Health Economics

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Week – 08

Lecture 41- Principles of Economic Evaluation: Cost-Utility Analysis (CUA)

Welcome friends once again to our NPTEL MOOC module on Health Economics. So, before starting this particular lecture, we need to recap what happened in our earlier episodes. We discussed about CEA, we discussed their effectiveness, their ratio (the cost-effectiveness ratio etc.). We started with their introduction and discussed the theoretical basis of CEA, which indeed provides the basis for comparing the cost and benefits of different units. So far as the cost-effectiveness ratio is concerned, it is important basically because neither the cost nor the effects can be held constant. In that case, we also talked about the role of the cost-effectiveness ratio.

We emphasised two important limitations of CEA, which has led to the introduction of cost-utility analysis (CUA). They are basically like- it is difficult to choose the best measure of effect and it cannot compare interventions for two different health issues at a go. That is why the CUA analysis is required.

Here, we will emphasise CUA (i.e., cost-utility analysis) and how to carry out this CUA against CEA.

So, as a definition of cost-utility analysis, it is a specific type of CEA. This form of comparative economic analysis evaluates two or more policy alternatives in terms of their relative cost and generic outcomes (as mentioned in Turner et al., paper). The outcomes are measured as the generic measure of health status, considering both the effects (i.e., mortality and morbidity), but not by their number but rather through certain index values. It used to be measured as QALY (quality-adjusted life years) and DALY (daily-adjusted life years) etc. The objective of this measurement is to maximise societal health status.

How come it is different from the cost-effectiveness analysis? CEA relates to the output of a particular type of healthcare, whereas the utility analysis refers to the output of healthcare as a whole. Under CUA, the effectiveness of different healthcare interventions can be directly compared to each other, unlike in CEA. So, how do we carry out this? We will just discuss it. CUA or even CEA do not directly compare values of effects or cost. Carrying out policy recommendations using CUA or CEA is far more complex than the CBA measurement (which we did earlier).

Three approaches have been developed to carry out this CUA evaluation.

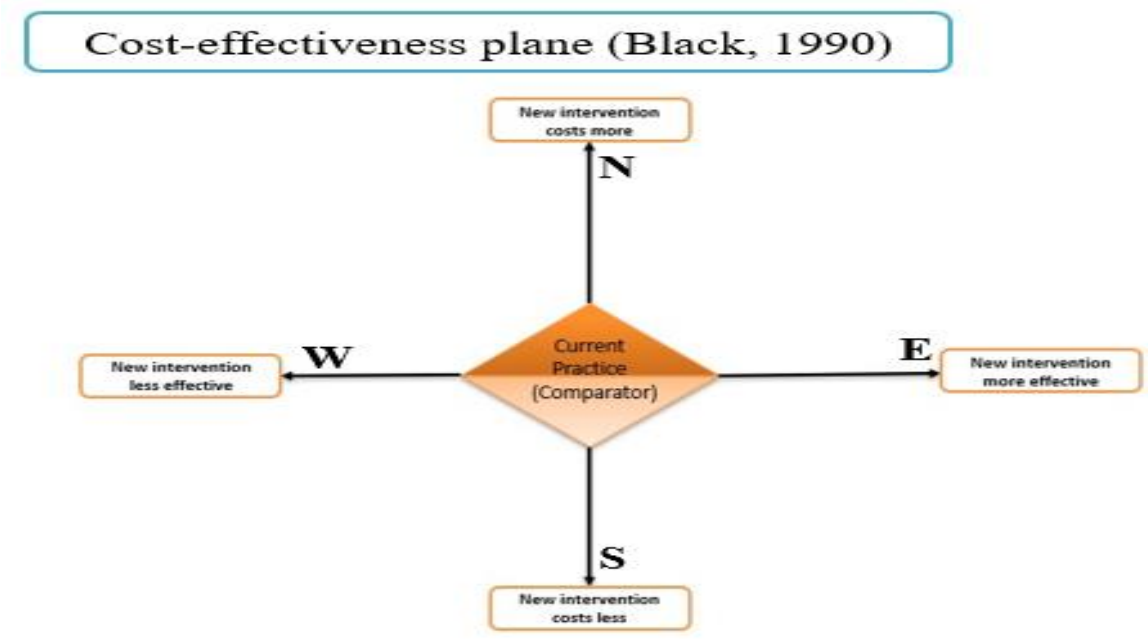
The first one is ICER (i.e., Increased Cost Effectiveness Ratio). Then the second one is the Net-Benefit Approach (i.e., NBA). The third one is called the Probabilistic Approach (PA). We will also discuss how far these three are important. Usually, the probabilistic approach is difficult to estimate the probability value of it. We will discuss this at the end.

