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The menu-setting problem and subsidized prices: drug formulary illustration

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Abstract

The menu-setting problem (MSP) determines the goods and services an institution offers and the prices charged. It appears widely in health care, from choosing the services an insurance arrangement offers, to selecting the health plans an employer proffers. The challenge arises because purchases are subsidized, and consumers (or their physician agents) may make cost-ineffective choices. The intuitively comprehensible MSP model—readily solved by computer using actual data—helps structure thinking and support decision making about such problems. The analysis uses drug formularies—lists of approved drugs in a plan or institution—to illustrate the framework. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

A menu lists the goods or services an institution offers, and the prices it charges. When a profit-seeking organization, such as a restaurant or mail-order clothier, sets its menu it cannot simply decide on an item-by-item basis. It must worry about cannibalization of purchases due to cross-elasticity of demand. The

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pasta dish may draw customers from the more expensive and profitable meat items, and similarly for the clothier with sweaters cheap and cher. Taking inexpensive items off the menu is not the solution, because they allow profitable sales to some customers who would not otherwise buy. Here lies the essence of the menu-setting problem (MSP): making an item available to one group of persons will draw off more desirable purchases from other individuals. This paper sets forth the MSP, identifies its particular salience in the health-care arena, and illustrates with drug formularies.

The MSP is of greater importance in the health-care arena, and takes on an additional salient dimension, because so many goods and services are offered at heavily subsidized prices. The goal in health care, at least implicitly, is to spend treatment dollars where they will produce significant benefits. However, once items are subsidized, the menu-setter has a significant concern that inappropriate purchases will be made. Why is health care subsidized, as opposed say to meals or clothing? Risk spreading provides the primary argument for subsidy of health-promoting items: they are expensive and random factors make their consumption desirable. Hence, the providing institution would like to offer the items at little or no cost to appropriate users, those who would derive significant expected medical benefits from them, but charge inappropriate users, i.e., those who benefit marginally, the full costs of provision. Yet once the subsidized item is placed on the menu, it is available for consumption by those who reap high value and those who do not. Self-interested patients, or physicians acting on their behalf, will choose items that are expensive relative to the health benefits secured; in other words, they will undertake consumption that is not cost effective. There may be other justifications for subsidy beyond risk spreading, such as paternalism, or that needed health care is a right. The same conflict between ready affordability for some and cost/ineffective consumption for others would apply.

Note, the majority of health care expenditures in most developed nations are paid for by government. Even in market-oriented United States, employers subsidize their workers' health care, since it is an employee benefit, not a source of profitability, and is tax favored. Most care-giving institutions, such as HMOs and hospitals, are nonprofits. Moreover, even for-profit insurers and providers subsidize health-care purchases at time of sale. This caters to risk aversion, and allows profit makers to charge higher premiums and government and nonprofits to produce greater welfare. All these subsidy-offering entities strongly encounter the MSP: What services should be made available?

We take the objective of the health-care provider, whether government or private, for-profit or nonprofit, to be to maximize expected health-care outcomes subject to a constraint on resource expenditure. [1] (Setting the constraint appropri-

[1] Presumably, a for-profit entity can charge more if it secures better outcomes; hence it also solves this constrained maximization problem.

ately is a problem left for another day.) If all patients desiring a particular treatment were homogeneous, there would be no problem. All cost-effective treatments and only such treatments would be placed on the menu. The challenge is that patients desiring a treatment are heterogeneous; for some the treatment is well worthwhile, for others not. This paper addresses the problem of setting the menu to balance effective and wasteful provision. The drug formulary is our central example. A formulary provides a crisp example of a menu. Its prices are almost invariably subsidized, implying that inappropriate or excessive use may be a problem. There is also the possibility of cannibalization, with the use of one drug replacing another.

Though we focus on the problem of drug formularies, we could have easily directed attention to health care more generally. As they proceed, readers are encouraged to apply the MSP to their own areas of interest, such as mental-health care, or the use of diagnostic technologies, such as MRIs, indeed to any problem where the expected benefits of particular treatments or procedures vary widely from person to person. The MSP also applies at a higher level to the menu of health-plan options that an employer presents to employees. We provide brief illustrations from these areas before turning to drug formularies.

Most health plans offer their insureds a fixed number of subsidized visits, say eight, to a mental-health professional per year. For a person with an anxiety disorder, this may be a roughly appropriate number. But this number may be far too few for a person with a serious mood or psychotic disorder, and many more than is worthwhile for milder stress-related conditions. Assuming the health plan cannot discriminate among such individuals in services offered, it encounters the MSP. [2]

An MRI machine is a patient magnet. A health plan with such a machine will incur many uses that are at best of marginal value. But it is difficult for health plans to direct physicians to use MRIs only when they are cost effective. The doctor just might get some diagnostic insight from an MRI, and the patient wants it. In many such cases, the doctor just goes along with a cost/ineffective use. The use of diagnostic technologies, such as MRIs, will also depend on how readily competitive services are available. To some extent, MRIs will substitute for CATscans, or even regular X-rays. The MSP captures any propensities to substitute among goods or services.

Frequently, the alternative to a procedure is doing nothing at all, but still the MSP applies. If PSA tests (screening for prostate cancer) are routinely offered to men over 50, their highest value use, knowledgeable men under 50 may request

[2] Many health plans, recognizing the need to draw distinctions among individuals, now contract out management of their mental health service to firms that specialize in drawing such distinctions. The contractors are given considerable latitude in allocating treatments. Essentially, mental health care is made a non-menu item.

them. Once a health plan makes flu shots cheaply available, even individuals in their 20s may request them. Undesired choices may also result when offering a health plan. An employer might wish to offer a strongly subsidized version of a generous health plan to allow employees with significant health problems to secure intense treatment at affordable rates. The strong subsidy may also attract to the plan people with ordinary health risks, who were not the employer's intended recipient group. This 'you can't get one without the other' feature is the essence of the MSP, which suggests that the MSP is first cousin to the problem of adverse selection.

We develop the remainder of our analysis in the context of drug formularies, which are explicit lists of approved pharmaceuticals within a health plan or institution. Such formularies are used in one form or another by most health care providers in the US. Their objective is to maximize expected health-care benefits for a heterogeneous population subject to a constraint on pharmaceutical expenditures. Drug formularies encounter a serious agency problem, given the subsidies they offer. To spread risks and possibly to pursue distributional goals, patients are charged much less for drugs than the marginal cost to the provider. Patients, who are allowed to choose their drugs, will not count costs to the provider (or plan). Thus, moral hazard will result in excess expenditures on drugs as judged by the people covered by the provider, because it is these individuals who ultimately pay the costs of pharmaceutical use, whether through premiums or reduced subsidies for other health services. [3] In this situation, where choosers are both subsidized and self-interested, how is a provider to set the optimal menu of alternatives?

We present the MSP as a mathematical model that explicitly accounts for patient heterogeneity, and considers all medical conditions and drugs together when selecting the formulary. This model is flexible enough to accommodate a variety of objectives and cost structures, and can be used as a decision support tool by formulary decision makers. The interest in the model stems from the fact that drug prices are subsidized. Therefore, marginal cost pricing does not carve the path to efficiency. The drug formulary example is illustrative of any attempt to limit resource use by a group of subsidized, heterogeneous individuals choosing for themselves, such as defining an approved set of procedures for a health plan. [4]

[3] As Newhouse (1998) points out, subsidizing drugs may promote allocative efficiency, from the standpoint of society at large. The social marginal cost of drugs is often quite low relative to the price charged to a health provider; pharmaceutical companies need to set prices high to recover the fixed costs of R&D and marketing, and they are able to do so given their market power. Subsidizing consumers' purchases brings the prices they face closer to the producer's marginal cost.

