Proposals to improve the US health system are commonly supported by models that have only a few variables and overlook certain processes that may delay, dilute, or defeat intervention effects. We use an evidence-based dynamic simulation model with a broad national scope to analyze 5 policy proposals. Our results suggest that expanding insurance coverage and improving health care quality would likely improve health status but would also raise costs and worsen health inequity, whereas a strategy that also strengthens primary care capacity and emphasizes health protection would improve health status, reduce inequities, and lower costs. A software interface allows diverse stakeholders to interact with the model through a policy simulation game called HealthBound. (Am J Public Health, 2010;100:811–819. doi:10.2105/AJPH.2009.174490)

The multiple shortcomings of the US health system are well known. US health care spending per capita is the highest in the world, but Americans have comparatively high rates of morbidity and premature mortality, along with persistent disparities among subgroups. People with lower socioeconomic status, for example, are much more likely to develop disease and injury and to become disabled or die prematurely as a result, in part because they face greater health threats and are also less likely to have access to high-quality health care. Various theories have been offered to explain why the US health system performs so poorly and is so costly. Many point to the lack of health insurance for millions as the system’s chief problem, along with persistent disparities among subgroups. People with lower socioeconomic status, for example, are much more likely to develop disease and injury and to become disabled or die prematurely as a result, in part because they face greater health threats and are also less likely to have access to high-quality health care. Variations in medical practice and costs are then tested to determine whether alternative approaches might yield better results.

METHODS

We used the well-established methodology of system dynamics simulation modeling.
Figure 1 displays the major elements of this simulated system, and Table 1 lists the interventions that may be tested, individually or in combination.

Our intent was to trace the consequences of selected interventions in sufficient detail to calculate their likely combined impact over time on morbidity, mortality, health equity, and cost. Several hundred elements were needed to adequately represent the concepts and interactions depicted in Figure 1. Early in the process of developing the model, the Centers for Disease Control and Prevention (under whose auspices the model was developed) convened a stakeholder review involving about 25 policy leaders—including the senior staff of national health organizations, university faculty, and health policy analysts—to help ensure that the model’s boundaries, relationships, and level of aggregation were appropriate for representing the most important interventions and outcomes.

National-level data from the late 1990s and early 2000s were used to calibrate the model’s input parameters and to confirm that its output faithfully reproduced key historical metrics. These data included measures of death rates (National Vital Statistics Reports) and their disparity by income level, unhealthy days and access to primary care providers by income level (Behavioral Risk Factor Surveillance System), rates of health care utilization (National Ambulatory Medical Care Survey, National Hospital Ambulatory Medical Care Survey, National Nursing Home Survey, National Home Health Care Survey), prevalence of disease and asymptomatic disorders (National Health Interview Survey, National Health and Nutrition Examination Survey) and their disparity by income level, and health care costs by category (National Health Expenditure Accounts).

Model Logic and Assumptions
The model simulates changes over a 25-year period for the entire US population, which is divided into 2 socioeconomic groups—the advantaged and the disadvantaged—and further subdivided among 3 states of health: those with (1) symptomatic disease or injury, (2) asymptomatic disorders that may lead to symptomatic disease, and (3) no significant health problems. In the model’s causal structure, disadvantage erodes health partly by making life more stressful. Disadvantage also makes it harder for people to choose healthier behaviors and exposes them to more hazardous environments, leaving them more vulnerable to disease and injury.

The disadvantaged also have less access to health care than do the advantaged, because they have less insurance coverage and less sufficiency of primary care providers (PCPs) to meet current patient demand. The adverse conditions of the disadvantaged combined with poor access to health care means that the disadvantaged experience higher morbidity and mortality than do the advantaged, resulting in substantial health inequity.

Another factor in the model that affects health outcomes is the quality or thoroughness of care delivered, reflecting the extent to which providers follow guidelines for best practices in detecting and preventing illness, managing chronic diseases, and handling urgent events.

The model captures all reported health care costs associated with personal health services and supplies, plus administrative costs of health insurance. Together these costs account for more than 90% of all health-related spending in the United States. The model differentiates among payments to hospitals, office-based physicians, nursing homes and home health care, and dental and other health services, as well as spending on prescription drugs and other personal medical products.