Let us stick to ICER. This is indeed called the incremental cost per unit of output or effect or per unit change in the output or effect. This is the most popular measure of an activity's cost-effectiveness. This implies that the lower the cost-effectiveness ratio (CER), the better it is. We will emphasise this now with further clarity.

Two alternatives, i.e., a and b, were given. The cost of both would be C_a and C_b, and its effects will be E_a and E_b. Hence, the ICER is calculated as. So, we are trying to find out the change in cost with respect to the change in the effect. So, it is: $\frac{\Delta C}{\Delta E} = C_a - C_b / E_a - E_b$.

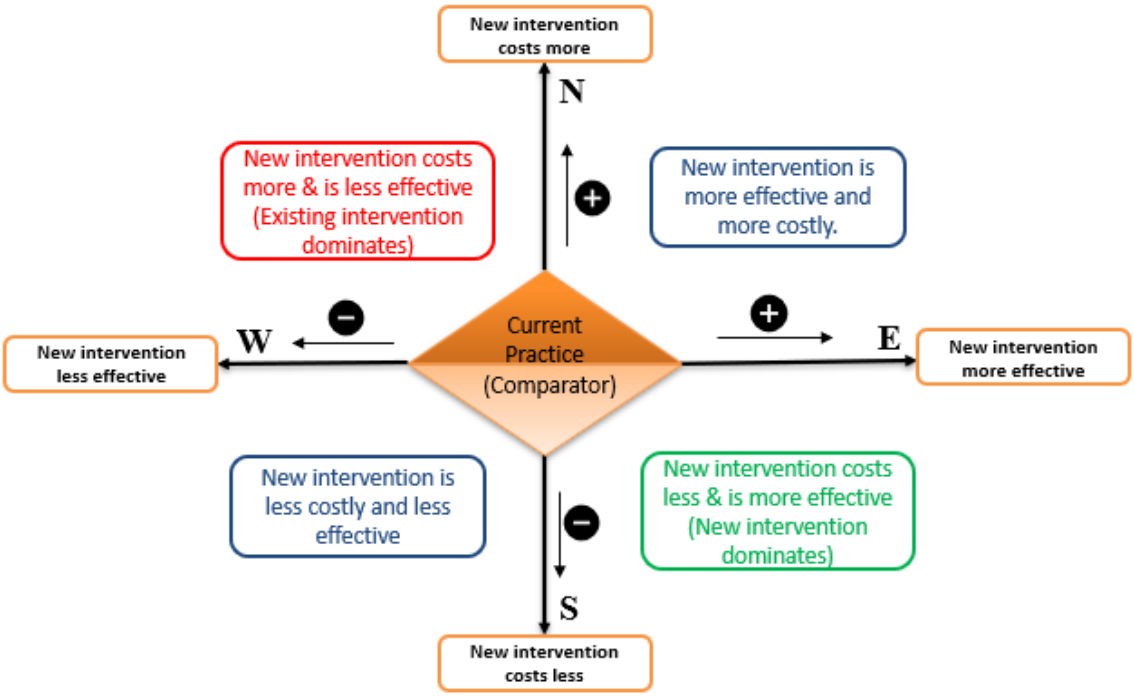
This is how the incremental cost and effects are measured. The visual representation of decision rules that are applied to ICER is presented by the cost-effectiveness plane (used initially by Black 1990). We will be emphasising this plane, and it is going to be very interesting for all of you.

Let's start with this two-dimensional space or simply a plane, where we are presenting the alternative options in terms of cost and effect (that is presented here as intervention):



Let us understand whether we should go for the cost-cutting model or whether we should go for effective new intervention model or something. So, we are just pointing here that we are measuring the cost in the vertical line (that is, north to south). From east to west, we measure the effects. Along the east-to-west line, zero additional cost since it only measures effectiveness, so cost is zero. In the case of the vertical line (the north-to-south line), new

intervention is considered to have zero or no additional effects. So, these lines are currently divided into four quadrants, showing all possible cases.