[4] Baumgardner (1991) analyzes an HMO setting quantity restrictions to control the use of new, expensive technologies. He observes that a principal competitive advantage of HMOs is their ability to control costs in this way.

(In what follows, we say that individuals choose, recognizing that it is usually the physician choosing on their behalf.)

This paper consists of seven sections. Section 2 provides information about formularies, including a description and assessment of the methods typically used to determine them. Section 3 considers the problem of seeking the optimal drugs to treat a single medical condition, framing it as an MSP, allowing but not requiring charges to patients. Section 4 extends our single-condition MSP formulations to the multiple-condition problem considering all medical conditions and drugs simultaneously. Section 5 discusses pricing in MSPs. Section 6 discusses several limitations on the use of the MSP framework to determine drug formularies, and Section 7 concludes, and relates the analysis back to menus in health care more generally.

2. Drug formularies

A *formulary* is a listing of pharmaceuticals permissible to use in a given institution, such as a hospital or HMO. It is continually revised to reflect the current judgment of the institution's medical staff. A formulary *system* enables the staff, typically working through a committee, to evaluate and select from among numerous available drug entities and drug products, those considered most useful in patient care (American Society of Hospital Pharmacists, 1986a, 1991). Formularies are also concerned with cost effectiveness.

The first known formulary in the US was published for the Continental forces during the American Revolution (American Society of Hospital Pharmacists, 1986b). In 1933, the first guidelines for operating a formulary system were formulated by a physician and a pharmacologist (Nash et al., 1993). In 1965, the development of hospital formularies was mandated by the Joint Commission on Accreditation of Hospitals (Joint Commission on Accreditation of Hospitals, 1965), and an estimated 95% of managed care plans currently use a formulary (Freundlich, 1995).

There are three basic types of formularies: open, closed or restricted, and incentive-based. An *open* formulary serves merely as a guide: a physician may prescribe any drug, but is encouraged to use the formulary list in prescribing decisions. In contrast, a *closed* or *restricted* formulary lists the drugs that will be reimbursed by the health care provider; nonformulary drugs will be reimbursed only if they are authorized prior to prescribing. An *incentive-based* formulary represents a hybrid between the open and closed formularies; patients pay a higher price for nonformulary drugs.

Health-care providers use formularies to generate safe, effective, and cost-conscious use of medications for patients. By assuring drug-by-drug review of all medications, the formulary system can reeducate and remind physicians of alterna-

tive cost-effective therapies and balance the promotional tactics of pharmaceutical manufacturers. Formularies can save money through the lowered prices that come from bulk purchasing and competitive bidding, and by reducing waste and overuse. By giving physicians in-depth experience with a limited number of drugs with proven superiority, formularies can reduce the risk to patients of medication errors and drug reactions which may result from sound-alike drug names and a proliferation of drugs that caregivers must know and to which patients might be exposed. The advantages of such a focus are growing given the increased number of new drugs being marketed, many highly potent with significant side effects, and the increasing influence of possibly biased and unscientific advertising information (U.S. Congress, 1995).

Like all management tools, formularies possess certain intrinsic limitations. They cannot, for example, determine whether the therapy of choice should be a drug product rather than rest or diet, and they have limited power to cope with the inappropriate use of even the most appropriate medication (Rucker and Schiff, 1990). Moreover, the formulary system has been severely criticized for placing too much emphasis on cost and too little on quality. A common complaint is that formularies often include only those drugs that are cost effective for the 'average patient' while overlooking the special needs of individuals (Bakst, 1995; U.S. Congress, 1995). Even if physicians can seek authorization to prescribe nonformulary drugs, such procedures can delay needed treatment for the patient and ultimately lead physicians to prescribe a suboptimal formulary drug instead (U.S. Congress, 1995).

Despite their widespread use in the US, the impact of formularies on the quality of care for patients has not been well studied. A few controversial studies have indicated that formularies lead to either higher costs (Horn et al., 1996) or lower quality of care for some patients (U.S. Congress, 1995), but much work remains to be done in this area before any sound conclusions can be reached (Freundlich, 1995).

Drug formularies are determined by formulary committees. [5] The membership of formulary committees varies, but most include physicians, pharmacists, nursing representatives, lawyers, and ethicists. Large committees may consist of several subcommittees, each responsible for reviewing a given therapeutic class of drugs (Nash et al., 1993). Health-care providers typically have formal procedures for changing their formulary, and most formulary committees meet at least quarterly to vote on the acceptance or elimination of formulary drugs (Rascati, 1992).

Determining an 'optimal' drug formulary requires tradeoffs between the cost and relative effectiveness of numerous pharmaceuticals for the heterogeneous

[5] In hospitals, these are often known as pharmacy and therapeutics (P&T) committees.

group of people who are on the health plan. A major difficulty is that once a drug is placed on the formulary, it will be selected by many individuals—actually, their doctors often choose on their behalf—even when it is not cost effective. [6]

For example, heart-attack patients can be treated with a variety of thrombolytic drugs to increase their chance of survival. Two of the most effective drugs are streptokinase, a drug derived from bacteria that costs US$240 per dose, and tissue plasminogen activator (TPA), a genetically engineered substance that costs US$2400 a dose. Although TPA is ten times more expensive than streptokinase, it is on average more effective in preventing death. A recent study involving over 41,000 heart-attack patients found that 6.3% of patients treated with TPA died within 30 days, compared to 7.2% of those treated with streptokinase (GUSTO Investigators, 1993). The problem is that the relative effectiveness of the two treatments varies across patient groups, and a cost-benefit (or cost-effectiveness) analysis of the two treatments will reach different conclusions for different patients. Table 1 summarizes the results of the study, disaggregated by important patient subgroups. For all subgroups TPA was statistically significantly superior. [7] TPA is more effective (if only slightly) than streptokinase in preventing death for all patient subgroups. Hence, each subgroup would choose TPA and not worry about cost.

We discuss infarct location and hours to drug therapy first. There are severe differences in net benefits, suggesting that the plan might prefer to make TPA available only for some groups. Due to practical restrictions, however, if a plan makes TPA available to patients with an anterior infarction who arrive at the emergency room less than 4 hours after the attack—the group whose mortality reduction is probably the greatest—it must also make it available to patients with an inferior infarction who arrive at the emergency room five hours after the attack, though their smaller survival gains may make the choice of TPA cost-ineffective. Thus, a health-care provider faces the agonizing dilemma of deciding which thrombolytic drug or drugs to offer its members. If it offers TPA, all rational

[6] Health-care professionals claim that the provider cannot, in practice, offer a given drug to some patients and deny it to others on the basis of cost effectiveness (Basskin, 1998; Caul, 1998; Glomski, 1998; McLaughlin, 1998; Nash, 1998; Sorrenti, 1998). This restriction may also have some legal bite. The Patients' Bill of Rights Act of 1998 states that ''patients should not be discriminated against in their access to covered health-care services.'' And a few years ago, a court awarded US$89 million to the family of a California woman who died after her HMO refused to pay for a controversial bone-marrow transplant that doctors hoped would cure her breast cancer. The court's decision hinged on the fact that the HMO had earlier approved identical treatments for two other women, both of whom testified at the trial as living proof that the therapy might have worked (Shoop, 1994).

[7] The group experiencing greater than 6 hours to drug therapy actually had better results with streptokinase (8.3 vs. 10.4% mortality). Since the group comprised only 4% of the population, the difference is not statistically significant, and the group is not included in the table.

