A Systems Dynamics Analysis of Recent Health Care Reform in the U.S.

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ESE 499 Systems Design Project
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Abstract

The Patient Protection and Affordability Care Act of 2010 (PPACA) aims to make numerous changes to reform the United States Health Care Industry. Many of these changes fall under three categories: improving the quality of health care, expanding health insurance coverage, and increasing the efficiency of the delivery system. This review analyzes what impacts these intervention programs could potentially have using a dynamic simulation model developed by the Center for Disease Control and Prevention (CDC) with input from stakeholders, subject-matter experts, and systems scientists.

This analysis finds that increasing insurance coverage or the quality of care will cause health care costs to increase, but increasing efficiency results in a decrease in total costs relative to no intervention. Combining all three interventions at once results in a decrease in the change of health care costs.

Examining net benefits, improving solely the quality of care results in a $10.1 trillion net benefit change over 25 years, and increasing efficiency leads to a $1.2 trillion net benefit change. On the contrary, increasing insurance coverage alone results in a $438 billion loss. However, when the three programs are completed together, the health gains due to expanded insurance coverage are increased by the gains from efficiency and quality. This results in a net benefit of $15.6 trillion, significantly higher than the net benefit of $14.0 trillion if only quality and efficiency are improved.

Increasing insurance coverage, efficiency, and quality simultaneously results in the highest net benefit. These findings have significant implications for health care decision makers. To achieve the greatest benefit from PPACA and other health care reforms it is important to accompany expansion of health care insurance coverage with increases in the quality of care and efficiency of the health care system.

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Background

US Health Care Industry
The growth rate of health care spending in the United States is significantly higher than the growth rate of the economy (CBO 2010). It is predicted that by 2080 health care spending will make up 40 percent of the US economy (CBO 2010). Although overall spending is high, large disparities remain between advantaged and disadvantaged populations. These differences are largely due to lack of insurance coverage and limited access to high-quality health care (Gruber 2011). The two major sources of public insurance coverage are Medicare, which provides universal insurance to the elderly, and Medicaid, which provides coverage for the poor, particularly those with children.

Patient Protection and Affordability Care Act
The Patient Protection and Affordability Care Act (PPACA) was passed in 2010 in attempt to expand insurance coverage and address disparities in health care in the United States. Three of the primary ways the PPACA plans to impact the health care system are through improving the quality of care, increasing insurance coverage, and increasing efficiency.

Improved Quality of Care
The PPACA seeks to improve the quality of care a number of ways. Preventative care will increase through the Medicare expansion to cover the full cost of annual wellness visits and personalized prevention plan services. Medicare will also create a physician payment program to reward physicians based on the quality of care rather than the volume of their services. Physicians will further be encouraged to form accountable care organizations to improve the quality and efficiency of care. Finally, Medicare will implement an incentive program to improve quality outcomes for urgent care. Hospital readmission rates will be tracked and financial incentives will seek to lower preventable readmissions (Gruber 2011).

Increased Insurance Coverage
The three primary goals of the insurance coverage component are to make insurance more affordable, outlaw exclusions for pre-existing conditions and other discriminatory practices, and mandate insurance (Gruber 2011). State health insurance exchanges will open for small businesses and individuals. Medicaid will expand to cover individuals with income up to 133 percent of the federal poverty level.
Individuals with incomes of up to 400 percent of the poverty level will be able to use healthcare tax credits to purchase insurance. The insurance mandate will require almost everyone to purchase health insurance or pay a $695 tax penalty (Andrews 2010). Health plans will no longer be able to exclude individuals from coverage based on pre-existing conditions.

**Increased Efficiency**

The PPACA aims to cut costs through improving the efficiency of delivery and coordinating care across the health care system. Physicians will be incentivized to increase their efficiency through accountable care organizations. A national pilot program will begin in 2013, bundling payment to encourage care providers to better coordinate patient care (Gruber 2011).

**The HealthBound Model**

This project extends an analysis of the HealthBound policy simulation model, developed by the Center for Disease Control and Prevention (CDC) to model the United States health care system. The model was designed with input from stakeholders, subject-matter experts, and systems scientists.

This model approximates conditions observed in 2003, the last year for which key data were available. It is based on data from ten national databases and key reference studies. The model does not predict exact forecasts, but offers insight into how the US health care system tends to respond to significant intervention initiatives. The simulation results allow the comparison of broad categories of interventions based on their timing, costs, benefits, and impact on other key areas.