Better access to and quality of care can improve health outcomes, but the effects of better access and quality on costs are less certain. For example, better preventive and chronic care can reduce the frequency of more costly acute complications and urgent hospital visits, but better preventive and chronic care require additional visits and medications. As a result, although good preventive and chronic care is typically cost-effective (improving health at reasonable cost and thus arguably worth doing), it does not typically reduce total health care costs.

For learning purposes, we have initialized the model in a “status quo” equilibrium, with all outcome variables unchanging and closely matching historical values circa 2003, the latest year for which some key data were available. The equilibrium setting lets planners easily understand the effects of their simulated interventions by comparing output values with the corresponding starting values. Interventions begin immediately at time zero and continue to the end of the 25 years of simulation, with specified direct effects and time delays.

Evaluating Interventions
Summary measures of population health simulated by the model include the number of unhealthy days per month and the annual death rate per 1000 persons. A less familiar but
TABLE 1—Intervention Options and Effects in Model Simulating the US Health System

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expand insurance coverage(^a)</td>
<td>Would improve access to quality care, meaning better health but also more spending on visits, procedures, and medications. Also would put more demand on limited supply of PCPs and would increase total insurance administration expenses.</td>
</tr>
<tr>
<td>Change self-pay fraction for the insured(^a) (cost sharing)</td>
<td>Increased cost sharing would reduce utilization of high-quality office care, meaning worse health but less spending. Also would alleviate some demand on limited supply of PCPs.</td>
</tr>
<tr>
<td>Change reimbursement rate for office visits</td>
<td>A lower rate would reduce spending on office visits but also would reduce PCP net income, which may lead to a decline in primary care supply.</td>
</tr>
<tr>
<td>Change reimbursement rate for hospital visits</td>
<td>A lower rate would reduce spending on hospital visits but also would hurt the quality of urgent care. A lower rate also would lead to reduced elective hospital capacity, thereby impairing the effectiveness of disease and injury management in some cases.</td>
</tr>
<tr>
<td>Simplify insurance (reduce administrative overhead)</td>
<td>Insurance plan standardization would reduce PCP administrative costs and thereby improve PCP income. Single-payer approach would do the same and also would eliminate the marketing, eligibility review, and negotiation costs of private insurance administration.</td>
</tr>
<tr>
<td>Increase preventive and chronic care quality</td>
<td>Would slow progression of asymptomatic disorders into disease and reduce frequency of acute and urgent episodes, but also would increase spending on office visits and medications while increasing demand on limited supply of PCPs.</td>
</tr>
<tr>
<td>Improve urgent care quality</td>
<td>Would reduce mortality and need for inpatient stays and extended care.</td>
</tr>
<tr>
<td>Expand primary care supply(^a)</td>
<td>Would alleviate shortages of PCPs, but if a surplus results, would reduce PCP average net income.</td>
</tr>
<tr>
<td>Improve primary care efficiency</td>
<td>Would alleviate shortage of PCPs and increase PCP net income.</td>
</tr>
<tr>
<td>Coordinate health care</td>
<td>Would reduce volume of office visits as well as elective hospital procedures and inpatient stays without adversely affecting quality of care. Could help alleviate PCP shortages, but if a surplus results, would reduce PCP net income.</td>
</tr>
<tr>
<td>Enable healthier behaviors(^a)</td>
<td>Would reduce the fraction of the population at elevated risk for asymptomatic disorders or disease and injury resulting from unhealthy behavior.</td>
</tr>
<tr>
<td>Build safer environments(^a)</td>
<td>Would reduce the fraction of the population at elevated risk for disease and injury, and for unhealthy behavior, resulting from an unsafe environment.</td>
</tr>
<tr>
<td>Create pathways to advantage</td>
<td>Would increase the flow of people from disadvantaged to advantaged.</td>
</tr>
</tbody>
</table>

Note. PCPs = primary care providers.

\(^a\)For advantaged or disadvantaged subgroups.

equally important metric is health inequity, which we calculate as the fraction of unhealthy days in the overall population attributable to the disparity between the advantaged and disadvantaged subgroups.