Table 1
Mortality after thrombolytic drug therapy for heart attacks ($n = 41{,}021$ patients)

Subgroup	Percent of patients	Mortality rate (%)		Absolute improvement using TPA (lives saved per 1000)
		Streptokinase	TPA	
Infarct location				
Anterior	39	10.5	8.6	19
Inferior	61	5.3	4.7	6
Hours to drug therapy				
0 to 2	27	5.4	4.3	11
2 to 4	51	6.7	5.5	12
4 to 6	19	9.3	8.9	4
Age (years)				
< 75	88	5.5	4.4	11
≥ 75	12	20.6	19.3	13

heart-attack patients will select it, at great expense to the provider, making it less feasible to offer some other desirable drug under a restricted budget, or raising the cost of the health plan, thereby making it unaffordable to some segments of the population and less attractive to the rest. If the plan offers streptokinase and not TPA, all patients will select it, getting less effective treatment than with TPA; but it may then be feasible for the plan to support some other desirable drug. Or, the cost of the plan will decrease, becoming affordable to more segments of the population, or leaving its members with resources for other purposes.

Age presents a more challenging problem. Patients over 75 secure a slightly greater mortality reduction when they take TPA rather than streptokinase. However, they have far fewer years to live; hence they benefit much less in terms of measures such as quality-adjusted life years (QALYs).[8] The choice of output measure involves ethical judgments.

The formulary problem becomes more complex when all relevant pharmaceuticals, medical conditions, and patient subgroups are considered simultaneously. Formulary committees deal with the complexity of this problem by making two simplifying assumptions that can lead to suboptimal results.

First, instead of considering all drugs simultaneously, committees usually consider only one therapeutic class of drugs at a time (Seaver, 1995; Garrelts, 1997). Unfortunately, determining the most cost-effective drugs within each

[8] This pattern, and the accompanying ethical challenge, arises whenever the more expensive drug gives the greatest mortality benefit to those already at the greatest mortality risk.

therapeutic class will not necessarily result in the most cost-effective formulary, because marginal benefits may vary across classes, and drugs provided for one category may be inappropriately selected by another. In fact, such a localized procedure is inconsistent with the fundamental objective of welfare economics, which seeks to maximize the benefits from society's scarce resources (Birch and Donaldson, 1987). [9]

Second, committees tend to group together patients with the same disease and then recommend drugs that are the most cost effective for the 'average' patient in the group (Bakst, 1995; U.S. Congress, 1995; Garrelts, 1997). However, the cost effectiveness of a drug often varies among patient groups. Pharmacogenetic research, for example, has discovered important differences among racial and ethnic groups in the metabolism of drugs, in their effectiveness, and in their side effects (Levy, 1993). [10] A major conclusion of this research is that the most cost-effective drug (or dosage) for treating a given disease often differs by ethnic and racial group. [11] Therefore, an assumption that all patients are the same can result in a formulary that overlooks the special needs of important subpopulations of patients or spends cost-ineffectively on others.

In the past decade, a number of decision analytic models have been developed to help committees determine better drug formularies. [12] Unfortunately, these models typically evaluate the relative desirability of medications *within* a given therapeutic class for an '*average*' patient; while they undoubtedly reduce the amount of subjectivity involved in the formulary decision-making process, they fail to correct the incorrect simplifying assumptions.

It is clear that formulary committees would benefit from a formal model that explicitly accounts for patient heterogeneity and that considers all drugs simultaneously, both within and across medical conditions. We introduce patient heterogeneity in Section 3, and then develop a model with heterogeneity and multiple medical conditions in Section 4.

[9] Exactly how this welfare economics mandate should be carried out in practice is controversial. The central question is: How should benefits be aggregated across different groups of individuals? The usual answer is to use some metric, such as total QALYs gained, as an output measure. Such metrics, in effect, maximize the expected utility gain of a randomly chosen individual.

[10] Levy (1993) provides specific examples of racial and ethnic differences in response to the following commonly used agents: cardiovascular drugs (including beta-blockers, diuretics, and ACE inhibitors), central nervous system agents (including tranquilizers, antidepressants, and neuroleptics), analgesics (including acetaminophen, codeine, and morphine), and alcohol. Other important factors involved in determining a patient's response to a medication include age, gender, multiple disease states, presence of other drugs, and pregnancy.

[11] Clearly, as difficult as it would be to prioritize on, say infarct location, it would be much harder to do so on a racial basis, even if this resulted in some drugs being precluded for all patient groups.

[12] See, for example, Kresel et al. (1987); Senthilkumaran et al. (1987); Cano and Fujita (1988); Calvo et al. (1990); Barriere (1991); Schumacher (1991); Einarson et al. (1995); Lee et al. (1995); Harvey et al. (1996).

3. The optimal formulary for heterogeneous patients with a single medical condition

We first use our model to determine which drugs to include in the formulary to treat a *single* arbitrary medical condition experienced by three groups of patients. The condition can be treated with any of four different drugs, whose costs and efficacy for patients with different expected responses to the drugs are shown in Table 2. For simplicity, we measure efficacy in QALYs. Since patients within a category may have different medical responses to a drug, QALYs should be thought of as an expected value. We assume that patients choose the formulary drug that gives them the most QALYs, neglecting cost, and that the health-care provider cannot offer a given drug to some patients and deny it to others. [13] To facilitate exposition, we assume that there is one patient in each group (equal numbers of patients in the groups would produce the same result).

If the objective is to maximize total QALYs in the population of patients suffering from this condition, the obvious solution to the single-condition problem is to include on the formulary each drug that is best for some patient group. Thus, the formulary should contain Drugs 1, 2, and 3. [14] In total, such a formulary will yield 30 QALYs and cost US$11. In general, if money were no object, such an approach could be used for as fine a partition of patients as data permit.

In practice, it may be prohibitively expensive to give each patient group its best drug, but it is not often obvious how to make the necessary tradeoffs between the cost of the drugs and their relative effectiveness. A simplistic approach used by formulary committees, and described in the decision-analytic literature cited earlier, is to rank the drugs according to how they perform on the ‘average’ patient and then select the one or two highest-ranked drugs for the formulary. Unfortunately, when patients receive differing benefits from drugs, such an approach will often result in suboptimal formulary decisions. In our example, if the committee decides to include the best drug to treat an ‘average’ patient, Drug 4 will undoubtedly be selected because it is ‘good’ for all patient groups, resulting in 18 QALYs at a cost of US$15. But this strategy is both less effective and more expensive than including Drugs 1, 2, and 3, which provides more QALYs, 30, at less cost, US$11.

Appropriate optimization considers the number of QALYs attainable for a given level of expenditure. For example, Fig. 1 shows that 17 QALYs can be attained for US$3, 23 QALYs for US$5, 26 QALYs for US$9, and 30 QALYs for

[13] The assumption that providers cannot discriminate comes from interviews with Basskin (1998); Caul (1998); Glomski (1998); McLaughlin (1998); Nash (1998); and Sorrenti (1998), asking their views of medical practice. Only Bakst (1998) demurred from this opinion, believing it to be too idealistic.

[14] Patients in group A will select Drug 1, those in B will select Drug 3, and those in C will select Drug 2.

Table 2
Quality-adjusted life years

Patient group	Drug 1	Drug 2	Drug 3	Drug 4
A	10	1	2	6
B	3	2	10	6
C	4	10	2	6
Unit cost (US$)	1	3	7	5

US$11. [15] Fig. 1 enables committee members to evaluate the cost effectiveness of a drug within the appropriate context. That is, in the presence of patient heterogeneity, the cost effectiveness of a given drug depends on the *set* of drugs in the formulary.