The model includes approximately 850 variables, 200 specified constants, and 9 X-Y lookup functions that capture dynamic relationships within the health care industry. It spans health status, equity, and costs, and it is detailed enough to allow insight into health delivery, financing, and decision making. More technical detail regarding the model can be found in the attached Technical Appendix.
Figure 1: Major Causal Pathways in the Model
Main outcome variables are red. Possible areas for policy intervention are brown. Blue arrows indicate increasing effect and green arrows indicate decreasing effect.

**Systems Dynamics Modeling**

The HealthBound model is developed according to the principles of system dynamics modeling. It focuses on dynamics due to causal relationships between elements in the system and seeks to gain insight about reinforcing and balancing feedback loops. Systems dynamics modeling differentiates itself from other forms of mathematical modeling by including the impacts of accumulations, time delays, resource constraints, and behavioral feedback (Milstein 2010).

**Model Analysis**

**Intervention Programs**

**Improved Quality of Care**

The intervention simulating an improved quality of care impacts urgent care, preventative care, and chronic care. As seen in Figure A-1, this intervention affects hospital quality by gradually increasing quality of care and the number of hospitals impacted by the intervention. Figure A-2 shows how the intervention increases the number of providers it influences over time as well as the intended quality of preventative and chronic care. The intended quality of preventative and chronic care is decreased due to patients not following recommendations and prescriptions of their health providers.
Increased Insurance Coverage
The insurance intervention program increases coverage for both the advantaged and disadvantaged populations, as seen in Figure A-3. This intervention increases coverage from 84.4% to 99.7% after 25 years. In reality, it is expected that the uninsured population would remain higher, partly due to undocumented immigrants and others who choose to risk paying fines (Gruber 2011). However, this scenario can offer insight into system impacts if an insurance coverage intervention program were able to perform more ideally.

Increased Efficiency
This intervention increases the efficiency of the health system by increasing the coordination of care between hospitals and non-urgent care settings and by increasing the efficiency of primary care physicians. Care coordination gradually decreases the demand for the management of disease and injuries (Figures A-4 and A-5), decreases the fraction of patients going to a specialist for non-urgent care (Figure A-6), and increases demand for acute non-urgent visits (Figure A-7). Increasing primary care physician operational efficiency gradually increases the providers benefitting from the increased efficiency and increases the level of efficiency over time (Figure A-8).

Improved Quality of Care + Increased Insurance Coverage + Increased Efficiency
By layering intervention scenarios, we are able to see how complementary endeavors may increase the net benefits. This program combines the previously described interventions of improved quality of care, increased insurance coverage, and increased efficiency.

Results

Key Findings

Health Care Costs
An influencing factor in health-care decision making is the impact on overall health care costs. Financial impacts weigh into the value of a program and impact whether or not it is worth the cost of implementation. Increasing efficiency leads to a decreased total cost, while increasing insurance coverage and improving the quality of care increase the total cost (Figure 2). The intervention that combines all three programs shows an initial sharp decline in costs followed by a gradual increase, although it is still less than the cost if no intervention occurs.
Comparing advantaged and disadvantaged populations, we see that health care reform will have different economic impacts for these two groups. Improving the quality of care will increase costs for both groups, but will increase costs slightly more for people from an advantaged background.

Increasing insurance coverage will increase costs per capita for the advantaged population by $254 and for the disadvantaged population by $1167 cumulatively over 25 years. This difference is likely due to the difference in insurance coverage between the two groups. The intervention increases coverage for the disadvantaged population from 75.9% to 99.5% and for the advantaged population from 86.8% to 99.7%. As the uninsured become insured, more health resources are used, increasing total health care costs.