Another key simulation output is the net benefit of interventions, which is our summary measure of cost-effectiveness. Net benefit is calculated by subtracting the simulated change in total costs (health care costs plus direct costs of interventions) from the monetized change in quality-adjusted life-years (QALYs). We used a value of $75 000 per QALY, which falls in the middle of the range recommended by health economists.\(^{39,40}\) The change in QALYs resulting from intervention is calculated on the basis of changes in the simulated number of unhealthy days and in the simulated number of deaths.

Proposed interventions are evaluated according to 5 outcome measures: unhealthy days, deaths, health inequity, health care costs, and net benefit. Multiple metrics are needed to reflect distinct values at stake in the health system, as well as the potential trade-offs among them. Even if an intervention produces positive net benefit (improving health at reasonable cost), it may still be unacceptable to some stakeholders if it raises total health care spending or worsens inequity.

Many of the model’s input parameters are subject to some imprecision, often because diverse concepts have been aggregated. In particular, several interventions listed in Table 1 may encompass an array of activities having different costs and direct effects. For example, the cost of enabling healthier behaviors may range from relatively inexpensive population-wide measures (e.g., social marketing) to more costly individual interventions (e.g., smoking cessation therapy). Accordingly, sensitivity tests were performed around the ranges of possible parameter values to determine what effect, if any, the uncertainties may have on the rank ordering of scenarios according to various performance measures. For each scenario, the model was run under 3 settings: baseline, pessimistic (i.e., assuming weaker intervention effects with higher costs), and optimistic (i.e., assuming stronger intervention effects with lower costs). Specific values for these
configurations and additional details on the model’s information sources, logic, and assumptions are included in the technical appendix (available as a supplement to the online version of this article at http://www.ajph.org).

RESULTS

The results of 5 simulated intervention scenarios are presented below, starting with a strategy to expand insurance coverage and improve the quality of health care services. Table 2 shows the percentage changes in selected outcomes for the 5 scenarios at year 5 and year 25 relative to starting values, with all uncertain parameters set to baseline values. Figure 2 shows the impacts of the intervention scenarios over time in terms of per capita costs, QALYs, and net benefit. Cumulative 25-year impacts on costs, QALYs, and net benefit are presented in Table 3, which shows results corresponding to the baseline parameter settings as well as to the optimistic and pessimistic settings, to assess the effects of numerical uncertainties.

Coverage Plus Quality

In the scenario of coverage plus quality, insurance coverage was expanded for the entire population, advantaged and disadvantaged, causing the uninsured fraction to drop from 15.5% to less than 2% (data not shown). At the same time, initiatives were implemented to improve the quality of preventive, chronic, and urgent care. The fraction of office-based physicians following guidelines rose from 80% to 88%, leading to better diagnosis and care of asymptomatic disorders, disease, and injury, which in turn reduced the volume of visits for acute and urgent care. Also, the fraction of hospitals following guidelines rose from 80% to 88%, which reduced fatalities and ensured fewer inpatient stays and less need for extended care.

This strategy produced mixed results (Table 2). On the positive side, morbidity (unhealthy days) declined by about 6% by year 25, and mortality declined by about 12%.

### Table 2—Percentage Changes From Initial Value in Selected Outcomes in Model Simulating the US Health System at Year 5 and Year 25, by Scenario

