white paper

An Economist's Vision of the B-to-B Marketplace

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by **Paul Milgrom, PhD**

Paul Milgrom is a distinguished Professor of Economics at Stanford and Harvard, a world-renowned expert in auction dynamics, and Chief Economist of Perfect. Paul is the co-inventor of both Perfect's technology, and the simultaneous ascending auction, variations of which have been used to sell over $100 billion of radio spectrum rights around the world over the last decade.

PREFACE

"Dynamic pricing!" "Network effects!" "Empowering the buyer!" "Content, commerce and community!" The jargon and hype of Internet marketplaces, like fragments of a shattered mirror, reflect shards of truth, but they also obscure the bigger and more fundamental truth: buyers and sellers flock to Internet markets only when those markets add value and share it among participants. In this short essay, I apply elementary economics and my studies of other markets to debunk the hype of the new "e-conomics," to glue the shards back into their frame, and to use the assembled mirror to reflect on how Net markets can create sustainable, profitable businesses that attract buyers and sellers by adding value for both.

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GETTING PAST THE HYPE

At the present stage in the development of B2B markets, with few actual e-markets running at substantial volumes, there is little experience to use in identifying the key ingredients of success. Journalists, analysts, and commentators of all stripes, hungry for something to say, ignore lessons gleaned from physical markets and instead turn to generalizations based on this limited experience. Technological visions of what can be done are promoted as panaceas, preempting consideration of what should be done. Net markets (including private exchanges and consortia exchanges like Covisint), eager for guidance, jump too quickly on ill-conceived bandwagons and divert money, energy, and attention from the real keys to their success.

"DYNAMIC" PRICING

Take, for example, "dynamic pricing," which is just a fancy name for auctions of various kinds. The "reverse auction," which refers to an auction among suppliers initiated by a buyer, is a particularly popular version. According to its most enthusiastic advocates, dynamic pricing improves efficiency and empowers buyers in an endless range of markets.

In fact, the usefulness of dynamic pricing depends on characteristics of the market. When auctions improve efficiency, they usually do so in one of two ways.

First, auctions enable participants to discover appropriate prices for unique or rare items quickly and at low cost. eBay, like traditional auction houses, provides numerous examples of that kind.

Second, dynamic pricing may allow markets to respond more quickly to changes in supply and demand. Electrical power markets are an important example. In much of the United States, when summer temperatures rise, the demand for power rises with them, as millions of air conditioners consume vast amounts of power. The power demanded varies hourly over the day and daily over the year. There can also be sharp changes in supply, as when a major generating plant is taken down for servicing. The electrical generation system needs to adjust quickly to these changes as they occur, and prices in power markets provide one way of making that adjustment.

Electrical power is an especially illuminating example because it has the two characteristics that maximize the usefulness of simple dynamic pricing. Electricity is a *highly perishable* and *mostly undifferentiated* commodity. Both of these attributes require their qualifying adverbs. Electrical power is not completely perishable; it can sometimes be stored, for example, by using excess power to pump water into a reservoir above a hydroelectric generating plant. Nor is power completely undifferentiated. Power at the source can be distinguished in terms of the reliability of the generator or the guaranteed availability of transmission capacity. If electricity were completely perishable and undifferentiated, auctions would provide a near-perfect way to set prices that are quickly responsive to changing conditions. In the real world, there are limits on the value of auctions, even for electricity.

Even for goods that are hard to store, price-only auctions are of little value if the goods, or their suppliers, have widely varying characteristics, because the buyer will not normally buy based on a comparison of prices alone.

The example of electrical power demonstrates that both the value and limits of dynamic pricing are dependent on the character of the market. The capacity to set prices in response to changing supply and demand conditions is less important for goods that are easier to store. For that very reason, dynamic pricing is seldom used for standard manufactured goods that are neither perishable nor costly to hold in inventory. In both physical and online markets, manufactured goods are mostly priced using catalogs. Even for goods that are hard to store, price-only auctions are of little value if the goods, or their suppliers, have widely varying characteristics, because the buyer will not normally buy based on a comparison of prices alone. Nothing about the technology of the Internet changes the market-dependent character of dynamic pricing.

