current version of the good, and therefore the firms that are least interested in inventing a better version of it. While the incumbents are less motivated to cannibalize their products, the pure R&D firms ("outsiders") are the most interested in investing in drastic improvements of the existing products. However, in the presence of credit market imperfection, little can be done to help outsiders enter the market through public procurement.

Since the aggregation of public expenditure often impacts a relevant size of the market for the innovative goods, it can have a big impact on the profits of the innovative firms. Since profits are the main signal for R&D expenditure, public procurement indirectly affects the demand for R&D inputs, such as the highly skilled workers. Therefore, it may be the case that an increase in profits, by raising the demand for the R&D inputs, has an immediate major impact of the R&D input prices, while leaving R&D employment almost unchanged. This happens because increasing the supply of skilled workers takes time: years of college education and of on the job learning, months of re-training by skilled workers specialized in different sectors, etc. Hence the supply of R&D workers is not elastic, if there are few unemployed skilled workers in the same sector or if it is difficult to attract skilled workers from other sectors, as often happens during economic booms. In such cases, it may not pay to try to stimulate R&D through procurement, unless the government accept the initially higher wages as a signal for the production of future R&D inputs, for example by incentivating the educational choices of future cohorts of college students.

We can summarize the discussion so far:

Practical conclusion 10

- *To stimulate R&D and innovation in financially constrained sectors the government should increase the current cash flows of innovative firms, by buying more at higher prices.*
- *To stimulate R&D and innovation in sectors that easily raise external capital the government should commit to a policy that increases innovative firms' future expected profits. For example, by promising to buy future innovative goods more and at higher prices.*
- *Government expenditure should increase expected profits in sectors in which the supply of the R&D inputs is more elastic and reduce them where they are less elastic.*
- *Public procurement should increase expected profits in innovative sectors during recessions or, more generally, when there is excess capacity of R&D inputs (e.g. human capital).*

In many cases, the ability of buyers to understand what new product is best for her is limited and the information about product qualities tends to disseminate too slowly. The decision by firms to invest in innovative activities becomes less motivated in markets in which the buyers do not respond quickly to the introduction of new goods, but instead keep demanding obsolete products for a while, due to habits, brand loyalty and imperfect knowledge. Besides aggregating demand, public procurement can also aggregate the search efforts of several single buyers, thereby allowing them to save on unit search costs and to promptly single out the best available products. More responsive public demand rewards the firms who innovate more and immediately penalizes laggards, thereby inducing more R&D effort. Such a policy would stimulate perpetual innovative efforts by firms in order to win future profitable opportunities and not to lose current profits.

It is often the case that, with sequential innovation, in some sectors the opportunities to innovate are becoming lower and lower. In fact, R&D difficulty tends to increase as a result of the previous innovative efforts by firms: the easiest ideas are normally invented first, and there is a progressive fishing-out of the remaining good ideas in some of the mature sectors. Despite more costly future innovations, firms may feel encouraged to invest in R&D anyway by the expectation that in case of success their next innovation would be subject to lower obsolescence. As a consequence, being the private firm's time horizon quite limited, the private R&D investment decisions fails to account for the increased complexity of future R&D generated by their current R&D. Therefore, it may be better to discourage R&D in those sectors and to stimulate the reallocation of R&D inputs into other more promising sectors in which complexity is increasing less intensely. Hence, we have reached the following:

Practical conclusion 11

- *Government procurement should make prices and quantities demanded responsive to quality ranking modifications: top quality products should be guaranteed immediate profits whereas for obsolete goods the public buyer should bargain for very competitive (zero profit) prices.*
- *Government expenditure should reduce expected profits in sectors in which the future innovative prospects are low and re-direct R&D towards the more technologically under-exploited sectors.*

5.2 Large Firms

In several industries there are big firms endowed with some degree of monopsonistic power viz-a-viz a large number of small potentially innovative suppliers. Each big firm may be interested in spurring the innovative activity of its suppliers as well as in inducing the acquisition of specialized skills by new workers entering their sector. Viewed in this light, as big procurers, they share some similarity with governments in national and international environments. They share with governments a good bargaining power in the procurement of its inputs, a macroscopic vision of their whole industry, and intertemporal considerations. With this in mind, the large firm might develop a reputation to use its bargaining power selectively in order to stimulate innovation by the multitude of its exclusive suppliers as well as to encourage the continual renovation and extension of the supply of human capital to its innovative suppliers.