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Coverage + Quality</th>
<th>Coverage + Quality + Capacity</th>
<th>Coverage + Quality + Capacity + Reimbursement Cut</th>
<th>Coverage + Quality + Protection</th>
<th>Capacity + Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhealthy days per capita per mo (initial = 5.26)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>-4.7</td>
<td>-6.4</td>
<td>-3.4</td>
<td>-9.5</td>
<td>-4.5</td>
</tr>
<tr>
<td>Year 25</td>
<td>-6.1</td>
<td>-11.1</td>
<td>-5.3</td>
<td>-20.7</td>
<td>-13.0</td>
</tr>
<tr>
<td>Deaths per 1000 persons per y (initial = 7.46)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>-9.7</td>
<td>-11.3</td>
<td>-5.4</td>
<td>-14.2</td>
<td>-4.5</td>
</tr>
<tr>
<td>Year 25</td>
<td>-11.8</td>
<td>-16.4</td>
<td>-8.2</td>
<td>-25.5</td>
<td>-13.1</td>
</tr>
<tr>
<td>Health inequity (initial = 0.143)</td>
<td>+2.3</td>
<td>-7.1</td>
<td>+0.5</td>
<td>-14.2</td>
<td>-15.2</td>
</tr>
<tr>
<td>Year 25</td>
<td>+6.9</td>
<td>-20.6</td>
<td>+3.3</td>
<td>-32.9</td>
<td>-26.8</td>
</tr>
<tr>
<td>Health care costs per capita per y (initial = $5434)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>+4.9</td>
<td>+3.5</td>
<td>-8.5</td>
<td>+1.3</td>
<td>-3.4</td>
</tr>
<tr>
<td>Year 25</td>
<td>+5.8</td>
<td>+2.6</td>
<td>-8.3</td>
<td>-4.6</td>
<td>-8.8</td>
</tr>
<tr>
<td>Disease and injury prevalence (initial = 0.378)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>-0.2</td>
<td>-0.3</td>
<td>-0.4</td>
<td>-3.3</td>
<td>-3.1</td>
</tr>
<tr>
<td>Year 25</td>
<td>-1.0</td>
<td>-2.0</td>
<td>-1.7</td>
<td>-12.6</td>
<td>-11.1</td>
</tr>
<tr>
<td>Effectively managed fraction of disease and injury (initial = 0.583)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>+14.8</td>
<td>+20.3</td>
<td>+10.0</td>
<td>+20.8</td>
<td>+4.6</td>
</tr>
<tr>
<td>Year 25</td>
<td>+17.2</td>
<td>+30.3</td>
<td>+12.0</td>
<td>+30.2</td>
<td>+6.9</td>
</tr>
<tr>
<td>Fraction of acute nonurgent visits to hospital versus physician office (initial = 0.143)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>+16.6</td>
<td>-15.3</td>
<td>+0.6</td>
<td>-18.5</td>
<td>-31.5</td>
</tr>
<tr>
<td>Year 25</td>
<td>+26.7</td>
<td>-40.1</td>
<td>+6.2</td>
<td>-41.0</td>
<td>-41.7</td>
</tr>
<tr>
<td>Sufficiency of PCPs (initial = 0.905)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>-6.8</td>
<td>+7.0</td>
<td>-0.1</td>
<td>+8.1</td>
<td>+10.5</td>
</tr>
<tr>
<td>Year 25</td>
<td>-7.8</td>
<td>+10.5</td>
<td>-1.3</td>
<td>+10.5</td>
<td>+10.5</td>
</tr>
</tbody>
</table>

Note. PCP = primary care provider. All scenarios computed according to baseline parameter settings.

*aWorst result among the 5 scenarios or an undesirable result.

*bBest result among the 5 scenarios.

*cHealth inequity is the fraction of unhealthy days in the overall population that is attributable to the disparity between the advantaged and disadvantaged subgroups.
improvement reflected greater utilization of higher-quality care, including a 17% increase in the effectively managed fraction of disease and injury. On the negative side, health care costs rose nearly 6% (5% because of increased coverage alone; data not shown). This result is in line with Hadley and Holahan’s statistical analysis indicating that extended coverage would increase health care spending by 3% to 6%.^42^ Health inequity in this scenario also worsened by 7%.

If preventive and chronic care prevented costly urgent events, why did costs rise? First, as noted above, good-quality preventive and chronic care, though cost-effective, do not in general reduce costs. Second, improved chronic and urgent care extends the lives of persons who often have costly conditions.^43^ Third, higher care utilization resulting from increased coverage and quality of care reduced the sufficiency of PCPs in the simulation, especially for disadvantaged patients. As a result, minor acute events that would otherwise have resulted in a visit to a PCP increasingly shifted to more costly care in hospital emergency departments.

If expanded coverage helped the disadvantaged more than the advantaged, why did health inequity become worse? Overloaded PCPs are at the root of this problem as well. Increased coverage and quality of care put some strain on PCPs for the advantaged population, but the increased demand for care for this subgroup was gradually met by an increased supply of PCPs, so the strain was minimized. By contrast, the supply of PCPs serving the disadvantaged was far from adequate to meet demand, even before our interventions. Because PCPs lacked the capacity to improve preventive and chronic care for all of the additional patients who obtained coverage, the health of the disadvantaged population did not improve nearly as much as that of the advantaged population. Recent experience in Massachusetts confirms that limited PCP capacity undercut the effect of expanded insurance coverage. ^44^ ^45^ There, expanded coverage enrolled more than 300 000 people, but a lack of PCP availability meant that many of the newly insured could not find a regular source of primary care.