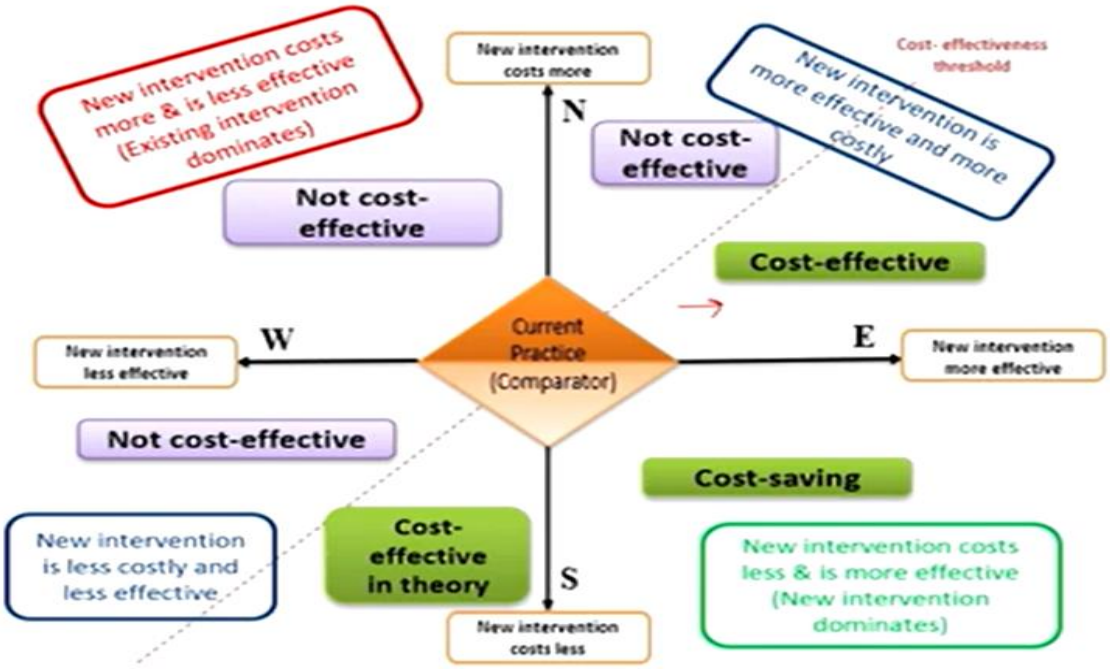
In the northwest area (you can just see the north and west quadrant). I am not making any rough work as it is clearly visible. Then, other is the southeast area. So, what is the difference between these two? In the northwest area, the cost of new interventions is higher but less effective. Basically, existing intervention dominates in this case. In the southeast area, just the contrast is observed. We are effective enough to add the effects; the intervention has a huge effect, which is why the plane says that a new intervention is dominant in this case. These are considered to be idealistic, and we will be emphasising the one where we will be relating to the reality.

We are referring to the northeast area, which shows that the new intervention is more effective because we are moving towards the intervention axis. And also, they are costly. However, the new intervention is less costly and less effective in the southwest area. So, any intervention you have taken is considered less costly and less effective because we are on the negative side. Here, in these two options, we have a strong trade-off of how to make the better choice. For example, in the northeast region, costs are increasing. In another case, new intervention is less costly, but it is considered to be less effective. We will also try to find out the best option out of these two. Should the interventions be taken or not taken? We have some possibilities (in NE and SW). But in the red and green ones, which we have highlighted for the northwest and southeast region, we need not discuss the role of intervention because they are extreme cases.

But why do we need to use the CER plane if we can decide on alternatives based on ICR alone? Although it seems tempting to conclude that if two interventions have different ICERs, one with the lowest CER is most cost-effective and should be chosen. This is where things turn complex. Strictly, ICERs can only be used if alternatives can be scaled up or down to achieve the same cost or effects without affecting the CER. In terms of production relationship, it requires the presence of constant returns to scale and no indivisibilities. If that is not the case, one has to look for the cost-effectiveness ratio (i.e., CER) plane to arrive at a decision. Further, although the cost-utility analysis (or the CUA) is very useful, it has a strong limitation in that it does not provide absolute recommendations (in terms of value like CBA does). Instead, it provides a mere contingent on comparison with alternatives.