Therefore the previous practical conclusions can easily be re-interpreted in this context, by replacing the words "government" with "big firms" and other obvious modifications. For example, big firms should try not to use their bargaining power to slash the profits of financially constrained but potentially innovative suppliers: this would depress their formal and informal R&D expenditures and therefore restrict their future opportunities to acquire highly innovative inputs (components, research tools, etc.) from their exclusive suppliers, thereby weakening the future competitive advantage of the big firms themselves and compromising their primacy.

Similarly, during recessions big firms should commit to buy more generously high technology inputs, because current R&D expenditure by potentially innovative suppliers would increase in real terms and not only get inflated by higher costs. Notice that, with efficient capital markets – in which suppliers are not financially constrained - such counter-cyclical commitment does not necessarily imply counter-cyclical expenditure: it is very likely that by the time the innovative inputs are finally introduced the economy would be recovering from the recession, if not booming, with excellent results for the big firm that encourage its exclusive suppliers' R&D.

Hence we can conclude that:

Practical conclusion .12

- *To stimulate R&D and innovation in financially constrained input sectors a big firm should safeguard the current cash flows of its innovative suppliers, by accepting buying more at generous prices.*
- *To stimulate R&D and innovation in sectors that easily raise external capital the large firm should commit to a policy that increases innovative firms' future expected profits. For example, by promising to buy future innovative goods more and at higher prices.*
- *Large firm's procurement should increase expected profits in the input sectors in which the supply of the R&D inputs is more elastic and reduce them where they are less elastic.*
- *Large firm's procurement should increase expected profits in innovative sectors during recessions or, more generally, when there is enough excess capacity of R&D inputs (e.g. human capital).*

Also, the large firms should react promptly to quality improvements in their input markets, by penalizing laggard suppliers to the advantage of the most innovative ones. However, in this case, the buyer should also be concerned with the survival – or at least the prompt potential entry - of enough supplier R&D firms, in order not to get captured by a too small number of exclusive suppliers.

Finally, large firms should not only monitor the quality of the existing inputs in order to buy the best ones at generous enough prices, but they should also consider the innovative prospects of each category of inputs. If for some inputs further innovation is becoming increasingly difficult at an abnormal pace, the firm should reconsider its input-output mix in order to try to spur its exclusive suppliers' investment in more easily improvable input categories.

To summarize:

Practical conclusion 13

- *Large firm's procurement should make prices and quantities demanded responsive to quality ranking modifications: top quality suppliers should be guaranteed immediate profits whereas for obsolete goods the big buyer should bargain for very competitive (zero profit) prices.*
- *Large firm's procurement should reduce expected profits in sectors in which the future innovative prospects are low and re-direct R&D towards the more technologically under-exploited sectors.*

6. Innovation and Risk Management in Procurement

As discussed in detail in Chapter 13, risk management is an important component of successful procurement. The supply chain may break down if a contractor interrupts supply, say, because he is in financial troubles, hence – in normal situations – good procurement should select more reliable suppliers/offers and screen out more unreliable/risky ones.

When stimulating innovative activity is a concern, management of procurement risk remains important, but must be implemented rather differently. In particular, there are three policy issues. First, because the probability of failure is higher and much harder to evaluate for more innovative projects, to stimulate innovation more risk must be taken. There is, therefore, a trade-off between innovation and the risk of selecting bad suppliers: more innovation against less safe procurement. In addition, the risk management techniques discussed in Chapter 13 may have to be adapted to cope with the need of providing incentives for innovative activity.

Second, the uncertainty surrounding innovative activity may be resolved only at late stages in a multi-stage research contest. This means that there is a trade-off between selecting the winner at an early stage to save research costs and waiting for more uncertainty to be resolved, much as discussed in Section 19.4 for standard setting activity.