Increasing efficiency will cut costs per capita for the advantaged population by $899 and by $1148 for the disadvantaged population cumulatively over 25 years. Increasing efficiency decreases the demand/capacity ratio for primary care physicians (PCPs) serving the advantaged population from 85.2% to 65.1% and for those serving the disadvantaged from 119.5% to 73.2% after 25 years. Not only is there a greater decrease in the demand/capacity ratio for the disadvantaged population, we see that the utilization of PCPs becomes less than the critical value of 100%, meaning that more patients have access to a PCP and can avoid high costs associated with seeking care elsewhere or delaying treatment. Care coordination also decreases these costs by reducing the demand for visits due to disease and injury as well as decreasing the fraction of patients going to a specialist for non-urgent care.
Death Rate

Death rate can offer insight into how well an intervention program can prevent avoidable deaths. In Figure 3 we see that increasing efficiency has very little effect on the number of deaths. Increasing insurance coverage slightly decreases the number of deaths, but is still relatively flat. However, improving the quality of care significantly reduces the number of deaths. Notably, the layered intervention magnifies the effect of the individual programs to yield a much greater reduction of death.

The number of deaths is influenced by the number of people with disease or injury and the death rate of those with disease or injury. Increasing efficiency and increasing insurance coverage have very little impact on these variables. Improving the quality of care, however, decreases the death rate for this group after 25 years by 11.3%. Small changes to a system accumulated over time can result in large impacts to a system. Comparing the 25 year end results for this model we see that the solution that combines improving quality of care, increasing insurance coverage, and increasing efficiency results in a decrease of 1.96 deaths per thousand. Individually, improving quality of care decreases deaths by 1.33, increasing insurance coverage decreases deaths by 0.17, and increasing efficiency decreases deaths by 0.08. Summing these values together would result in a reduction of 1.58 deaths per thousand. However, examining the model shows that the intervention programs are reducing the rate of death, so over time a greater reduction is achieved by combining the interventions.
**Quality of Urgent Care**

Increasing efficiency and insurance coverage has almost no impact on the quality of urgent care. However, the intervention program that sought to improve the quality of care was effective in impacting urgent care. Figure 4 shows that improving the quality of care results in an 11.5% increase in the fraction of hospitals offering high-quality urgent care after 25 years. The benefits of the program level off after about 10 years with 88.3% of U.S. hospitals having high-quality urgent care, indicating that there are factors outside of the program’s reach impacting urgent care quality.

![Change in Quality of Urgent Care](image)

*Figure 4: Change in Quality of Urgent Care Over 25 Years*

The quality of urgent care increases by 10% for the advantaged population and by 15% for the disadvantaged population. Figure 5 shows the increase in care for both groups over time. The disparity in the quality of urgent care slightly decreases due to the intervention, but the disadvantaged population still makes up the same percentage of the uninsured population. The benefits from the program changes level off after about 8 years.
Uninsured Populations

The intervention program that focused on increasing insurance coverage was able to increase coverage rates from 88.4% to 99.6%. Without any intervention the uninsured population will continue to grow (Figure 7). As a result, the change in the uninsured fraction continues to decline rather than leveling off (Figure 6). Increasing efficiency significantly decreases health care costs per capita. This corresponds with a change in the fraction of the population that is insured based on previous research. Similarly, improving the quality of care raises health care costs, resulting in a slight increase in the number of people who are uninsured.
Quality Adjusted Life Years

Quality-adjusted life years (QALYs) are the number of years of life discounted for loss of quality. After 25 years, increasing efficiency and increasing insurance coverage result in a slight increase in QALYs per capita. Improving the quality of care has a much larger influence on the change in QALYs at 0.028 years per capita. Simultaneous increase in quality of care, insurance coverage, and efficiency results in the highest increase in QALYS per capita at 0.044 years.
**Net Benefit**

The net benefit is the summary measure of cost-effectiveness. The net benefit of an intervention program is assessed by multiplying the cumulative improvements in QALYs by the value per QALY and subtracting the cumulative change in costs. The value of one QALY was assumed to be $75,000, a mid-point value based on the recommendations of health economists (Milstein 2010).

Only improving the quality of care results in a large net benefit change of $10.1 trillion over 25 years (Figure 9). Increasing efficiency while holding other values constant results in a $1.2 trillion net benefit. However, only increasing insurance coverage leads to a $438 billion net loss. Combining the three intervention programs leads to a net benefit of $15.6 trillion. Intuitively, one may assume that omitting the expansion insurance coverage with its negative net benefit would result in the solution with the highest benefit. However, if only efficiency and quality are increased the net benefit over 25 years is only $14.0 trillion. Revisiting the QALY analysis, the factors that lead to a relatively small increase in QALYs due to increased insurance coverage lead to a much larger increase in QALYs when combined with increased efficiency and quality.