With only a few drugs and a few patient groups, it is straightforward to construct the equivalent of Fig. 1 by hand. However, the problem rapidly becomes unwieldy as the number of drugs or patient groups increases. Fortunately, the single-condition problem can be modeled as an MSP for which good solution techniques already exist. [16]

3.1. Menu-setting problems

MSPs arise when one individual, the setter, puts an array of permissible options on a menu, from which each of a heterogeneous group of choosers will select their preferred alternatives. The setter's task is to define the menu that maximizes her objective function subject to the choosers' known preferences and various constraints. [17] (For clarity, we treat the setter in this paper as female and the choosers as male.) Though we develop our analysis in terms of the MSP generally, our

[15] The respective menus and choices leading to these outcomes are as follows: Drug 1 is offered, all groups choose it. Drugs 1 and 2 are offered, A's and B's choose Drug 1, and C's choose Drug 2. Drugs 1, 2, and 4 are offered, A's choose Drug 1, B's choose Drug 4, and C's choose Drug 2.

[16] Although MSPs are generally quite common, formal treatment of MSPs did not begin until the early 1980s, when marketing researchers began publishing articles on the problem of designing an optimal product line. The 'MSP' is known as the 'product-line design problem' in the marketing literature. The objective there is to maximize the setter's profits. Olmstead and Zeckhauser (1996) discovered this problem independently, gave it the menu-setting name, and pioneered the subsidized-menu problem, the context where purchases are likely to be subsidized and maximizing consumer welfare or social surplus is likely to be the setter's objective.

[17] MSPs are characterized by a principal–agent relationship in which: (1) there is a group of heterogeneous agents, the choosers, with a known distribution of preferences; (2) there is one principal, the setter, who sets the menu from which each member of the group must choose; (3) each agent gets *one* choice from the menu; and (4) the agents' and the principal's preferences differ. See Pratt and Zeckhauser (1991) for a thorough discussion of agency problems.

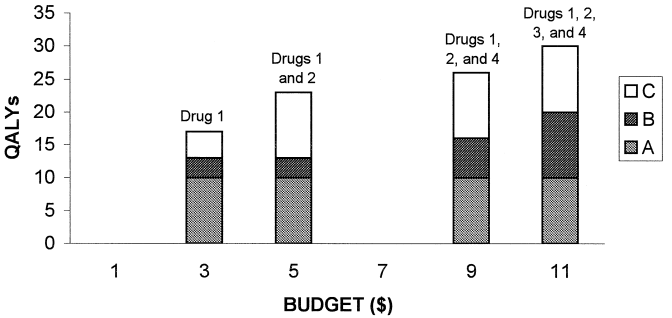

Fig. 1.

primary interest, given our health-care audience, is contexts where price is set below marginal cost, the subsidized menu problem.

MSPs are solved from the perspective of the setter. [18] The setter's objective function may be purely self-interested; for example, a private-sector firm with some market power may select a mix of competing products to maximize profits. In the drug formulary case, the objective function is likely to relate to the welfare distribution among choosers, with some measure of overall welfare as the maximand. In the single-condition problem, the formulary committee is the setter; all patients are the choosers; and the menu consists of the drugs on the formulary. One possible objective of the formulary committee is to define the menu of drugs (that is, the formulary) that will maximize the expected 'health utility' of a randomly chosen patient, subject to a budget constraint. [19] This objective can also be thought of as maximizing the expected total health benefit from the formulary.

The challenge to efficient allocation within the MSP framework arises when two conditions apply: first, the choosers are heterogeneous either in their preferences, or in the setter's preferences for their choices, and second, the setter's and at least some choosers' preferences differ. For example, the setter might like to make option #1 available to chooser *i*, but she will not do so because that would also make it available to chooser *j*, who would select it, and she finds the pair of combinations #1-*i* and #1-*j* highly unfavorable; she decides to refuse option #1 to chooser *i*. If the choosers were not heterogeneous, the setter could put solely her preferred choice on the menu. If the choosers' preferences corresponded to her own, she could put all options on the menu, knowing that the choosers' selections would be her own. [20] Sometimes the choosers are clustered into categories—say

[18] Note that the solution to an MSP tells the setter which specific options *already under consideration* to include on the menu; it does not tell the setter which options to consider in the first place.

[19] This might be the objective selected by a chooser in an 'original position' (Harsanyi, 1955); that is, before he knew who he would be and before he knew from what conditions he would suffer.

[20] At this stage in the paper, we ignore considerations such as set-up costs, or economies of scale, which would limit choices to capitalize on decreasing average costs.

patients with ear infections—with a menu offered to each category. If the choosers in each category remain heterogeneous, then each category would present its own MSP.

The divergence in preferences in the context of the formulary problem arises because the patients, whose drug purchases are subsidized (price below marginal cost to the provider), will have insufficient incentive to be concerned with the cost to the provider, hence to their fellow enrollees, of the treatments they receive. In contrast, the health-care provider must usually meet some budget constraint. [21] If cost effectiveness is a concern, letting each patient or patient group choose for itself may be a poor system. Table 3, which parallels Table 2, but with different entries, illustrates this point.

Say that the budget is US$21. The optimal *assignment*—the one that maximizes QALYs for the dollars spent—gives Drug 1 to Group A, Drug 3 to Group B, and Drug 4 to Group C. Thus 35 QALYs are obtained at a cost of US$20. However, if the *menu* contained Drugs 1, 3, and 4, B's would choose Drug 3, as the optimum requires, but A's and C's would deviate, selecting Drugs 4 and 3 respectively, each gaining only 1 QALY at respective additional costs of US$6 and US$5. Expenditures would then be US$31, hence out of reach. If the plan lets patients choose for themselves, the optimal menu with a budget of US$21 includes only Drugs 1 and 2. In this case, Group A chooses Drug 1 and Groups B and C choose Drug 2. Thus 25 QALYs are obtained at a cost of US$21. Interestingly, B's and C's are both worse off under the menu system than they would be if the plan used an assignment system with the same budget.

3.2. Model for the MSP

We now present a mathematical model of the single-condition formulary problem. To highlight the menu-setting aspect of the problem, we take drug prices as fixed, though formularies can in fact often bargain for lower prices, possibly yielding significant savings. We also allow for a fixed cost in having a drug on the formulary. Though order costs represent fixed costs, the more consequential fixed expense that results from including a drug is keeping doctors informed about its properties.

Let i index the groups of patients with the medical condition, $i = 1, \ldots, m$; and let j index the drugs capable of treating the medical condition that are being considered for inclusion in the formulary, $j = 1, \ldots, n$. Let u_{ij} = the expected

[21] Doctors are agents for both the health plan and their patients, which produces a conflict of interest. Presumably, professional ethics (the Hippocratic Oath) requires that they place their patients' interest first, and consider resource expenditure only secondarily. In this spirit, resource-saving concerns, say by an HMO, may dictate prescribing generic rather than equivalent brand-name drugs in most circumstances, since there is likely to be little or no therapeutic difference.

Table 3
Quality-adjusted life years

Patient group	Drug 1	Drug 2	Drug 3	Drug 4
A	10	2	1	11
B	2	6	15	3
C	0	9	11	10
Unit cost (US$)	1	10	12	7

utility a patient in group i gets from drug j. [22] Let c_{ij} = the unit cost of treating a patient in group i with drug j, let f_j = the fixed cost of including drug j in the formulary, and let B = the pharmaceutical budget. Let N_i = the number of patients in group i.