Economists have sought the means to overcome such a strong limitation, i.e., recommending using a cost-effectiveness threshold or ceiling ratio, also called a 'standard cost-effectiveness threshold'. This is an explicit cost per unit of the outcome, such as, suppose it is 200 rupees per QALY (quality-adjusted life years) gained that any intervention must meet to be considered cost-effective. A variety of methods can determine such a threshold (refer to the references). We will clarify the exact intervention and, out of these options of cost-effectiveness threshold, which one is more effective. We have to take certain decisions on it.

The decision rules are straightforward. Like, the two areas that we have highlighted, (Northwest and Southeast), do not require trade-off because it is very clearly understood, and there is no question of trade-off requirement. The decision of the other two quadrants, the Northeast and the Southwest, requires some trade-off. We will clarify to what extent this trade-off is possible. In this case, any interventions that are effective must be below the cost-effectiveness threshold. We will just see, what this threshold is?



For the first case (Northeast area), we have already mentioned that this requires intervention and is also costly, but the approach should be to understand to what extent it is possible. So, if the CE threshold (cost-effective threshold) is greater than that of the intervention (i.e., $\frac{\Delta C}{\Delta E}$), the intervention is cost-effective. So, you can just see, if it is toward this (→), so it is cost effective. So, if the change in cost with respect to this(effect), where CE threshold is becoming higher than that of the change in cost, then intervention is cost-effective, otherwise, no.

The second case (i.e., in the Southwestern area) is practically questionable. So, we have highlighted what is acceptable and what is not. I have just mentioned that the acceptable threshold is where the intervention is effective, and the other part (we have just highlighted) is non-acceptable above the threshold. Once this exceeds the threshold, it is unacceptable. So, this (issue) you see is often referred to as a concern of acceptability. In this diagram, we have clearly identified the clear-cut decision out of the four quadrants. Here, we divided within the conflicting regions (i.e., the North Eastern and the Southwestern regions), where we try to derive through the cost-effectiveness threshold level.

It is common in economic evaluations to compare more than two mutual alternatives. In such situations, the calculation of ICER becomes a bit complex. Some works by Hallienen et al., (2010) gave the correct picture for comparing alternative healthcare interventions. There are some steps given by them as- i) rank options by increasing cost, ii) eliminate simple dominance option, iii) eliminate extended dominance options and, iv) calculate incremental cost and effects level, and also, v) calculate ICER for remaining options. We will understand each of them, step by step, using an appropriate example.

Example: Imagine a scenario with three treatments for managing migraines: A, B, and C. The baseline treatment is the current standard practice for migraine management (1- 10 levels → where 10 is highest and 1 is lowest).

Interventions	Cost (in ₹)	Effect (Reduces Migraine)
Standard Practice	80	4 levels
Treatment A	102	5 levels
Treatment B	150	7 levels
Treatment C	120	6 levels

Objective:
Our goal is to assess the cost-effectiveness of these treatments and identify the most efficient options.

Here we have an example where there are three treatments (A, B, and C) for managing disease called migraine, and their costs are given. The baseline treatment is the current standard practice for migraine management. Others are treatment A, treatment B and treatment C. The standard practice cost ₹80 and that reduces the migraine of upto level 4, whereas treatment A is more costly, but the effectiveness is more (i.e., upto level 5). Similarly, we will find out

about others as well. We will just see. The objective here is to understand the cost-effectiveness of these treatments and identify the most effective options. Starting with the rank options, that we can easily rank. Initially, in our example, it is here A, B and C. But, now you can see, there has been a flip of these because C is more effective than that of treatment B:

Ranked Intervention	Cost (in ₹)	Reduce (**Reduces Migraine**)
Standard Practice	80	4 levels
Treatment A	102	5 levels
Treatment C	120	6 levels
Treatment B	150	7 levels

So, you can see that C requires ₹120 of cost for meeting the treatment for migraines and even it is more effectiv. So, we have changed it. This is called the rank option.

The second one is called 'eliminate the simple dominance options'. Here, the elimination of simple dominance refers to eliminating an option for which another option is cheaper or more effective. So, based on this definition, we will exclude treatment B because it is more costly and less effective than A and C. So, B is excluded. That is why we have highlighted it here in red.

Now, we are emphasising the 'eliminate through extended dominance options'. Let me see. In this case, we check if combining two other options is cheaper or more effective than the option under consideration. So, we will see how. So, two options can be combined. We will look at the baseline and the treatments (i.e., A and C). In this case, which we have already cited, we only have three remaining options left. Hence, no further elimination through extended dominance is needed, and we can move directly to the next step. So, in that case, our next step is 'calculating incremental cost and effect'. We have already shown its formula. However, we will calculate the ICER for each remaining treatment compared to the next lower-ranked options.