![Change in Cumulative Net Benefits](image)

*Figure 9: Change in Cumulative Net Benefits Over 25 Years*
Conclusion

Increasing the quality of care, insurance coverage, and efficiency of the U.S. health care system has the potential to bring many benefits. System dynamics modeling offers insight into how these changes, even small ones, can build up into large results over time.

This analysis shows that interventions aiming to improve the quality of care and increase efficiency have the potential to have high net benefits. On the other hand, it predicts a decline in net benefits if the only intervention is increasing insurance coverage. However, based on this simulation model, if insurance coverage is increased along with increasing efficiency and quality, the intervention programs complement each other resulting in the highest net benefits.

Decision makers involved with health care reform should note the vital role that changes to efficiency and quality of care bring to the PPACA. These components are not secondary components added to an insurance overhaul, they may in fact be critical to yielding the potential benefits of increased insurance coverage.
Works Cited


Efficient frac of PCP offices initial

- Efficient frac of PCP offices
- Max possible increase in efficient frac of PCP offices from program
- Time to influence PCP operational efficiency from program

- Increase in efficient frac of PCP offices from program
- Program cost to get operational efficiency for additional PCP

- PCP operational efficiency program spending
- Providers benefiting from PCP efficiency program
- <Primary care providers total>
## Cumulative 25-Year Changes Relative to No Intervention

<table>
<thead>
<tr>
<th>Metric</th>
<th>Improved Quality</th>
<th>Increased Insurance Coverage</th>
<th>Increased Efficiency</th>
<th>Improved Quality of Care + Increased Insurance Coverage + Increased Efficiency</th>
</tr>
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<tbody>
<tr>
<td>Total Health Care Costs ($ Billions)</td>
<td>118.0</td>
<td>137.2</td>
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<td>-79.3</td>
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<tr>
<td>Health Care Costs Per Capita ($)</td>
<td>229.75</td>
<td>448.6</td>
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<td>-497.77</td>
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<tr>
<td>Health Care Costs Per Capita Advantaged</td>
<td>239.13</td>
<td>253.81</td>
<td>-898.69</td>
<td>-534.12</td>
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<td>Health Care Costs Per Capita Disadvantaged</td>
<td>205.64</td>
<td>1167.69</td>
<td>-1148.14</td>
<td>-313.60</td>
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<tr>
<td>Deaths Per Thousand</td>
<td>-1.32</td>
<td>-0.17</td>
<td>-0.08</td>
<td>-1.96</td>
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<tr>
<td>Deaths Per Thousand Advantaged</td>
<td>-1.19</td>
<td>-0.16</td>
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<td>Deaths Per Thousand Disadvantaged</td>
<td>-1.86</td>
<td>-0.23</td>
<td>-1.12</td>
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<tr>
<td>Quality of Urgent Care (Fraction of Hospitals with High-Quality U.C.)</td>
<td>0.12</td>
<td>0.00</td>
<td>0.00</td>
<td>0.12</td>
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<tr>
<td>Quality of Urgent Care Advantaged</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.10</td>
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<td>Quality of Urgent Care Disadvantaged</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.15</td>
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<tr>
<td>Uninsured Fraction of Population</td>
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<td>-0.175</td>
<td>-0.02</td>
<td>-0.18</td>
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<tr>
<td>Uninsured Fraction of Advantaged</td>
<td>0.00</td>
<td>-0.15</td>
<td>-0.02</td>
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<tr>
<td>Uninsured Fraction of Disadvantaged</td>
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<td>-0.27</td>
<td>-0.03</td>
<td>-0.27</td>
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<tr>
<td>Total Program Spending ($ Billions)</td>
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<td>1.07</td>
<td>8.00</td>
<td>10.51</td>
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<td>Sufficiency of PCPs (Utilization)</td>
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<td>-0.05</td>
<td>0.10</td>
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<td>Sufficiency of PCPs Advantaged</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Sufficiency of PCPs Disadvantaged</td>
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<td>0.30</td>
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<tr>
<td>Cumulative Improvement in QALYs (Millions)</td>
<td>154.47</td>
<td>25.14</td>
<td>6.48</td>
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<td>Cumulative Net Benefit ($ Trillions)</td>
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<td>-0.438</td>
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<td>Cumulative Net Benefit Per Capita ($)</td>
<td>1423</td>
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<td>241</td>
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<td>1420</td>
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