Let y_j be a binary variable indicating whether or not drug j is put on the formulary, and let x_{ij} be a binary variable indicating whether a patient in group i chooses drug j. We would normally expect that the formulary's objective is to maximize consumer welfare—or equivalently, the expected welfare of a randomly chosen individual—subject to an expenditure constraint. [23] The formulation is then:

$$\text{Consumer Welfare: Maximize}_{x,y} \sum_{i=1}^{m}\sum_{j=1}^{n} N_i u_{ij} x_{ij} \tag{1.0}$$

subject to:

$$\sum_{j=1}^{n} x_{ij} = 1 \quad \forall i \tag{1.1}$$

$$x_{ij} \le y_j \quad \forall i, j \tag{1.2}$$

$$\sum_{k=1}^{n} u_{ik} x_{ik} \ge u_{ij} y_j \quad \forall i, j \tag{1.3}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} N_i c_{ij} x_{ij} + \sum_{j=1}^{n} f_j y_j \le B, \tag{1.4}$$

and

$$x_{ij}, y_j \in \{0,1\} \quad \forall i, j. \tag{1.5}$$

Constraints (1.1) require each patient to choose exactly one formulary drug. Constraints (1.2) ensure that only drugs in the formulary can be chosen by the

[22] The u_{ij}'s are assumed to be normalized within individuals so that their addition across patients is more meaningful, as it is with QALYs. Measures other than QALYs are possible, of course, including healthy-year equivalents (HYEs), willingness-to-pay (WTP), and direct utility.

[23] This objective function evaluates welfare within the boundaries of the plan, i.e., for the provider's enrollees, and does not consider, for example, society's resource costs in producing drugs, profits to drug companies, or pharmaceutical R&D expenditures.

patients. Constraints (1.3) guarantee that each patient chooses the formulary drug that gives him the most utility. Constraint (1.4) ensures that the budget constraint is not violated. And constraints (1.5) ensure that drugs are either offered or not, and if offered, either chosen or not. [24]

The above formulation (1.0–1.5) parallels a model presented by Green and Krieger (1985). Other formulations are also possible. Dobson and Kalish (1993), for example, extend the Green and Krieger model by explicitly considering prices and costs. The net utility to the patient is defined as the difference between value and price, and is measured in dollar terms, as opposed to the QALY metric that we considered above. That is, $u_{ij} = v_{ij} - p_j$, where v_{ij} is the expected dollar value of the drug to the patient, and p_j is the price of the drug j that is charged to the patient. [25] Each drug has an invariant per-unit cost, c_j, and a fixed cost, f_j. In this formulation, prices may vary. The objective is to maximize social surplus, which equals consumer welfare less the plan's expenditure on drugs, both quantities measured in dollar terms. The objective is thus:

$$\text{Social Surplus: } \underset{x,y,p}{\text{Maximize}} \sum_{i=1}^{m} \sum_{j=1}^{n} N_i (v_{ij} - c_j) x_{ij} - \sum_{j=1}^{n} f_j y_j. \qquad (2.0)$$

The equivalents of constraints (1.3) and (1.4) change for this objective. See Appendix A, which formulates the multiple-condition problem with patient utilities set equal to expected value from the drug less their price.

The MSP framework is very flexible and can be modified to model the particular requirements of many scenarios. The MSP framework can adopt a societal, institutional, or patient perspective, depending on how the setter defines the objective function and the factors she includes in the costs and benefits. The MSP framework can also allow for a variety of interdependent drug restrictions. Such restrictions may arise from negotiations with pharmaceutical suppliers and take the form of 'either/or' constraints (i.e., two drugs cannot both appear in the formulary) or 'all or none' constraints (i.e., the setter wishes to offer either all of a given set of drugs or none of them). [26] If concerns about particular patient groups

[24] One can now obtain a graph like Fig. 1 by iteratively solving the above formulation using successively larger budgets, B.

[25] This formulation is soundly based in microeconomics: u_{ij} is a measure of consumer surplus—willingness-to-pay for the drug minus the price of the drug. Dobson and Kalish note that little work has been done on measuring monetary utilities.

[26] If the setter wishes to offer Drug 1 or Drug 2, but not both, she adds the constraint: $y_1 + y_2 \leq 1$. If the setter wishes to offer either all q of the drugs from a set M or none of them, she adds the constraint: $\sum_{j \in M} yj = \lambda q$, where λ is a binary variable. Many other types of linear integer constraints may be incorporated within the standard MSP mathematical programming formulation.

or regulatory constraints make it essential to have a particular drug j in the formulary, then y_j can simply be set to 1, and the remaining problem solved. [27]

4. The multiple-condition formulary problem

We now consider all medical conditions and drugs simultaneously. [28] This is important, since many drugs can be employed in treating a number of different conditions. Simply combining the results of single-condition optimizations will not work. When conditions are examined one at a time, there is no way to allocate the fixed costs of a drug used to treat multiple conditions. More important, drugs that may be highly cost effective in treating some conditions may be only marginally beneficial in treating others, yet still selected for those conditions. Thus Prozac, which is highly beneficial for individuals suffering from depression or obsessive–compulsive disorder, may offer only marginal positive (and possibly negative) benefits for individuals experiencing normal reactions to situations of stress, such as grief. Similarly Viagra, clearly useful in treating many forms of impotence, might offer at best mildly enhanced sexual performance to individuals without dysfunction. Yet, once on the menu, both drugs are likely to be demanded by marginal beneficiaries. [29]

Mathematically, the extension from the single-condition model to the multiple-condition model is relatively straightforward. We maintain the assumption that drugs approved for a given medical condition cannot be withheld from anybody with that condition. However, we allow drugs to be approved for some medical conditions and not for others. So, for example, powerful and expensive antibiotics can be approved for postsurgical recovery but not for low-grade infections. [30] This results in a powerful model that combines the MSP framework with the classic assignment framework. It creates a group of MSPs—one for each medical condition—connected through either a budget constraint or an objective function. In practice, some desirable restrictions of drugs to particular conditions (or diagnoses) may not be feasible; our formulation below allows for situations where a drug made available for one condition must be made available for some others.

[27] Olmstead and Zeckhauser (1996) consider a variety of nonutilitarian objective functions for MSP problems, including citizen choice models with plurality, Borda and approval voting, and Rawlsian (maximin and leximin) objective functions.

[28] The same model that solves the multiple-condition *formulary* problem can be used to solve the more general multiple-condition problem—that considers all *treatments* simultaneously—by replacing the words ‘drug’ and ‘formulary’ with the words ‘treatment’ and ‘health plan’ in the following discussion.

[29] Frequently drugs are even prescribed for off-book (i.e., non-FDA approved) uses, though this may be due more to drug approvals lagging behind experimentation and knowledge, rather than drugs being deployed where their benefits are marginal.

[30] The decision to restrict a given drug to certain medical conditions must be made by the formulary committee when setting up the problem.

Let K be the set of all r medical conditions to be treated, and let J be the set of all drugs considered for inclusion in the formulary. Let $J_k \subseteq J$ be the set of all drugs that may treat condition k, and let $K_j \subseteq K$ be the set of all medical conditions that may be treated with drug j. Let I_k be the set of all patient groups with medical condition k. [31] Let u_{ijk} = the expected utility a patient in group i gets from receiving drug j for condition k, $k \in K$, $j \in J_k$, $i \in I_k$. Let c_{ijk} = the unit cost of treating a patient in group i with drug j for condition k, $k \in K$, $j \in J_k$, $i \in I_k$; let f_j = the fixed cost of including drug j in the formulary, and let B = the pharmaceutical budget. Let N_{ik} = the number of patients in group i with condition k, $k \in K$, $i \in I_k$.