Another claimed feature of dynamic pricing methods—particularly reverse auctions—is that they empower the buyer by forcing suppliers to compete for the buyer's valuable business. Actually, these low, buyer-empowering prices result from a temporary state of excess supply.

Electronic markets can improve efficiency and release capacity for other uses. When they do so, more efficient supply chains may create a temporary condition of excess supply, resulting in temporarily lower prices. This excess supply that arises when auctions are used is also present when prices come from catalogs, without any use of auctions. Regardless of the technology of pricing, as time passes, excess capacity will be eliminated. Once that happens, if the auction rules do promote lower prices than those determined by supply and demand, then suppliers simply won't participate. Without excess capacity in their industry, they don't need to participate to make sales, because they can sell even undifferentiated output for a competitive price at some other market site. If sellers have differentiated products, services, and other offerings, then price-only auctions will usually be unattractive to buyers as well, because the auction winner will typically be the lowest-cost and possibly lowest-quality supplier. Higher quality sellers will simply decline to participate.

Reverse auctions and buyer empowerment are not startling innovations, but classical economic phenomena that have limited use in most B-to-B markets.

NETWORK EFFECTS

"Network effects" is another phenomenon that commentators have tried to claim as characteristic of the Internet. The idea is that by creating a large network of buyers and sellers, a Net market occupies a special position that allows it to fend off competitors. Buyers prefer to shop in the existing market, rather than in one set up by a newer competitor, because the newcomer can't match the selection of the established market. Sellers will similarly want to sell where the volume of buyers is high. The "chicken and egg" problem that faces newcomers is said to give the first marketplace a sustainable advantage. eBay is usually offered as a leading example of this logic.

There is little doubt that auctioneers like eBay benefit from network effects. Indeed, the same effects have helped protect auctioneers in the physical world from competition—consider the dominance of Sothebys and Christys in auctions of fine art and jewelry. Interestingly, these two auction houses coordinate the timing of their sales in various categories—say, 20th century American artists—so that their sales occur at the same physical locations on consecutive days. That way, buyers may shop at both auction houses on one trip, reducing transaction costs and reinforcing the network effect. Other beneficiaries of network effects include Fasig-Tipton and Keeneland, the dominant auctioneers of thoroughbred racehorses. In these markets, discerning buyers who want only the finest specimens flock to these particular auction sites because only there can they find what they want. Sellers almost unanimously choose to offer their finest and rarest items—whether art, jewelry, or thoroughbreds—through the premier auctioneers because that is where the buyers come.

Likewise in the online world: if you want precisely one Beanie Baby and find one for sale at eBay, you will not simultaneously bid at Yahoo! Auction. The logic of network effects applies to sales of rare and special goods wherever they occur. More generally, it applies when participants find it most economical to participate in just one market at a time for each kind of good. It is not a new phenomenon inspired by the growth of the Internet.

For manufactured products especially, but also for many other non-unique goods, sellers may offer their wares in several markets simultaneously and buyers may search in several markets, both incurring little or no extra cost. This is especially so for electronic markets, in which search across multiple markets is only becoming easier. Even with older web technologies, the next market is just a mouse click away. Software agents and inter-operating trading technologies can reduce the distance to less than a click by allowing buyers to search through many markets as easily as through any single one.

Rather than network effects, it is “switching costs” that will most often limit buyers and sellers to a small number of B-to-B markets. When users need to invest in learning the market protocols or integrating their software and systems with those of the Net market and updating them to keep pace with their growing functionality, the users will be motivated to integrate most closely with just a few systems. Of course, these investments by users must be worthwhile: they must involve system innovations that add value for them. Only by continuing to add value can Net markets motivate customers to keep their investments localized. Network effects, even where they are available, will not protect markets that fall behind in the race to add value!

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THE THREE C’S: CONTENT, COMMERCE AND COMMUNITY

Yet another part of the fragmented wisdom of the new e-conomics is that Net markets win by providing content, commerce and community. Advocates argue that once buyers are regularly present at a Net market site, reading about recent industry developments and getting the information they need to make a transaction, they will execute the transaction right there!