The calculation is done through-

ICER = (Cost of Treatment - Cost of Baseline) / (Effect of Treatment - Effect of Baseline)

Formulating ICER for the current example

$$\boldsymbol{ICER} = \frac{(\boldsymbol{C_{intervention}} - \boldsymbol{C_{baseline}})}{(\boldsymbol{E_{intervention}} - \boldsymbol{E_{baseline}})} = \Delta \boldsymbol{C}/\Delta \boldsymbol{E}$$

These can be interpreted as the cost of treatment minus the cost of baseline (which we have already shown as ₹80) and the effect of the baseline. So, we will see both cases using the following-

ICER for Treatment A:

$$\boldsymbol{ICER(A) = \frac{(C_A - C_{baseline})}{(E_A - E_{baseline})} = \Delta C/\Delta E}$$

ICER(A) = ((₹102 - ₹80) / (5 - 4)) = 22/1 = 22

Here, we are referring to C as against E (that is effect). So, accordingly it is presented. To calculate this, we have taken C_A minus baseline, and the is cost divided by effect of A minus baseline effect. We have seen that the baseline cost was 80 and the baseline effect was 4 levels. Hence, we can calculate for against C. You can easily see what really happens. At this moment we are referring to ICER(A). We can also compare with other B option, C option as well. But, as B, we have already sidelined. So, better to compare with C. So, in this case, we have calculated that it is actually 22. And in another case, i.e.,- *ICER for Treatment B:*

$$\boldsymbol{ICER(C) = \frac{(C_C - C_{baseline})}{(E_C - E_{baseline})} = \frac{\Delta C}{\Delta E}}$$

ICER(C) = ((₹120 - ₹80) / (6 - 4)) = 40/2= 20

Here, we just derived the result 20. So, it is surprising to see that C is even more effective than that of the case of A, so far as ICER is concerned. Hence, we excluded treatment A because its ICER is higher than treatment C, although, based on only cost, it was ranked lower. So, you can see that this is where the details are, and we have picked up and derived the results. The last one is 'calculate ICER for the remaining options'. Since no more options are left in our case, we do not need further ICER calculation. Hence, in this case, we need to conclude that treatment C is considered the most cost-effective of all the interventions based on the cost-effectiveness criteria.

However, there are certain limitations of the cost-effectiveness ratios. i) 'Assumption of linearity': ICER assumes linearity, which means the relationship between cost and effect is constant. In reality, that assumption does not hold. ii) 'Threshold dependency': The choice of this threshold can be arbitrary and may vary across different contexts or decision-makers. iii) 'Generalizability': ICER values may not be directly comparable across different interventions, Diseases or healthcare systems. iv) 'Time horizon challenges': Different time perspectives can lead to different conclusions about cost effectiveness.

With all the problems attached to ICER, there have been challenges to their dominance. The most prominent is the Net-Benefit approach, which was propounded in Stinnett and Mullahy's 1998 paper. This Net-Benefit approach (NBA) essentially restores the original concept of cost-benefit analysis without imposing a welfarist framework. One can say that it was developed not because of the theoretical problems of ICER but because of the undesirable mathematical and statistical properties only. This aims to obtain a single number that is not in ratio (like in ICER). So, recall the ICER formula→ $\frac{\Delta C}{\Delta E}$ in the case of ICER, where

ΔC measures in monetary terms and ΔE in non-monetary terms (converted to monetary terms using threshold values). However, in the Net-Benefit approach, an activity is defined as Net-Benefit, i.e., basically equal to NB $= \Delta E - \Delta C$, where ΔC & ΔE are measured in the same units in this case. So, to convert, there are conversion approaches to convert cost and effects in the same units in NBA. The NBA relies on a ceiling ratio i.e., a ratio or threshold called R_C, which is an implicit value attached to the cost or effect.