Let z_j be a binary variable indicating whether drug j is included on the formulary, $j \in J$; let y_{jk} be a binary variable indicating whether drug j is included on the formulary and approved to treat condition k, $k \in K$, $j \in J_k$; and let x_{ijk} be a binary variable indicating whether a patient in group i chooses drug j for condition k, $k \in K$, $j \in J_k$, $i \in I_k$. When the setter's goal is to maximize consumer welfare, the formulation is:

$$\text{Consumer Welfare: Maximize}_{x,y,z} \sum_{k \in K} \sum_{j \in J_k} \sum_{i \in I_k} N_{ik} u_{ijk} x_{ijk} \tag{3.0}$$

subject to:

$$\sum_{j \in J_k} x_{ijk} \leq 1 \quad \forall k \in K, \forall i \in I_k, \tag{3.1}$$

$$x_{ijk} \leq y_{jk} \quad \forall k \in K, \forall i \in I_k, \forall j \in J_k, \tag{3.2}$$

$$\sum_{l \in J_k} u_{ilk} x_{ilk} \geq u_{ijk} y_{jk} \quad \forall k \in K, \forall i \in I_k, \forall j \in J_k, \tag{3.3}$$

$$\sum_{k \in K} \sum_{j \in J_k} \sum_{i \in I_k} N_{ik} c_{ijk} x_{ijk} + \sum_{j \in J} f_j z_j \leq B, \tag{3.4}$$

$$x_{ijk}, y_{jk}, z_l \in \{0,1\} \quad \forall k \in K, \forall i \in I_k, \forall j \in J_k, \forall l \in J, \tag{3.5}$$

and

$$\sum_{k \in K_j} y_{jk} \leq r z_j \quad \forall j \in J. \tag{3.6}$$

There are two significant differences between (3.0–3.6) and its single-condition counterpart, (1.0–1.5). [32] First, (3.1) is written as an inequality to enable the provider to avoid treating certain medical conditions altogether. If this is undesir-

[31] The partition of patient groups can vary by medical condition.

[32] If we were dealing with medical treatments in a health plan, this formulation would apply if there were a unified budget for the plan, covering pharmaceuticals, diagnostic tests, mental health, etc. If there are separate budgets for different categories, then there would be one budget constraint equation, equivalent to 3.4, for each category.

Table 4
Quality-adjusted life years

Condition 1				Condition 2			
Patient group	Drug 1	Drug 2	Drug 3	Patient group	Drug 4	Drug 5	Drug 6
A	5	7	10	D	5	3	8
B	6	7	3	E	5	4	1
C	8	7	5	F	5	6	3
Unit cost (US$)	2	4	6	Unit cost (US$)	1	5	10

able, the provider can ensure that a particular medical condition is covered by at least one formulary drug by changing the appropriate constraint in (3.1) to an equality. Second, (3.6) is necessary to model the fixed costs of putting a drug on the formulary.

We now demonstrate this model in action. We consider two conditions, each with three possible drugs and three classes of patients. The data are shown in Table 4.

The setter's objective is to maximize the total QALYs in the population of patients suffering from these two conditions, subject to a budget constraint and an additional equity requirement that at least one drug be offered to treat each condition.

The results of this problem for the case in which each group contains five patients are shown graphically in Figs. 2 and 3. For each budget level, Fig. 2 shows the number of QALYs that can be obtained and Fig. 3 shows which drugs should be offered. [33] Note that some of the drugs move on and off the formulary as the budget varies. Such jumps as a response to relaxing a constraint are common in models like the MSP that contain binary variables and linear constraints and objectives.

Figs. 4 and 5 underscore the importance of accurately modeling the size of each patient group. These figures, which differ significantly from Figs. 2 and 3, show the results of the problem for the case in which groups A through F contain 10, 2, 3, 1, 7, and 7 patients, respectively. (The same number of patients, 15, suffer from each condition as before; only the mix of patients among the three groups suffering from each condition has changed). Given the crowding of outcomes, Fig. 4 does not indicate the drugs associated with each outcome.

[33] When constructing Fig. 3, we broke ties in favor of the least expensive formulary. With a budget of US$85, for example, the setter can obtain 200 QALYs in the patient population either by offering Drugs 1, 3, 4, and 5, or by offering Drugs 1, 2, 3, and 4. However, since a formulary comprising Drugs 1, 3, 4, and 5 costs US$85 and a formulary comprising Drugs 1, 2, 3, and 4 costs US$75, the latter formulary is assumed to be optimal for an US$85 budget.

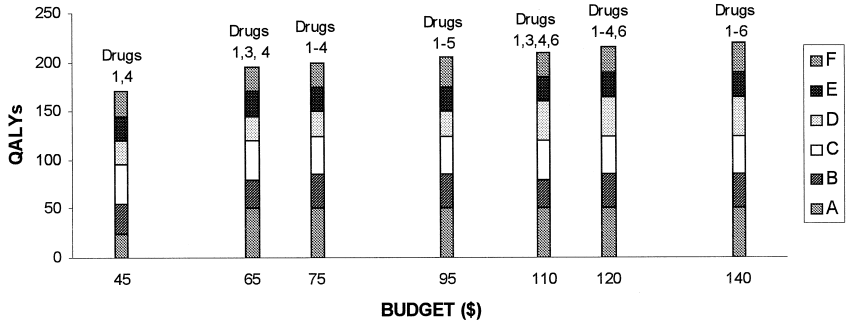

Fig. 2.

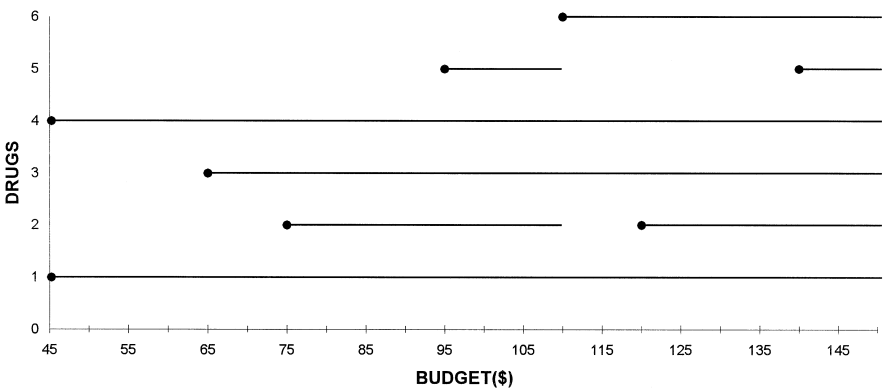

Fig. 3.

The optimal formulary differs considerably between these two cases (Figs. 3 and 5) over the budget intervals [US$55–US$89] and [US$95–US$140]. In

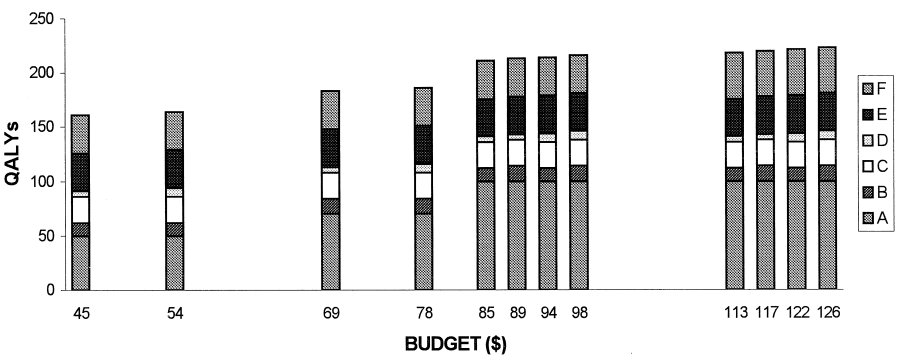

Fig. 4.

