SUID: | |

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Exam 3
Fall 2019

DO NOT OPEN THIS EXAM UNTIL YOU ARE TOLD TO DO SO.

Instructions

1. Write your SUID in the upper right corner of this exam. **DO NOT WRITE YOUR NAME**.

2. **SHOW ALL YOUR WORK**. Answers without supporting work will receive little or no credit.

3. There are 120 points on the exam and you'll have 180 minutes to complete it. Be sure to budget your time accordingly.

4. Some questions provide a blank table you can use to organize your calculations. Be sure to label the columns clearly. Where applicable, show the equation for the column in the bottom row of the table. The tables may have more rows or columns than you need.

5. Do all your work on the exam. If you need extra space, write on the backs of the pages. However, if you do write an answer on the back of a page, be sure you've **NOTED THAT NEAR THE QUESTION.**

6. Some potentially helpful formulas and equations:

$$\frac{1}{2}bh \qquad \frac{F_t}{(1+r)^t} \qquad \frac{F}{r}$$

Question 1 (15 points)

The US has more than 50,000 community water supply systems. Many are small, very old, and need a lot of maintenance and upgrading. One policy sometimes suggested is to merge several small systems into one large one because a large system can be cheaper to build and maintain. This question explores the tradeoffs involved.

Suppose a community needs to upgrade its water system and is considering two options: I and M. Under I the community would remain independent and upgrade its system on its own. Doing so would cost $4 million per year for 5 years (years 1-5). Starting in year 6 the new system would begin providing $2 million of benefits per year, which would go on forever. Under M the community would merge its system with that of a neighboring town and then carry out the upgrade. The upgrade would cost less per year, $2 million instead of $4 million, but the need for coordination would cause it to take 7 years instead of 5 (years 1-7). It would also provide slightly lower benefits, $1.8 million per year, since the community would have to give up some control of the system. The benefits would begin in year 8 and go on forever. The community uses a 5% interest rate in present value calculations.

Please ☐ determine the net present value of each option and ☐ indicate which the community should choose.

Question 2 (15 points)

Ransomware, which encrypts a computer's files and then demands a payment for decrypting them, is an increasing problem for cities. For example, two days ago, Pensacola, Florida, was the victim of what appears to be a ransomware attack and many of its systems are currently down. Dealing with cybersecurity threats in general, and ransomware in particular, involves two kinds of actions: prevention, which reduces the chance of an attack (installing operating system patches, using firewalls properly, adopting two-factor authentication, etc.) and recovery, which reduces the damage caused by an attack (frequent backups, business-continuity plans, etc.). This problem examines a stylized example of the tradeoffs.

Suppose a large city believes that it currently has a 10% chance of being a victim of a ransomware attack, and that the damages from an attack would be $100 million. It is considering two policies: P and R. Policy P would focus on prevention. It would cost $4 million and would reduce the chance of an attack to 3%. Policy R would focus on recovery. It would cost $2 million and would reduce the damage from an attack to $40 million. In addition, if it has enough funding, the city could do both P and R. That would save money relative to doing them separately and cost $4.5 million total. The impacts of the policies would be the same if they were done separately (the probability of a successful attack would fall to 3% and the damages would fall to $40 million).

You may assume that the city is risk-neutral and would like to pick the approach that has the best expected value. You may also assume that everything (costs, attacks, recovery) happens in a single year, so no PV calculations are needed.

Please determine: ☐ What the city should do if the maximum it can spend on cybersecurity is $4M; ☐ Why is that best? ☐ What should the city do if it could spend up to $6M? ☐ If the larger budget changes the decision, briefly explain why the overall benefit changes the way it does; if it does not change the decision, explain why not.

Question 3 (15 points)

A city would like to build a new sports stadium and is considering two locations: G and B. Location G is a "greenfield" site: open land that has not been used before. Building at G would cost $10 million per year in years 1-4, and starting in year 5 the stadium would produce $3 million in benefits per year forever. Location B, in contrast, is a brownfield and may be clean (state C) or contaminated (state D for dirty). The probabilities of C and D are both 50%. If the site is clean, construction would have the same cost and schedule as location G and benefits would begin in year 5. However, because the city eliminated a brownfield in the process, the benefits would be larger: $4 million per year rather than $3 million. If the site is dirty, construction would still cost $10 million per year but would take twice as long (years 1-8) due to the need to remove the contamination. In year 9 the stadium would begin producing $4 million in benefits. Once the city begins construction at either site it must finish the job: it can't abandon a partly-completed stadium. However, the city could hire a testing company to determine whether or not B is contaminated before choosing the site. The test results would be available in year 0 and would not delay construction. Unlike the memo assignment, however, the test is not mandatory: the city could opt to build the stadium at B without testing if that were the best option.

Assuming the test is infallible, and that the city is risk-neutral and makes decisions by maximizing expected value, what is the maximum the city would be willing to pay for the test? The city uses a 5% interest rate in present value calculations.