The coverage plus quality scenario resulted in an increase in QALYs, but it also resulted in an increase in costs. Both QALYs and costs grew for the first 5 or so years and then remained at their increased levels (Figure 2). The net benefit for this scenario was positive throughout the simulation, amounting cumulatively to trillions of dollars over 25 years (baseline: $10 trillion; optimistic: $20 trillion; pessimistic: $5 trillion; Table 3). The positive net benefit tells us that this approach was cost-effective, though it appears to have serious drawbacks. Other

![Figure 2](image-url)

**Figure 2.—Outcomes in model simulating the US health system, by scenario for (a) per capita costs, (b) quality-adjusted life-years (QALYs), and (c) net benefit.**

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Note. The change in per capita costs equals the change in health care costs plus spending on intervention programs. The change in QALYs results from fewer deaths plus fewer unhealthy days. Net benefit is calculated as the product of the change in QALYs × $75 000 minus the change in costs. All 3 measures are presented here on a per capita basis, using total population as the denominator. All outcomes shown are computed according to the baseline parameter setting.
interventions would be needed to reverse the adverse cost and equity impacts.

**Coverage Plus Quality Plus Capacity**

The next scenario combined the coverage plus quality scenario with 2 interventions that increase primary care capacity. One intervention subsidizes the training and placement of new PCPs for the disadvantaged population, and the other makes existing primary care offices more efficient. A more efficient office has lower operating expenses and allows PCPs to see more patients in a day without skimping on quality. Reduced expenses, in turn, raise PCP incomes and encourage more medical students to become PCPs. As a result of these interventions, the shortages of PCPs seen in the previous simulation were eliminated in this second scenario by year 8 (data not shown).

Eliminating PCP shortages improved access for the disadvantaged and eventually reduced health inequity by 21%, leading to a 12% reduction in unhealthy days (11% decrease) and deaths (16% decrease). The effective management of disease and injury expanded by 30%, and improved preventive care among the disadvantaged allowed disease and injury prevalence to be reduced by 2%.

The extension of preventive and chronic care to disadvantaged persons caused no net increase in health care costs and in fact reduced the 6% increase seen in coverage plus quality alone to only a 3% increase. Why did the cost situation improve? When the shortage of PCPs was eliminated, many of the disadvantaged shifted their locus of care from hospital emergency departments to less expensive PCPs. This shift from emergency care to PCPs was the opposite of what occurred in the coverage plus quality scenario.

Adding capacity interventions to coverage plus quality increased net benefit by both increasing QALYs and reducing total costs (Figure 2). The cumulative net benefit increased by 48% to 84%, depending on the uncertainty settings (Table 3). Costs were still lower than in the status quo with no intervention at all, but with the elimination of PCP shortages, this approach improved health outcomes more cost-effectively while also reducing health inequity.

**Coverage Plus Quality Plus Capacity Plus Reimbursement Cut**

A third scenario combined the previous interventions with 20% cuts in reimbursement rates. These cuts applied to both office and hospital care and for all insurance types (both private and public), with no change in the fee-for-service payment scheme. The previous interventions improved health outcomes and equity but did not lower overall health care costs. We wanted to determine whether including reimbursement cuts would reduce health care costs while maintaining the previously achieved benefits.

These cuts did lower health care costs, by about 8% relative to the baseline. However, they also impeded the ability of hospitals to provide first-class urgent and elective care, thus undermining the quality interventions. The entire package with lower reimbursement reduced morbidity and mortality relative to the baseline, but by less than in the previous scenarios. The cuts also reduced PCP incomes, thereby inhibiting PCP supply and ultimately undermining the capacity interventions as well. The sufficiency of PCPs for the disadvantaged increased, but only negligibly and only in the short term, erasing the equity gains seen in the previous simulation. In addition, the cost-saving movement of disadvantaged patients from hospital emergency departments to PCPs seen in the coverage plus quality plus capacity scenario no longer occurred. In this way, the reimbursement cuts somewhat undermined...
their own intended purpose (to reduce health care costs).