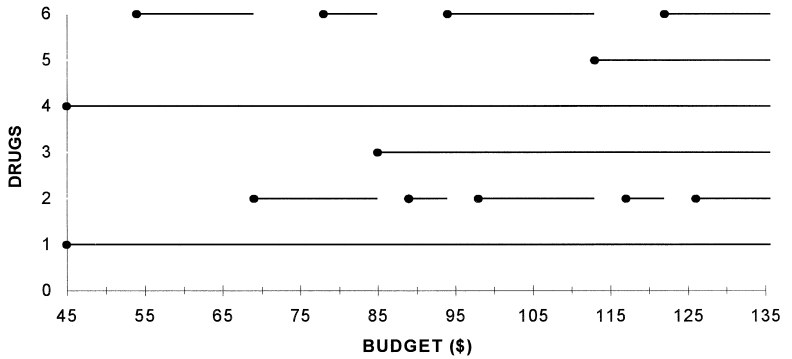

Fig. 5.

addition, the QALYs vs. budget 'curves' shown in Figs. 1, 2 and 4 are ill-behaved in that each exhibits both increasing and decreasing returns to scale over various budget intervals; this effect is especially pronounced in Fig. 4 over the budget interval [US$45–US$94]. Such curves are common in MSPs. While the MSP is, in general, a difficult problem to solve to optimality, general-purpose math programming software and specialized heuristics can readily find near-optimal solutions to problems of realistic size. [34]

5. Pricing in MSPs

Whether prices are modeled explicitly, as in (2.0) and Appendix A (A.0–A.5), or implicitly, as in (1.0–1.5) and (3.0–3.6), they are an integral part of the solution to any MSP. What do we expect these prices to look like? The answer depends on a number of important factors, including the objective of the setter (e.g., social surplus, consumer welfare maximization, or profit maximization), the degree to which the setter can price discriminate among the choosers, and the degree of market power enjoyed by the setter (e.g., price-taker vs. monopolist). The essence of the subsidized-menu problem is that prices are set below marginal cost, presumably to promote risk spreading and, possibly, distributional goals.

Our discussion of pricing applies to MSPs in general, and is not limited to formulary drug pricing applications. There are a number of other important

[34] The MSP belongs to the class of problems known as NP-complete, which means that the time it takes to find the optimal solution may grow exponentially with the size of the problem. GAMS and LINDO are commonly used to solve math programming problems like the multiple-condition MSP. Dobson and Kalish (1993) and Green and Krieger (1985) provide a technical discussion of specialized heuristics that can solve large single-condition MSPs to within 1% of optimality in seconds.

applications of MSPs in the health-care arena, and we discuss pricing in this broader context. The most general is what mix of services a provider, such as an HMO or an insurance plan, should offer. A key problem for such plans is the challenge that leads to MSPs: once an option is on the menu it will be selected by individuals who receive little benefit from it, since they pay but a fraction of the cost. Price could be raised to deter low-value users, but not high-value users, but that would sacrifice efficiency in risk spreading.

5.1. Profit maximization and price discrimination

The menu-setting formulation is adaptable to a range of objectives, including profit maximization, the presumed objective of a for-profit medical enterprise. The setter's strategy will depend on the extent to which she can price discriminate among the choosers. If she can perfectly price discriminate, she is a monopolist who has complete information about her choosers and is permitted to offer them different menus. Then the setter is no longer solving an MSP, but rather a classic assignment problem. In practice, such tailoring is rarely feasible in a medical setting; the same products must be offered at the same price to all individuals, or at least to broad classes of individuals. For example, all privately insured patients might pay one price, government-insureds another, and charity patients (who cannot be denied treatment) nothing. Moreover, even in a for-profit setting, if patients are risk averse with respect to monetary expenditures, there will be an up-front charge with use prices set below marginal cost. Thus, the MSP may appear even in a for-profit setting.

In many real-world situations, the choosers cluster into categories—say, patients with knee injuries—with a menu offered to each category. If the choosers remain heterogeneous within categories, then each category presents its own MSP. Consider, for example, the problem of a health plan deciding which medical treatments to offer its enrollees. In practice, patients are probably grouped by medical condition (e.g., knee injury, ear infection), and each patient with a certain medical condition is offered a menu of treatments designed specifically for that condition. The MSP framework can be adapted to model this type of problem by defining the decision variables to reflect the feasible chooser-item choice combinations, as in (3.0–3.6) and in (A.0–A.5). The resulting model is a powerful hybrid of the 'pure' MSP and assignment frameworks.

When the setter cannot identify the choosers but knows their distribution of preferences, then adverse selection prevents her from extracting as much surplus as above, but she can still price discriminate indirectly. If the setter is a monopolist, for example, she will provide products of quality lower than the ideal to the less lucrative segments of the population to minimize the switch to these products by the more lucrative segments. Alternatively, gold-plated products might lure and extract rent from the highest value customers, a pattern we see with luxury wings of hospitals. Of course, such tailoring can be done by altering any of

the products' attributes, including price. As the market power of the setter declines, prices will approach marginal costs.

5.2. Marginal cost pricing?

Let us return to the formulation where the setter seeks to maximize social surplus, as defined by the consumer welfare of participants in the plan. It is tempting to conjecture that efficiency concerns will lead a benevolent setter to use marginal cost pricing. However, benevolent setters are often concerned with more than mere economic efficiency. In many public and nonprofit settings, for example, prices are heavily subsidized or set at zero. In most medical care settings, including hospitals, HMOs, and drug formularies, the price to the consumer at the time of purchase is set well below its marginal cost. Such subsidies facilitate risk spreading and cater to various conceptions of social welfare (such as arguments that health care is a merit good or right). [35]

Distributional concerns may lead a benevolent social planner (who can differentiate among choosers) to cross-subsidize medical care by charging 'well-insured' patients a greater portion of their marginal costs than 'under-insured' patients. Moreover, marginal cost pricing may be ruled out by political considerations. For example, tuitions at most colleges are subsidized, and few people would prefer to charge chemistry majors more than English majors, even if the former cost more to educate.

Thus, while marginal cost pricing may promote efficient resource allocation, we do not expect to see it in practice in many settings in the health care field. Virtually all drug formularies subsidize drugs to some extent. [36] In MSPs with benevolent setters, marginal cost pricing, or indeed any pricing in pursuit of efficiency, should be thought of as one desideratum competing with such goals as political acceptability, distributional concerns, and risk spreading. Even for-profit medical plans may employ subsidies to promote risk spreading, thereby making their plans more attractive and permitting them to remain competitive at a higher premium.

The MSP framework can accommodate real-world constraints on pricing in a number of ways. For example, if the prices are predetermined (e.g., zero or a nominal copayment), they are in effect set *exogenously* and treated as *parameters* in the MSP. [37] The resulting problem then seeks the menu that maximizes welfare

[35] Note that in settings where subsidies occur, the setter is usually constrained by available resources such as the budget, and subsidies often must be covered by the premiums charged to all participants. See also [2], which discusses the drug-pricing problem taking society's rather than the provider's resource costs into account.

[36] In some circumstances, subsidies may be desirable from the standpoint of the plan's budget because they will induce drug compliance and thereby reduce future medical costs.