If only it were so...

The “high-quality-services-leads-inevitably-to-sales” myth has been repeatedly disproved in the physical world. The advent of discount stock brokerages, resulting from deregulation of commissions, provides a case in point. The full-service, high-commission brokers used to provide research to customers for free; indeed, such services were how they competed for customers. Once commission rates were deregulated, many customers were delighted to accept the free information provided by full-service brokers and then to do most of their trading with the discount brokers. Similarly, discount department stores found that they could attract consumers who got their fashion information for free from high-service stores.

The same pattern will inevitably be found on the Internet: procurement managers will not countenance having buyers pay more or transact less efficiently at a non-preferred site just because the site has news and free information. Buyers will be told: “Read and learn at those places if you like, but make purchases only at our preferred market sites.” Unless the free services and transactions are tightly integrated, so that it is much easier to make transactions at a site where the free services are supplied, Net market makers will find it difficult to recover the cost of the free services they provide from the transactions they host.

THE ENDURING PRINCIPLE: "ADD VALUE AND CAPTURE PART OF IT!"

The way for market makers to build share and earn profits is not to add fancy services of little real value, but to add and charge for valuable new services.

Adding value starts with the fundamental observation that users come to electronic markets primarily because they promise enormous savings in transaction costs and significant improvements in information and control. The numbers one sees vary enormously: 50%, 75%, even 90% reductions in time and cost from moving transactions away from paper-based processes and toward the automated, paperless transactions of the Internet. Automated transactions lead to more flexible reporting, fewer coding errors, and better management control.

It is these indisputable advantages of electronic markets that most strongly attract users and allow the markets to grow. A successful Net market maker cannot succeed without focusing first on these primary drivers of value, but competition among market makers ensures that most can't earn profits from this alone. As in other businesses, most successful Net market makers will distinguish themselves either by high volume and low costs or by offering services that others cannot easily copy.

To be consistently profitable, Net markets need to be innovative, finding ways to add new sources of value and charge for them. In the near term, that requires that Net markets anticipate and prepare to deliver the new services that will come into demand immediately after automation of the simplest procurement transactions. Perfect's technology has been devised with that need in mind. It is a technology based on our careful economic analysis of how falling transaction costs will affect the way transactions are done, what technology is needed to support the new transactions, how real buyers and sellers interact off-line, and how technology can reduce the cost and increase the speed and accuracy of that interaction.

ANALYZING NEAR-TERM NEEDS

The economic analysis begins with the simple observation that the secret of how users will want to buy and sell when transaction costs are low for all purchases is revealed by their current behavior in large purchases. The reason is simple: the transaction cost for today's physical procurement procedures are lowest relative to value when the value of the transaction is largest. Consequently, these transactions provide a clear view of what buyers will want to do as the costs of conducting smaller transactions continue to fall.

The RFQ process creates value by first promoting a better match between buyers and sellers and then by helping tailor the non-price aspects of the transaction to the buyer's needs and the seller's capabilities.

The next analytical step is to note that the largest, most valuable transactions are usually managed using various forms of written requests: requests for quotes, for bids, or for proposals. We lump these all here into the single category that we call "RFQs." The physical-world process of soliciting and evaluating RFQs is a highly flexible one. It allows the buyer to express its needs and priorities and the supplier to offer customized solutions to satisfy those needs. Buyers like the process because it allows them to focus on articulating their needs, without having to guess exactly which configuration from which seller best serves those needs, and because it allows them to evaluate customized offers on the whole range of relevant product, supplier, and deal characteristics concurrently—not just price. Sellers like it too because most sellers prefer not to compete based on price alone. They prefer to compete based on their individual strengths and competencies: quality, service, delivery, or features. The RFQ process creates value by first promoting a better match between buyers and sellers and then by helping tailor the non-price aspects of the transaction to the buyer's needs and the seller's capabilities. It is for this reason that the patent-pending Perfect Market technology, unlike the technology of any of our competitors, features true multidimensional custom offers in response to complex, weighted, concurrent, multidimensional RFQs.