Although the reimbursement cuts reduced total costs below the starting level, they undercut QALYs to such an extent that they would do more harm than good in terms of net benefit (Figure 2). Under all uncertainty assumptions, the cumulative net benefit over 25 years (Table 3) was lower than it was in the coverage plus quality plus capacity scenario by 14%–57%.

**Coverage Plus Quality Plus Capacity Plus Protection**

A fourth scenario combined the coverage, quality, and capacity interventions with 2 broad-based interventions for health protection, a concept encompassing both promotion of health and the ensuring of safer, healthier living conditions. One of the interventions enables healthier behaviors, reducing the prevalence of unhealthy behavior by 30% by year 5 and 43% by year 25. The other intervention builds safer environments, reducing the fraction of the population living in an unsafe environment by 36% by year 5 and 52% by year 25.

Adding health protection to the mix of interventions reduced the onset of disease and injury, causing the prevalence of these conditions to decline over time, by about 3% relative to the baseline by year 5 and 13% by year 25. By reducing the prevalence of disease and injury, the health protection interventions improved most of the metrics in Table 2, including unhealthy days (21% decrease relative to baseline by year 25), deaths (26% decrease), health inequity (33% decrease), and health care costs (5% decrease). Inequity was reduced because the disadvantaged, who have a larger share of behavioral and environmental risks than the advantaged do to begin with, benefited disproportionately when these problems were addressed. Costs went down for 2 reasons. First, lower disease and injury prevalence translated directly into lower costs. Second, lower prevalence also meant less demand on PCPs, which further alleviated PCP shortages (eliminated by year 7 of the simulation) and further reduced the fraction of visits for acute care going to more expensive hospital emergency departments rather than PCPs.

Effective health protection interventions may be costly to implement, and we have estimated conservatively that they would cost hundreds of dollars per beneficiary, rising to thousands in the pessimistic setting. Greater spending was required in the earlier years, when there were more potential recipients, than in later years, after the interventions had time to reduce the number in need. This initial investment explains why, as Figure 2 shows, simulated total costs rose for the first several years above those of the previous scenarios. However, total costs dropped rapidly as the beneficial impacts of the combined investment began lowering health care costs, and as the magnitude of the investment itself declined. By year 14, total costs crossed the zero line into the region of net savings.

This scenario produced the greatest net benefit under all uncertainty settings, and the greatest increase in QALYs (Figure 2; Table 3). The fact that this conclusion held true even under the pessimistic setting, with its considerably larger assumed intervention costs, underscores how powerfully cost-effective these population-based interventions could be.

**Capacity Plus Protection**

Although the greatest overall improvement was delivered by combining interventions from 4 different intervention categories (coverage, quality, capacity, and protection), this combination did not reduce health care costs in the early years of the simulation; they were still up 1% as of year 5. During those early years, the reductions in health care costs resulting from the capacity and protection interventions did not reach their full potential to overcome the increases in costs caused by expanding coverage and improving quality.

A final scenario considered how much capacity plus protection by themselves could accomplish. Improvements in morbidity and mortality were not as substantial as for the more comprehensive 4-component scenario, of course, but over time these 2 measures did reduce morbidity and mortality more than did the coverage plus quality approach. Also, absent the additional demands on PCPs from expanded coverage and quality, the capacity and protection interventions caused PCPs for the disadvantaged to be sufficient by year 4—earlier than it was in any other scenario. As a consequence, health inequity was impressively reduced (27% by year 25), despite the lack of expansion in insurance coverage.

Health care costs declined in this scenario, even early on (down more than 3% in year 5), and increasingly over time (9% by year 25). Initially, the cost reduction came primarily from patient visits shifting from hospital emergency departments to PCPs as a result of the capacity interventions; but later, additional cost reductions came from the declining prevalence of disease and injury as a result of the protection interventions.

The capacity plus protection approach produced less net benefit than the full 4-component combination (Figure 2; Table 3), as expected, but it ultimately produced more net benefit than did the coverage plus quality approach. The capacity plus protection approach quickly (after the first couple of years of initial investment) became lower in total costs, and increasingly so over time (Figure 2). And though it took capacity plus protection a longer time to generate QALY improvements, by year 9 it surpassed coverage plus quality in this respect as well. Consequently, the net benefit from capacity plus protection started below that of coverage plus quality but surpassed it by year 7. Our simulations suggest that, over 25 years, capacity plus protection was likely to contribute significantly more cumulative net benefit than coverage plus quality alone, but with some uncertainty (Table 3).