The ceiling ratio helps to convert cost to the same unit as effects or vice versa. If effects are converted, it results in Monetary-Net benefit (MNB). This is represented as→

$$\boldsymbol{MNB} = (\boldsymbol{R_c})(\Delta \boldsymbol{E}) - \Delta \boldsymbol{C}$$

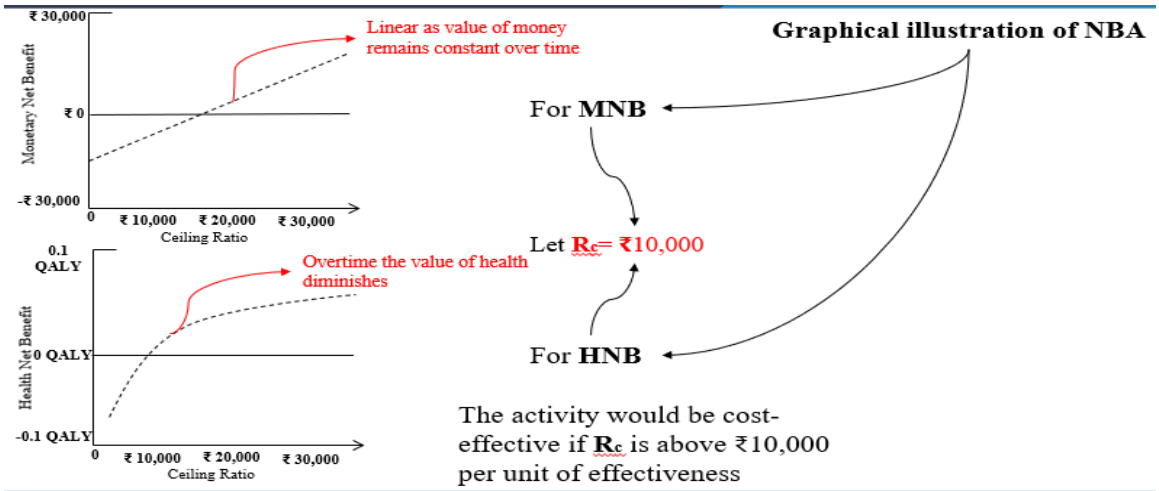
If costs are converted, it results in Health-Net benefit (HNB). When monetary benefit is converted, we multiply the R_C times its effect, changing its effect in monetary terms. If costs are converted, then that will be as a ratio, where $\Delta Cost$ is divided by Rc. It is represented here as-

$$\boldsymbol{HNB} = (\Delta \boldsymbol{E}) - \Delta \boldsymbol{C}/(\boldsymbol{R_c})$$

But in the other case (case of MNB), it is multiplied as R_C. So, how do we decide what is cost-effective and what is not? Is there any set of decision rules applied here? First of all, we are referring to MNB. If the benefit is multiplied with its ceiling level, and that too if the MNB difference is positive with respect to its cost, then it is more cost-effective. And if it is negative, then it is not cost-effective.

In case of HNB, just the reverse is done. Here, we divided the R_C with respect to the change in cost. If the difference is positive, then that is cost-effective. Otherwise, it is not cost-effective. However, deciding which R_C should be used is really problematic. If an organisation sets specific values for this, there is no problem, and it can be derived. If you do not have any value, reporting Net-Benefit for each Rc level is necessary.

Here, we are illustrating the NBA for MNB, which just we clarified.



For MNB, the relationship is considered to be linear as the value of money remains constant over time. Meanwhile, for the HNB concept (for health specifics, not monetary ones), the value of health diminishes over time, which is nonlinear. And, with a benchmark level, we are assuming 10,000 rupees as Rc here. Based on that, calculations are made. The activity would be cost-effective if R_C is above 10,000. If it is above 10,000 per unit of effectiveness, then it is really effective.

Let's understand each type of NBA with an example. For MNB,

Suppose three healthcare interventions, A, B and C, aim to reduce hospital readmissions. The **cost of Intervention A is ₹ 80,000**, and it **leads to a reduction of 10 readmissions**. **Intervention B**, on the other hand, **costs ₹ 100,000** and reduces **15 readmissions**. The **cost of C** is **₹ 120,000 and results in a reduction of 20.** The hospital feels the ceiling ratio should be ₹ 5,000 per reduced readmission

In that case, we can calculate the MNB (Monetary-Net benefit using $\boldsymbol{MNB} = (\boldsymbol{R_c})(\Delta \boldsymbol{E}) - \Delta \boldsymbol{C}$. So, we can just calculate and find out. Since, R_C we have already mentioned as ₹5000 per reduced readmissions. And, the ΔE_B, i.e., change in its effect will be 5 (because we have taken as difference between A and B, the effect is 15 -10 = 5), the difference in readmission cost between B and A (ΔC_B) will be of course, ₹20,000. Here, we are considering B over A where we are considering A as the benchmark, the standard one.