RFQs of more limited kinds are already used by certain search engines, as well as by Net markets that employ a bulletin board or post-and-reply technology. One approach entails building an interface that allows buyers who know exactly what they want to conduct tightly focused searches. For example, a personal computer buyer might specify a type (desktop or laptop), a processor type and speed, an amount of memory, the size of a hard drive, and so on. The system then searches one or more catalogues and reports price and availability based on the prescribed set of characteristics. The most flexible of such systems includes keyword searches. Even though some technology suppliers have called this “multidimensional” or “multi-attribute”, it is does not involve any customization of offers. Without the exchange of information about buyer preferences and seller capabilities, real customization of the kind that emerges in the physical world from discussions between buyers and suppliers remains impossible. Unlike Perfect’s technology, keyword-matching technologies can’t even come close to replicating the customization advantages of the human buying and selling experience.

Some bulletin boards offer a more flexible form of RFQ—one that allows the supplier to propose solutions that accord with the buyer’s needs without being hamstrung by a set of specifications that is more specific than required for the buyer’s intended use. However, without the right supporting technology, the very flexibility of bulletin boards makes them expensive to use, because there is so much for human agents of the buyers and suppliers to do. First, the buyer needs to create a posting that informs potential suppliers about its needs, but avoids specifying so many details of the final transaction that the suppliers cannot respond flexibly. Next, to respond effectively, the suppliers need to understand and evaluate the buyer’s needs and tailor an offering to those needs. Finally, the buyer faces the daunting task of evaluating responses that may differ in many dimensions, including price, features, delivery, quality, and service.

To make the market scalable, sellers need to automate at least part of their response to the postings. The simplest way to achieve that is to filter the requests automatically, so that sellers receive only RFQs that they are well qualified to bid upon.

Complex RFQ processes like these are traditionally used only for major purchases, because the labor costs they entail are so high. Moreover, because the process of bidding and evaluating such bids is not routine, the path to automating these processes is far from obvious. For Perfect, the automation challenge was threefold. First was the need to develop a technology that made the whole RFQ process inexpensive, flexible, scalable, and quick-and-easy-to-use. Second was the need for the technology to incorporate a natural upgrade path, so that sellers initially could create simple automated rules that reduce their processing costs immediately, before they are asked to entrust complex decisions to a highly automated system. As users gain experience and come to trust the system, we reasoned, their initial steps need to serve as a basis upon which to build more sophisticated procedures that can add even more value. Third, in order to pay for itself, the system needed to enable new revenue sources for the Net markets employing it.

A NEAR-PERFECT SOLUTION!

To see how Perfect's solution achieved these goals, let us start with traditional bulletin board markets. In the first generation of these markets, every posted request was forwarded by e-mail to every seller, who evaluated the requests manually. Markets designed in this way are self-limiting. As the volume of transactions on the market grows, so, too, do the demands placed on suppliers, trying to respond to a swelling sea of RFQs. To make the market scalable, sellers need to automate at least part of their response to the postings. The simplest way to achieve that is to filter the requests automatically, so that sellers receive only RFQs that they are well qualified to bid upon. This is the first step on the journey toward more complete automation. It asks sellers to set a particular kind of automated business rule, called a filter, that determines which RFQs reach the seller for detailed analysis and actual bids.

To the extent that the means of posting are idiosyncratic, markets like these can enjoy network effects. To the extent that the postings are standardized, buyers and suppliers can participate in many markets without incurring extra costs.

A fully automated solution is possible when the needs of the buyers are precise enough that the sellers can figure their costs accurately from an RFQ alone and buyers can determine value accurately from the seller's proposals. Sellers can then set automated business rules that specify firm bids for the requested goods and services. To assist the buyer, a scoring engine evaluates and ranks the bids according to the buyer's specified criteria, though it may leave the final choice about which bid to accept to the human buyer. If the bids, too, can be made sufficiently complete, it can become possible to allow the scoring engine to make the actual choice of products. This capability is less important for initial uses of the technology, but will become especially important for future generations of RFQs, which will use optimization methods to choose not just single products but whole packages of products to satisfy each buyer's needs in the best possible way.