**DISCUSSION**

These simulations suggest that a strategy of expanding insurance coverage and improving health care quality is clearly cost-effective (providing reasonable value for the money), but if implemented without other interventions would likely yield only modest improvements in health while increasing costs and worsening health inequities. One roadblock to the success of this approach is an insufficiency of PCPs to handle the additional workload, especially for the disadvantaged portion of the population. Expanding primary care capacity for the disadvantaged could dramatically improve access and equity and would help to lower costs by encouraging a shift to PCPs and away from expensive...
hospital emergency departments for the care of minor ailments.

This analysis also suggests that population-based health protection efforts enabling healthier behaviors and ensuring safer environments are indispensable for reducing the prevalence of disease and injury and thereby for improving health and reducing inequity while lowering costs. Improvements in health care quality would do little by themselves to reduce disease prevalence, because these improvements would do nearly as much to extend life as they would to reduce the onset of new disease and injury.

Broad cuts in insurance reimbursement rates to providers would likely be counterproductive, reducing costs at the expense of health and health equity. A previous dynamic analysis suggested that reimbursement cuts may not even accomplish their primary aim of reducing health care costs and instead may incite an inflationary tug of war between insurers and providers, who have a variety of ways to circumvent cost-containment efforts. Such cuts would undermine the benefits of the other interventions by impairing hospital services and making primary care an even more undesirable choice for medical students than it already is.

In the midst of an active national debate over health reform, it is useful to consider how the elements of coverage, quality, capacity, and protection could be addressed to maximize the opportunity for improvement and avoid the mistake of doing too little, as coverage plus quality alone would likely be. Indeed, with cost a primary concern, the cost-saving interventions of capacity and protection take on additional importance and are needed now, not later, to offset the likely cost increases from coverage and quality.

Limitations and Extensions

Our dynamic model of the US health system is, like all models, a simplified version of reality, with many limitations and uncertainties that make it impossible to use the model to predict the future with precision. Although this model is simplified, it integrates a wider spectrum of what is known about health system dynamics than do narrower analyses and thus more fully captures the potential impacts of possible interventions. Moreover, sensitivity testing demonstrated that the conclusions drawn from the model are robust to many numerical uncertainties. However, the model does have limitations and is a work in progress that will continue to evolve with new information, policies, and stakeholder perspectives.

One limitation is the use of an equilibrium base case, which required that we exclude several known trends affecting the health system. These include, for example, the spread of new medical technologies, population growth and aging, the practice of defensive medicine, the medicalization of common ailments through direct-to-consumer advertising, changing lifestyles, and changes in economic prosperity. To gauge the significance of these exclusions, we developed an extended model that includes 2 key trends: health care price inflation and aging of the population. Analyses using the extended model confirmed that the general conclusions described in this article are not affected by either of these exacerbating trends (data not shown).

Another possible limitation is that the model represents interventions in broad strokes, without detailing precisely how they might be implemented. We contend that there is value in first understanding the likely consequences of major intervention options before delving into specific tactics. Nevertheless, some policy leaders may want greater specificity.

An Opportunity for Game-Based Learning

Intervention planners and change agents can use this simulation model to improve their understanding of how the US health system may respond to different interventions and why. An Internet-based user interface allows nonmodelers to interact with the tool in the form of a policy simulation game called HealthBound. Serious games such as this one are gaining popularity, in part because they support both cognitive and experiential learning without relying on expert analysts as go-betweens. As players explore scenarios for themselves, they learn how to act more effectively in the real world.

One of the biggest impediments to health reform initiatives is that different stakeholders tend to approach the challenge differently, each focused only on a few parts of the overall system. By contrast, HealthBound offers a more comprehensive and neutral framework for intervention planning that can be especially useful for unfreezing attitudes and expanding perceptions. When used in multistakeholder groups led by a trained facilitator, HealthBound allows stakeholders to learn not only from the game but also from each other, as players test and refine their ideas in this simplified but realistic version of the US health system.

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Contributors

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