You can see this similar for the B and C case. Accordingly, we have derived all the important values and can put it and find out all the values.

MNB for B: MNB_B = (₹ 5,000 x 5)– ₹ 20,000= ₹ 5,000

MNB for C: MNB_C = (₹ 5,000 x 10)– ₹ 40,000= ₹ 10,000

So, C is actually 10,000. Whereas in the case of B against A is 5000. As per the decision rule, we already said that if it is greater than 0 (the difference is greater than 0), the activity is cost-effective. So, interventions B and C are cost-effective compared to intervention A. However, C is better, as it has a higher net benefit.

Another case is for health net benefit, not monetary benefit, where we discuss its non-linearity assumption.

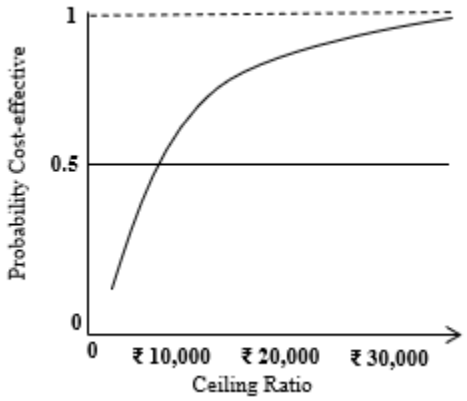
Consider a public health initiative to increase vaccination coverage in a community. The **standard vaccination program costs ₹150,000** and **leads to an increase in vaccination coverage by 20%**. A **proposed enhanced program**, **costing ₹180,000**, is **expected to** increase coverage by **30%** while the government fixes the ceiling ratio should be **₹ 5,000** per percentage point increase in coverage.

Hence, we need to calculate HNB, i.e., $\boldsymbol{HNB} = (\Delta \boldsymbol{E}) - \Delta \boldsymbol{C}/(\boldsymbol{R_c})$. We have already divided this by the benchmark level or the ceiling ratio. So, given this, we have derived all those figures for your reference. We just see, 5000 we have derived and finally, we found that the change is positive. So, that means the new option (i.e., B option) is cost-effective. So, compared to intervention A, intervention B is cost-effective and should be adopted.

Both the examples are hypothetical, and they illustrate how to apply these approaches, i.e., the Monetary Benefit approach (MBA) or the Health Benefit approach (HBA), to determine the cost-effectiveness in different contexts, using the concepts of MNB or HNB.

The last one that we want to explain is called the Probabilistic approach. This was developed in response to some difficulties attached to ICER. The probabilistic approach that is used as a replacement for ICER, is also known as the cost-effectiveness acceptability curve (CEAC), (Hout et al., 1994). Here, CER is no longer regarded as the number that is observed with certainty, but as a variable whose meaning is observed. This means it can take different values depending upon a sample of the observations on which it is based. This leads to the idea that with a given ceiling level (i.e., R_C), we can only state the probability that an activity is cost-effective. The probability here will be different for different levels of R_C.

Some graphical presentation is presented here, which I already said- it is an increasing function but at a decreasing rate-



Since probabilities are attached, so values at maximum will reach 1. So, from 0 till 1 is presented in figure. An advantage of CEAC is that it allows uncertainty to be expressed while retaining the familiar concept of the CER.

There are disadvantages as well. Although CEAC is an interesting concept, it is difficult to know how decision-makers are supposed to use it. As yet, there is no guide on how to read and use CEAC. Even not enough experience is present in the literature to use it.

So, that is all. I think we have already explained everything. However, these are the summary and conclusion. We discussed cost-utility analysis (a form of cost effectiveness analysis). We carry out CUA as part of CEA (in this lecture). However, CUA is an extension of CEA. We

discussed three popular methods: CER, NBA and CEAC. CEAC is part of the probabilistic approach. ICERs can be presented graphically on a cost-effectiveness plane. ICERs (incremental cost-effectiveness ratios) can be converted into the same units using ceiling ratios, and the methods are called MNB and HNB. CEAC accounts for statistical uncertainty in the CER and uncertainty in the ceiling ratios by using the probability that an activity is cost-effective at different levels of the ceiling ratio.

So, that is all I think. In the next lecture, we will discuss the monetary and non-monetary evaluation of healthcare. Here are the readings. I think we have already cited them in some of the slides. It will be useful for you. With this, I will stop here. Thank you.