Aside from filters and firm-bidding rules, there is a third kind of automated business rule: one that specifies indicative (non-binding) bids. These rules have a twofold purpose. First, they provide a way station on the path to firm bids. Sellers may not be willing initially to entrust their bidding to an automated rule or may not have integrated their internal systems, such as the inventory system, with the bidding rule. In that case, the non-binding bid is just an indication of the seller's terms, which require subsequent confirmation.

The other use of non-binding bids arises when the seller's bidding process is costly and not susceptible to full automation. For example, suppose a market includes services used in construction. A painter, plumber or electrician will not generally be willing to make a firm bid on a job without examining the blueprints or the physical properties to be worked on. Even without that detailed information, however, a contractor may know its capacity and schedule and its cost per unit for certain services, which it can use to make a preliminary estimate for the work. In traditional procurement, the seller expresses something about its knowledge using an indication of interest, which in the Perfect system takes the form of an indicative bid. The poster who receives the indicative, non-binding bids can use them as the first step in an extended negotiation with the best-qualified suppliers. In this way, indicative bids perform a filtering function that saves time and cost for both buyers and sellers while helping the parties to tailor a deal that satisfies their mutual objectives.

Most importantly, the entire process closely resembles the process upon which it was modeled—real buyers and suppliers sourcing and selling.

With PerfectMarket's technology, the actual bidding uses a maximization engine for both firm and indicative bids. The seller makes the most attractive possible offer (often including up to 100 dimensions) to the buyer, according to the buyer's specified bid scoring criteria (his quantified priorities), subject to the seller's offer rules and constraints. In principle, the seller's offer rules can be very much like those it would set for a sales representative, allowing discretion to meet competition subject to some specified limits. Of course, other kinds of rules are possible as well.

The appendix to this essay demonstrates mathematically that when costs and values depend on several dimensions, the PerfectMarket system, with its optimized offers and buyer scoring, can lead to fully efficient transactions—an accomplishment that cannot be duplicated by any traditional market method. Systems that fail to optimize offers are inevitably wasteful, creating unnecessary losses in total value for the market participants. The extra value created by the Perfect RFQ solution can be shared among the buyers, sellers, and Net markets. For buyers, the solution provides an easy-to-use interface that allows them to launch basic RFQs within seconds, keeping costs low and still avoiding the need to specify all the attributes of the goods before learning what the sellers have to offer. For sellers, the system allows them to compete on the basis of their strengths, creating value and serving their customers well without eliminating their own profits. For Net markets, the system provides a chance to use their superior expertise to specify attributes that are of maximum relevance to evaluating offers—a differentiation that allows them to generate revenues from transaction fees and possibly to create usable network effects. Also, by encouraging tailored, non-public offers at the Net market maker's site, the system integrates the buyer's search with the transaction in ways that allow the Net market maker to capture value from its content.

Most importantly, the entire process closely resembles the process upon which it was modeled—real buyers and suppliers sourcing and selling. But instead of a buyer calling three suppliers, verbally detailing his needs, and then meticulously weighting his trade-offs, the buyer can do the same thing across hundreds of suppliers in less time. Instead of quoting perhaps five offers a day, a supplier can bid on hundreds or thousands. The reduction in costs for both buyer and supplier can be enormous...without losing the qualities of buying and selling that have served them well for 50 years. The real savings will not come from beating up suppliers in price-only auctions, but rather from reducing the costs of sourcing for both buyer and supplier, creating better matches, in every dimension concurrently, between the supplier's capabilities and the buyers needs, and leveraging suppliers' individual strengths. The overall result is a nearly "Perfect Market" that offers benefits for which market participants will be willing to pay.

Perfect has scoured the world of sophisticated transactions and found ways to adapt the expensive practices that have so far been used only for complex, high-value transactions to the low-cost environment of the Internet.