Third, the market may be biased in favour or against risky research projects. Because of the "winner-takes-all" nature of innovation races, the market may induce a research strategy that is too risky from the social point of view. In the procurement context, this means that contestants may choose research strategies that are more risky than those preferred by the buyer.

Among the instruments used for managing risky bids in public procurement, discussed in more detail in Chapter 13, there are screening “Abnormally Low Offers”, screening firms’ financial health, and choosing “less competitive” scoring rules to leave more resources to contractors and reduce the risk of cost overruns, bankruptcy, etc. Let us discus them in turn.

6.1 Handling “Abnormally Low Offers” (ALO)

A bidder that offers a price below a certain cut off level, a percentage of the average offered price, may be asked to prove that the bid is not unrealistic. For example, in many European countries information are requested when the offer is below the 10-15% of the arithmetical average of offered prices.[60] However, when procuring highly innovative products, it is easier to receive highly heterogeneous offers, and the most effective innovations are likely those that offer the desired outcome at the lowest cost. It may be hard though to demonstrate how innovative, never implemented technologies are likely to deliver the estimated low cost. For this reason, a more innovative and competitive offer is more likely to be considered ALO. Hence, screening out ALO, i.e. not awarding procurement contracts to the lowest priced offer, might screen out precisely the more innovative (and risky) firms!

6.2 Scoring Rules

In order to soften competition on price, which may aggravate indebted contractors’ likelihood of going bankrupt, scoring rules are sometimes adopted that do not reward contracts to the best offer –

[60] In Italy details relating to components of the tender that are determined to be significant are requested when an offer presents a discount lower than 20% of the arithmetical mean of the all discounts considered valid (Art. 25, D. Lgs. 157/95). BESCHA (the German Federal Procurement Agency) follows a rule of thumb that a more than 20% deviation from the second best price triggers an explanation of the price made from the first bidder. The Turkish Public Procurement Authority requires explanations about an offer when it is below of a certain complex value called “Boundary value” (an offer is considered abnormally low if the offer is below of a defined Boundary value obtained multiplying a certain value “K” by the “Estimated cost” of the contract. To have the “K” value, the procurement agency calculates the ratio between the arithmetical mean of the tenders (tenders 120% above or 40% below of the “estimated cost” are not taken into account) and the “Estimated cost”. To any value of this ratio between 1.2 and 0.4 there is a correspondent “K” value.

but to offers closer to the average. For example, among the scoring rules applied around the world are:

- The winning offer is the closest to the arithmetic average of all submitted offers.
- The winning offer is the closest to the average among those below the average.

Again, these methods incorporate a potential bias against innovation, apart from increasing the cost of procurement. Not to award contracts to the lowest priced offer might screen out precisely the more innovative (and risky) firms! The first type, this “Average Price Competitive Procurement” is obviously the worst one: it eliminates all competition since each participant chooses its offer to be closer to the expected average. The winner is practically randomly selected. This is the opposite of what competitive procurement is constructed for: discriminating among efficient and inefficient suppliers. The second type is a bit “less bad”, but the interdependence among bids opens the door to incorrect bidding and possible manipulations (see Chapters 12 and 13 about the drawbacks of these scoring rules).

6.3 Screening Suppliers through Insurance Schemes

The best way to avoid unsustainable offers, according to Chapter 13, is to use insurance schemes that screen suppliers, discriminating among firms depending on their financial condition and ability to perform the project. Two are the main instruments usually applied to face this problem:

- Surety bonds: The winning contractors must have a surety bond to proceed with supply, but she can acquire it after winning the competitive procurement. If the contractor defaults, the surety firm has then to complete the project or cover the costs of finding another supplier. Surety firms screen bidders and projects, and the premium to the surety firm increases with risk. More risky firms expect to pay a higher fee for the surety bond, and will bid less aggressively, winning less often.
- Letters of credits: Contractors are admitted to bid for a procurement if guaranteed by a bank’s letter of credit. If the contractor defaults the bank pledges an asset. Letters of credit

exclude bidders with a very bad financial status but makes others more susceptible to bankruptcy[61].