[37] Labor negotiations sometimes set pricing rules for drugs, but the composition of the formulary is left to the health plan or plans offered by the employer.

subject to politically or socially determined prices (and often a budget constraint). Instead of exogenously setting the prices, we may wish to set price ceilings on certain items or to restrict prices for certain classes of drugs or services to be identical. Each of these situations can be modeled without difficulty by adding appropriate constraints to the basic MSP model.

6. Limitations of the MSP framework for drug formularies

In this section, we consider a number of limitations to using the menu-setting framework to determine drug formularies, one of their most immediate areas of application, and thereby highlight areas for future research.

6.1. Data

A practical limitation of the MSP framework is the need for information about the benefits and costs of using drugs to treat medical conditions. For example, the MSP framework requires a global outcome measure to assess health benefits both within and across medical conditions. Unfortunately, there is no general agreement on methods for combining the measurement of the different dimensions of health outcomes such as morbidity and mortality into a unidimensional measurement scale, and some researchers question whether there can be a single best measure (Detsky, 1994). For example, Johannesson et al. (1993) and Zeckhauser and Shepard (1976) recommend using QALYs, Mehrez and Gafni (1989) recommend using healthy-year equivalents (HYEs), Gafni and Birch (1993) recommend using willingness-to-pay (WTP), and still others recommend using conjoint analysis to assess utility directly (Chinburapa and Larson, 1989; Maas and Stalpers, 1992; Hornberger et al., 1995). None of these measures is universally accepted, which is not surprising given the distributional consequences and ethical implications of each. [38]

Even the measurement of costs for drugs can sometimes be difficult and contentious. Although charges for drugs and services are relatively easy to capture, the relationship between such charges and underlying resource costs is tenuous in a system where reimbursement schedules, charity cases, and other factors distort the market (Willke, 1995). While the full firepower of econometrics can be applied when analyzing cost data, the collection of such data for drugs is poor (Willke, 1995). Fortunately, both the quality and the quantity of data are improving with the maturation of the field of pharmacoeconomics—which describes and analyzes both costs and outcomes of drug therapy to health care systems and

[38] In the discussion of the thrombolytic drug data in Table 1, we saw that the choice of output measure had a salient effect on the relative well-being of ‘under 75’ and ‘over 75.’

society. In any case, the MSP framework is available for use by formulary committees where the appropriate data are or might be made available.

6.2. Scope

The MSP framework can be used to determine the formulary that maximizes the health returns from a given level of pharmaceutical expenditures. By varying the budget, the user can sketch out the frontier of possible outcomes. But the framework cannot tell us what the tradeoff rate should be between health outputs (for example, QALYs) and dollars, which must be known if we are to set drug budgets appropriately, or maximize social surplus directly.

Moreover, just as we criticized formulary committees for considering one class of drugs at a time, we too can be criticized for taking an overly narrow view. By focusing solely on drug expenditures, we assume that expenditures on all other types of medical treatments are set at optimal levels. A broader perspective would determine the optimal amounts to spend on medical treatments of all kinds, not just different drugs. But critics concerned with allocating society's resources for all welfare-related activities would consider even this perspective too narrow. Where to limit the scope of one's analysis is a political, institutional, and philosophical question that must be answered for each formulary committee before it embarks on an MSP analysis.

The models considered here reveal the implications of a wide variety of assumptions when determining drug formularies. For example, a committee could examine the relationship between patient benefits and the pharmaceutical budget, or evaluate the impact of approving a given drug for a particular medical condition in terms of its benefits for patients and the budget. It could look at the distributional consequences of assuming a utilitarian objective function, and modify the model accordingly. The models can be used for extensive sensitivity analysis by altering data values as well as objective functions.

7. Conclusion

The menu-setting framework, here focused on determining a drug formulary, helps to address problems in a wide range of health-care settings. Three key characteristics of such settings are that (1) subsidies are common, thereby ruling out marginal cost pricing as an instrument sufficient to ensure an efficient outcome, (2) there are multiple medical conditions, and (3) within each condition patients are heterogeneous with respect to benefits from treatment.

The challenge of the MSP arises because patients choose (or have their physicians choose for them) drugs or treatments on a self-interested basis. Hence, the substantially simpler assignment problem cannot be employed to allocate patients to treatments. The agency loss of excess expenditure arises. The MSP

formulation is designed to curtail agency losses in such situations. In similar fashion, it can assist the employer who must select the menu of subsidized health care plans to be offered to employees.

The MSP framework permits optimization in a subsidized situation, but it does much more. It highlights the payoffs to both expanding and constraining alternatives, and it illuminates the virtues and limitations of using prices to limit demand. The MSP framework offers insights whenever a principal must design a program for a heterogeneous group of subsidized, self-interested agents; in effect in the vast majority of circumstances where health care is offered.

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Appendix A. The multiple-condition problem with prices

The following formulation of the multiple-condition problem is an extension of objective function (2.0), with appropriate constraints.

Parameters

K	the set of all r medical conditions to be treated
J	the set of all drugs considered for addition to the formulary
J_k	the set of all drugs that may treat condition k, $J_k \subseteq J$
K_j	the set of all medical conditions that may be treated with drug j, $K_j \subseteq K$
I_k	the set of all patient groups with medical condition k
v_{ijk}	the value to patient i, measured in monetary terms, of using drug j for condition k, $k \in K$, $j \in J_k$, $i \in I_k$
p_{jk}	the price to the patient of using drug j for condition k, $k \in K$, $j \in J_k$
$u_{ijk} = v_{ijk} - p_{jk}$	the utility a patient in group i gets from receiving drug j for condition k, $k \in K$, $j \in J_k$, $i \in I_k$
c_{ijk}	the unit cost of treating a patient in group i with drug j for condition k, $k \in K$, $j \in J_k$, $i \in I_k$
f_j	the fixed cost of including drug j in the formulary
B	the pharmaceutical budget

N_{ik} the expected number of patients in group i with condition k, $k \in K,\ i \in I_k$

Decision variables

z_j a binary variable indicating if drug j is added to the formulary, $j \in J$

y_{jk} a binary variable indicating if drug j is added to the formulary to treat condition k, $k \in K,\ j \in J_k$

x_{ijk} a binary variable indicating whether a patient in group i chooses drug j for condition k, $k \in K,\ j \in J_k,\ i \in I_k$.

The objective of the setter is to maximize social surplus. The formulation is:

$$\text{Social Surplus: Maximize}_{x,y,z,p} \sum_{k \in K} \sum_{j \in J_k} \sum_{i \in I_k} N_{ik}(v_{ijk} - c_{ijk})\, x_{ijk} - \sum_{j \in J} f_j z_j \qquad \text{(A.0)}$$

subject to:

$$\sum_{j \in J_k} x_{ijk} \le 1 \quad \forall k \in K, \forall i \in I_k \qquad \text{(A.1)}$$

$$x_{ijk} \le y_{jk} \quad \forall k \in K, \forall i \in I_k, \forall j \in J_k \qquad \text{(A.2)}$$

$$\sum_{l \in J_k} (v_{ilk} - p_{jk})\, x_{ilk} \ge (v_{ijk} - p_{jk})\, y_{jk} \quad \forall k \in K, \forall i \in I_k, \forall j \in J_k \qquad \text{(A.3)}$$

$$x_{ijk}, y_{jk}, z_l \in \{0,1\} \quad \forall k \in K, \forall i \in I_k, \forall j \in J_k, \forall l \in J \qquad \text{(A.4)}$$

$$\sum_{k \in K_j} y_{jk} \le r z_j \quad \forall j \in J. \qquad \text{(A.5)}$$

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