Another important differentiator of the PerfectMarket technology is the information it generates. Here is a system in which buyers describe what they want and their buying decisions are observed and recorded. Even once aggregated to preserve anonymity, this kind of information about buyer demand is unprecedented! It will be extremely valuable to suppliers in evaluating their product lines and planning new products. That optimal use of information, however, is the topic of another paper.

PEERING FURTHER INTO THE FUTURE

The PerfectMarket technology described and analyzed in the preceding section is technology of the present. It is designed to add value for early users simply by screening offers in post-and-reply marketplaces, to add still more value in markets that employ indicative bidding by improving the matching of partners and helping them to quickly identify the mutually best terms, and to enable full automation with its associated cost savings in markets that are ready for that technology.

LINKAGES AMONG MARKETS

Looking to the future, Perfect has scoured the world of sophisticated transactions and found ways to adapt the expensive practices that have so far been used only for complex, high-value transactions to the low-cost environment of the Internet. A common attribute shared by many of these high-value transactions is linkage. Instead of making individual transactions in isolation, multiple transactions are linked or made contingent on one another.

As an ASP, Perfect will have the ability to work with Net markets to innovate solutions that link markets, enabling buyers to find the solutions they want.

The U.S. Federal Communications Commission auction for radio spectrum in the 700 MHz band, which I helped to design and which is currently scheduled for the spring of 2001, provides a noteworthy example. Bidders in that auction will be permitted to link their bids for various spectrum licenses, and indeed to bid for entire packages without specifying individual prices for the constituent licenses. Even with just twelve licenses on offer, this auction requires new algorithms to evaluate overlapping combinations of bids ("combinatorial bidding") and identify which offers are most attractive. This is an extreme example of a designed linkage in a context where the goods are worth many billions of dollars, but it is consistent with foreseeable developments in other market sectors.

A second example: in the deregulated electricity markets mentioned earlier, there are linkages of many kinds. A thermal (gas-, coal- or oil-fired) generating plant typically has relatively long "ramping up" and ramping down periods, so that it is normally uneconomical to deliver power during the hours of, say, 3:00-4:00PM unless the plant also delivers power during the interval 2:00-3:00PM or 4:00-5:00PM. The typical market for power is for supply in a particular hour, but these markets are linked in the supplier's planning for power generation. Another important linkage in these markets is between the power itself and transmission capacity. Failing to create a linkage runs the risk that the unlinked power market generates adequate power but no means to transmit it to customers.

There is a growing recognition that linkages of this sort are pervasive in industrial buying. Delivery is one element of the linkage. Buyers who must arrange their own shipping care about the total price, including delivery, of the items they buy; suppliers who are responsible for transportation are concerned about their total costs, including delivery. But delivery is just the tip of the iceberg.

Linkages among suppliers are also common when the buyer seeks to buy a total solution by issuing an RFQ that involves a bill-of-materials. The buyer wants to acquire all the line items of the bill solution without unnecessary duplication, to ensure compatibility among parts acquired from disparate suppliers, and to take good advantage of quantity discounts even when using multiple suppliers. Each of these objectives creates a link among purchases made from various suppliers in separate markets. Existing e-business technologies are not structured to exploit those links.

PERFECTING THE LINKS

As an ASP, Perfect will have the ability to work with Net markets to innovate solutions that link markets, enabling buyers to find the solutions they want. To make this more than a mere theoretical possibility, Perfect's technology is designed to allow this advanced state of e-commerce to be reached in a series of manageable steps, in which the value to participants is increased at each step.

The sequence of steps will differ among industries, but here is an example to illustrate my vision of the process. The first step exploits our existing PerfectMarket technology, in which market participants create business rules enabling multidimensional competition and negotiation. We have already seen how this step adds value and attracts participants. Then, data exchange methods and standards foster more successful searches, allowing customers to search for (still unlinked) solutions in more than one market and enabling some communications among participants in disparate markets. Once such communications are enabled, the communicating markets establish links that solve simpler problems, like purchasing both a large industrial machine and the means to transport it. As the capacity to link markets grows increasingly sophisticated, bill of materials technologies add the means both to link markets to provide total solutions to customers and to promote cooperation among suppliers in forging such solutions.