Question 4 (15 points)

Governments sometimes use subsidies and other incentives in the hope that they will accelerate the development of a market with a desirable characteristic. One example is a suite of policies in the US aimed at building a market for electric vehicles, since that would help reduce the carbon dioxide emissions from transportation. This problem explores a stylized example of such a policy.

Suppose there is a promising new technology T. If the government does nothing, development of T will take 20 years and has a 30% of succeeding and a 70% chance of failing. Call those two states MS for market-only success and MF for market-only failure. If MS occurs, the technology will produce $10 billion in externality benefits starting in year 21 and continuing on forever. If MF occurs, it will produce no externalities.

(a) 5 points. Please calculate: ☐ the expected present value of the externality benefits if the government does nothing. Throughout the problem you may assume the government uses an interest rate of 5% in present value calculations.

Question 4, continued.

Now suppose the government is considering a stimulus policy (P) to encourage development of the technology. The policy would cost $1 billion per year in years 1-20 and has three possible outcomes. In the best case, outcome PH (for policy-high), development of the market would be accelerated and the technology would succeed sooner than under the market alone: PH would produce $5 billion of benefits in years 11-20 and $10 billion forever starting in year 21. Under the next best case, outcome PM (for policy-middle), the technology would succeed on the original schedule: that is, benefits would $10 billion beginning in year 21. Finally, under lowest outcome, PL, the technology would fail and not produce any benefits at all. The probability of PH is 20% and the probabilities of PM and PL are each 40%.

(b) 10 points. Please: ☐ determine the expected net present value of the policy; ☐ indicate whether or not the government should undertake it. If the government goes ahead with the policy, determine ☐ which effect was more important: the early benefits in years 11-20, or the increased likelihood of the benefits from year 21 on. Be sure to be quantitative. You may assume the government is risk-neutral when making these kinds of decisions.

Question 5 (15 points)

A non-profit organization helps small businesses choose health insurance plans for their employees. It has total costs given by the following equation: $TC = 5{,}000 + 50 * Q^2$, where Q is the number of businesses it serves. It believes the demand for its advice is given by $P = 2000 - 20 * Q$, and there are no other organizations nearby providing a similar service. The organization wishes to serve as many businesses as possible without running a deficit.

What price should the organization charge and how many businesses will it be able to serve? How much profit will it earn? As a hint, the value of Q is between 19 and 29, inclusive.

Question 6 (15 points)

Suppose an engineer has an idea for a new device that would help make 5G cell networks much more secure. She's considering quitting her job to develop it. If she succeeds, she will be the only seller of the device and her demand would be given by $WTP = 19{,}000 - 200 * Q$. Her production costs would be given by $TC = 200 * Q$. Assuming she is able to develop the device, what price would she charge and what quantity would she produce in each year during the time she is a monopolist? What profits will she earn each year? As a hint, the quantity will be between 42 and 52, inclusive.

Question 7 (15 points)

Now consider the development decision. To develop the idea, the engineer would need to give up her current job, which would have paid her $150,000 a year over years 1-20. There's a 25% chance the project would succeed. If it does she'll be able to patent the device and collect the monopoly profit in years 1-20. After year 20, other firms would enter the market, the price of the product will drop to $200, and her firm's profit will drop to 0. If the project fails, the engineer will need to take a new job at a much lower salary: $60,000 a year in years 1-20. To keep things simple, you may assume that the project succeeds or fails right away in year 0, and that the engineer will retire in year 21 no matter what happens (that is, you only need to account for her salary or profits over years 1-20).

(a) Using an interest rate of 5%, please calculate the NPVs of: ☐ the monopoly profit if the project succeeds; ☐ the engineer's current salary, and ☐ the lower salary the engineer would receive if the project fails. Assuming the engineer is risk-neutral and makes decisions based on expected value, please ☐ determine whether she would undertake the project or keep her current job.

Question 7, continued.

(b) Now consider the potential consumer surplus the device would produce. Using an interest rate of 5%, ☐ what is the PV of the CS that would be generated if the engineer successfully developed and sold the product? ☐ Assuming the project is successful, which is larger, the PV of the monopoly profits or the PV of the CS? ☐ Briefly explain what drives that result.

Question 8 (15 points)

Finally, now suppose the engineer is actually risk averse and makes decisions by maximizing expected utility. Her utility from an NPV payoff of x dollars given by $u(x) = x^{0.5}$. Please ☐ determine whether or not she would still go ahead with the project. Suppose the government decides to make the project more attractive. It offers the engineer a one-time $250,000 grant to undertake the project and will also award her a $1 million prize if the project succeeds. If the project fails, the engineer would keep the grant money but would not receive the prize. To keep things simple, both payments would occur in year 0. Please ☐ determine whether the engineer would accept the government's offer. Please be sure to show your work.

Additional page for calculations
If you use this, please remember to indicate near the question that part of the answer is here.