Both instruments have the property that they could prevent the most risky but innovative firms to participate, or substantially reduce their chance to win. If the primary object of the procurement is innovation, it is essential not to discriminate too much *a priori* against firms presenting innovative and risky projects. Procurers have other, better tools to increase the likelihood to awarding the contract to innovative contractors or projects, while achieving some protection from risk. In particular, we suggest multi-sourcing, and a modified version of surety bonds without screening.

- Multi-sourcing: having several suppliers active in parallel and in back up reduces the risk of interruption of supply. Moreover, since ranking innovative products is typically very difficult in the beginning, by admitting more than one substitute innovation to be implemented prolongs the "testing" period, delaying the final judgement on which among the substitute innovation is better, and therefore allowing the selection of the best innovation more often. Among the costs of this solution are the usual ones of multi-sourcing: reduced scale economies, fixed costs duplication, etc. (See chapters 7 and 13 for more on this)

- Surety bonds paid by the procurer: to reduce the risk of procurement but take the risk of selecting innovative firms, the price of the winning firm's surety bond could be paid by the procurer. This allows the procurer to be insured against non-performing contractors, but not to screen out the most risky and innovative ones.

Practical conclusion 19.14

When innovation is a priority both multi-sourcing and surety bonds paid by the procurer may be useful tools to increase the likelihood to awarding the contract to innovative contractors or projects, while achieving some protection from risk.

[61] For more details about Surety bonds and Letters of credit see Chapter 13.

Because innovation is typically a very risky activity, managing risk is somewhat the opposite of innovating, of undertaking risky innovative activities. A final, obvious alternative when innovation is the main concern is of course that the procurer chooses not to manage risky bids. The procurer can just bear the risk that a contractor goes bankrupt. This alternative can be appealing particularly if the procurer is the government, a highly diversified procurer that is usually able to bear risk at low cost. Of course this strategy involves costs, but being the largest institution in a country, the government is clearly the most differentiated, hence the most able to pool risks from different activities; and the remaining costs may well be balanced by the benefits of more innovation.

19.7. Conclusion

In this chapter we have offered to firms and public agencies a number of practical suggestions on how to best manage the procurement of innovative goods, and how to use procurement to foster innovation. The uncertainty surrounding the innovative activity, and the dynamic perspective that it necessarily involves, make the procurement of innovation one of the most difficult issues in the theory and practice of procurement. The reader will have noticed that the strengths and weaknesses of each tool that could be used to procure innovative inputs depend on a number of variables. In real life, each procurer must take inevitably complex decisions, and we can only warn the reader that it is his or her own responsibility to mix the different ingredients we laid down on the table wisely. For example, the procurer’s assessment of his or her ability to describe an innovative input in advance, may tilt his or her preferences toward ex-ante prizes or ex-post prizes.

The range of potential applications of this chapter’s suggestions is large, encompassing small and large lots, private and public procurers, symmetric and asymmetric procurer-supplier relationships and different degrees of competition and risk. We stress that real world procurement often involves a blend of the stylised hypotheses we made in the text, and so the procurer needs to resort to a mixture of our recipes. Any mechanical and non-critical application of our practical suggestions may lead to errors. Our guidelines are intended for astute and responsible readers, to whom they can give inspiration and hints for reflection. However, the optimal choice is up to the procurer to make, and guessing correctly is more of an active artwork than of a passive technique.

Bibliographical Notes

An excellent, up-to-date and accessible source covering many of the themes treated in this chapter and providing references for further more technical analyses is Scotchmer (2004). For more on the role of public policy in standard setting battles see the forthcoming book edited by Greenstein and Stango (*forthcoming*). Branscomb and Florida (1998) and Hart (1998) offer interesting discussions of several technology policy issues related to this chapter from a US perspective. General reflections on practical procurement policies to foster innovation can be found in the EU Experts Group (2005) and in Maurer and Scotchmer (2004).

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