Paths such as these provide opportunities for innovators to profit at every step of the way by creating value at every step—lots of value in particularly well-suited markets. The value of successfully linking markets is so large—and the emerging precedents are becoming so clear—that this incipient trend is sure to gain momentum.

It is traditional value creation, and not gimmicks or new and untested "e-conomic" concepts, that lies at the root of the explosion of B-to-B trading. Only by adding value can participants in the new economy sustain profitable businesses. The PerfectMarket technology will be part of the winning solution.

APPENDIX

The purpose of this appendix is to demonstrate the technical advantages of the PerfectMarket system of RFQs in the case of firm bids. There are three formal propositions. The first establishes that a deal is efficient precisely when the non-price attributes maximize total value. This proposition confirms the fundamental importance of optimizing the non-price terms. The second establishes that in a multidimensional auction with firm bids and an accurate scoring rule, each bidder has an incentive to specify the non-price attributes of the winning bid so as to maximize the total value of its deal. Finally, the third proposition establishes that in the multidimensional Vickrey auction implemented by the PerfectMarket technology, if the buyer specifies his or her preferences accurately, then the winning deal will be efficient.

Let p designate the price of the product being sold and let x be a list of all the non-price attributes of the deal, including attributes of the product, the buyer, and the seller. Suppose the net profit, or net value added, or *utility* for the buyer from purchasing the product is $V(x)-p$ while the net profit or *utility* earned by the seller is $p-C(x)$. The buyer's *utility* may include just the profit from using and reselling the product, or it may include the value of experimenting with new features, testing new suppliers, etc. (In practice, it is up to the market manager to specify the list of attributes in whatever way is most relevant for the particular market.) Similarly, the seller *utility* or effective net profit may include the value of getting a foot in the door with this particular customer or the value of making early sales of a technologically advanced product, and so on.

A ***"deal"*** is formally represented by a pair (x,p), which specifies both non-price and price aspects. In the standard language of economics, a deal is called ***"efficient"*** if there is no other deal (x',p') that both the buyer and seller prefer. This means that a deal (x,p) is efficient if there is no (x',p') such that the buyer and seller both earn more: $V(x')-p'>V(x)-p$ and $p'-C(x')>p-C(x)$. An inefficient deal is one that is wasteful, meaning that it is possible to find another that both parties prefer.

Proposition 1. A deal (x,p) is efficient *if and only if* the non-price attributes x maximize the total value. Equivalently, (x,p) is efficient if and only if there is no other list x' of attributes such that $V(x')-C(x')> V(x)-C(x)$.

Proof. Formally, we prove the equivalent statement that (x,p) is *not* efficient if and only if the non-price attributes x fail to maximize total value.

Thus, suppose that (x,p) is not efficient. Then there exists a deal (x',p') such that $V(x')-p'>V(x)-p$ and $p'-C(x')>p-C(x)$. Adding these two inequalities leads to $V(x')-C(x')>V(x)-C(x)$. This proves that if (x,p) is not efficient, then the non-price attributes x fail to maximize total value.

Next, suppose that (x,p) is a deal such that the non-price attributes x fail to maximize total value. This means that there is some list x' of non-price attributes such that $V(x')-C(x')>V(x)-C(x)$. Let $p'=p+\frac{1}{2}[V(x')-C(x')-V(x)+C(x)]$. Then, the value of the deal to the buyer is $V(x')-p' = V(x)-p+\frac{1}{2}[(V(x')-C(x'))-(V(x)-C(x))] > V(x)-p$. Also, the value of the deal to the seller is $p'-C(x') = p-C(x)+\frac{1}{2}[(V(x')-C(x'))-(V(x)-C(x))] > p-C(x)$. So, the deal (x,p) is not efficient.

Proposition 2. In the Perfect multidimensional auction with firm bids, using either the Perfect multidimensional proxy bidding (Vickrey) rule or the rule that each bid is a firm offer scored according to the rule V, each supplier's optimal bid entails setting the non-price attributes x of its offer to maximize $V(x)-C(x)$.

Proof. Let (p,x) be the bid made by a supplier; let x^* be the non-price terms that maximize total value; and let $p^*=p+V(x)-V(x^*)$. Notice that p^* has been defined so that if the supplier offers (p^*,x^*) instead of (p,x), its score remains exactly the same. Consequently, the seller wins in precisely the same circumstances whether it bids (p^*,x^*) or (p,x). Under each of the two auction rules, the buyer receives a deal with the same utility for both offers.

Note that the total utility of the buyer and supplier corresponding to any deal (x,p) is the sum $[V(x)-p]+[p-C(x)]=V(x)-C(x)$. If the non-price terms of the original offer fail to maximize this sum, then the total utility is higher when the supplier bids (p^*,x^*) instead of (p,x). Since the buyer's utility is unchanged, this means that the supplier's utility must be higher. Hence, the supplier's original bid could not be optimal (that is, it could not maximize the supplier's utility).

Proposition 3. In a multidimensional Vickrey auction with firm bids and a scoring rule V that corresponds to the buyer's actual preferences, the resulting deal is efficient.

Proof. The Vickrey auction is a proxy auction in which it pays each bidder to specify a price that represents the lowest to which it will actually go. Using Proposition 2 leads to the conclusion that (1) bidder j optimally offers the deal (x_j,p_j) in which (1) the non-price attributes x_j to maximize $V(x)-C(x)$ over all j's possible deals and (2) the price is $p_j=C(x_j)$. The winning bidder will be the bidder who offers the best deal, that is, the deal for which $V(x_j)-p_j$ is largest. But this is the very deal for which $V(x_j)-C(x_j)$ is largest. Hence, the final deal maximizes $V(x)-C(x)$ over all possible deals from all possible sellers.

By Proposition 1, that deal is efficient.

ABOUT THE AUTHOR

Dr. Paul R. Milgrom is the Shirley R. and Leonard W. Ely, Jr. Professor of Humanities and Social Sciences and Professor of Economics at Stanford University, and the Taussig Research Professor of Economics at Harvard University. Dr. Milgrom is the former co-editor of the *American Economic Review,* the primary journal of the American Economic Association. Among various academic honors and awards, he is a fellow of the American Academy of Arts and Sciences, a Guggenheim fellow, and a fellow of the Econometric Society.

Paul is the co-inventor of both Perfect's technology, and the simultaneous ascending auction, variations of which have been used to sell over $100 billion of radio spectrum rights around the world over the last decade, as well as certain patent-pending innovations in combinatorial bidding technology. The forthcoming US Federal Communications Commission's 700 MHz spectrum auction will be conducted with procedures based largely on a paper presented by Dr. Milgrom, and he has been pivotal in various FCC spectrum auctions since 1994.

Dr. Milgrom has consulted the government of Mexico, to advise on privatization auctions for government-owned assets; the governments of Australia, Canada, Germany, and Mexico, for their spectrum auction sales; the Oregon Public Utilities Commission, to design an auction for sale of the power portfolio of Portland General Electric; and GTE, to design an auction solution to the provision of universal telephone service. In addition, he has consulted on bidding strategy for auctions in the US, the UK, and the Netherlands.

A world-renowned expert in auction and markets, he has delivered the Churchill lectures at Cambridge University on the subject "Putting Auction Theory to Work" and the Nobel Prize lecture on competitive bidding, in honor of deceased laureate William Vickrey. That lecture was published in *Le Prix Nobel,* 1996. Dr. Milgrom's manuscript, *Putting Auction Theory to Work* is currently in preparation and will be published by Cambridge University Press. Additionally, he has been asked to assist The Office on Public Understanding of Science of the National Academy of Science with an article on auctions, "Beyond Discovery." In April of 2000, Dr. Milgrom made a presentation about the economics of Internet markets to Chairman Greenspan and the governors of the Federal Reserve.

CONTACT INFORMATION

Perfect.com
1860 Embarcadero Road, Suite 210
Palo Alto, CA 94303-3320

tel 650.798.3335
fax 650.858.1095

WWW.PERFECT.COM