

Mineral Resources: Geology, Exploration, Economics and Environment
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Lecture - 55
Mineral Economics (Contd.)

Welcome. So, we have been discussing about certain interesting and important aspects of mineral economics. And in the process we were discussing about sustainability and discussed about the prospects of recycling as one of the means of sustainability as far as our mineral resources are concerned about as far as the demand of different metals are concerned.

The metals are being primarily produced in the primary cycle and there are always are scopes of producing these metals which can be as a secondary production cycle from scraps which are discarded materials. And although it is definitely not be possible to recover all the metals that have been consumed so far in different reservoirs, but there is always a hope. And more of innovative methods possibly could be found out in recovering the scraps. For example, we discussed that it is easier to recover new scraps which are being produced as waste in any fabrication, any industry using the any particular technology. It also depends on the nature of technology that decides what the quantity of scrap that will be generated.

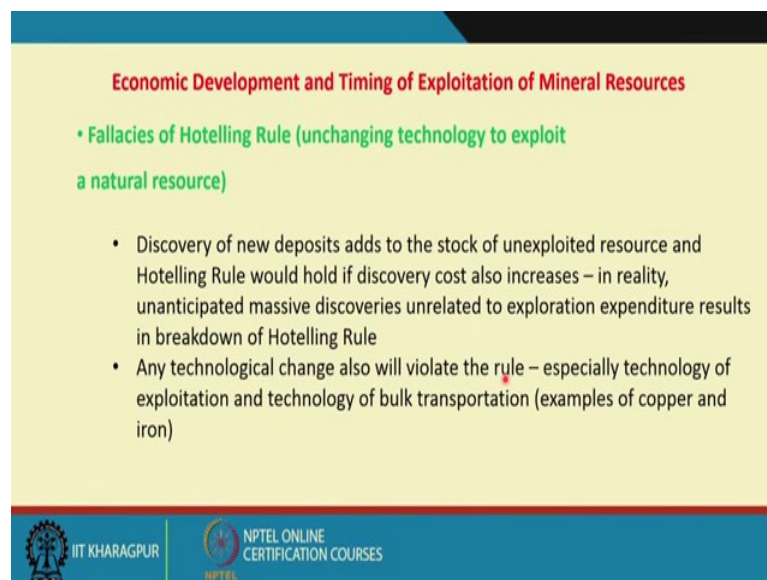
But it becomes very difficult to recover the metals in its pure form from the secondary scrap or the old scrap. We call them as old scrap for example; take the case of a automobile where there has been use of many different metals which has made up the automobile. And in order to get the metals in their pure form it will definitely take more of energy to be spent on that. So, the recovery cost of the metals from secondary from the old scrap will always be high.

The supply of metals from the old scrap will always be dependent on the market price. And we will not fix an upper limit in the quantity that could be supplied from the old scraps whereas; the quantity that will be available from the new scrap is all limited. Because even though the price was very high, the quantity of metals recovered from new scrap cannot be that high.

So, just a bit of from that of recapitulation let us discuss another important and rather interesting aspect of mineral resource exploitation which is also related to sustainability that we talk about. Often we ask ourselves that when an ore body is discovered or, when a mineral deposit is discovered. The question is whether we should start exploiting that particular mineral resource then or we would like to keep it stored or, saved or preserve it for our future use.

Because we all know mineral resources are exhaustible and a unit mass of the ore which is taken out, its place of occurrence is lost forever. It means the mother earth is depleted by that particular amount that is being mined and that is how the concept of the payment of royalty came up and which we discussed before.

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Economic Development and Timing of Exploitation of Mineral Resources

- **Fallacies of Hotelling Rule (unchanging technology to exploit a natural resource)**
 - Discovery of new deposits adds to the stock of unexploited resource and Hotelling Rule would hold if discovery cost also increases – in reality, unanticipated massive discoveries unrelated to exploration expenditure results in breakdown of Hotelling Rule
 - Any technological change also will violate the rule – especially technology of exploitation and technology of bulk transportation (examples of copper and iron)

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Now, we will try to answer this very basic query as to when to exploit the mineral resource. In this, there are several arguments in favor and against in economic development and the timing of exploitation of mineral resources.

There is a rule which is popularly known as the Hotelling rule. We do not go into the detail of the calculation procedure etcetera or the original idea, but, roughly it states that any commodity, any exhaustible commodity like mineral resource, its value increases with the rate of interest means, a particular ore body whose value is x at this point of time will go on increasing at the rate of interest.

So, it does not matter its value does not change whether it is being exploited today or is exploited sometime in the future. So, that is the Hotelling rule. So, the Hotelling rule will tell that defer means deferring the exploitation to a future time.

So, for Hotelling rule, in the simple way it is stated; it will always tell that the mineral deposit or, the ore body could be saved for future without its value actually decreasing. However, there are arguments and this Hotelling rule sounds fallacious on many real life examples.

For example, this Hotelling rule because mineral resources are a very special type of resources because there is a high risk economic activity where there is cost which is incurred for the exploration of deposits. So, there is a discovery cost and this discovery cost need not necessarily increase with time. There are developments of new technology by which the discovery cost also could go down. So, if there are some unanticipated massive discoveries which are unrelated to the exploration expenditure if that is which sometimes happen; we will not make the ore body the same cost even if it is preserved for the future.

So, the discovery of new deposits which adds to the stock of the unexploited resources; so the Hotelling rule would hold if the discovery cost also increases. But there are situations where the discovery cost need not increase and any amount or, any new discovery which is adding to the stock will not also increase.

And the other thing which can be argued in against this deferral is that if there is a technological change that also violate the rule especially technology of exploitation and technology of bulk transportation. For example, we take the case of iron and copper because the porphyry copper deposits which occur in very huge tonnage, but low grades were initially not getting exploited because of the non availability of the technology of transportation as well as the mining.

So, as and when the technological advancement took place, these deposits became exploitable. And in such kind of situation a Hotelling rule will not be appropriate or deferral will not be favored as we will be making it clear in our next points of discussion.

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Economic Development and Timing of Exploitation of Mineral Resources

- Saving for Future Generations (other than just saving)

Often countries making substantial progress in setting up a wide range of industrial activities but yet to reach a mature stage – starting out with the known resource base and pleads for preserving for the future growing needs of domestic industry and decides against export (example – Fe ore in Australia; Uranium in Canada; Iron ore in Venezuela)

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So, the one of the important aspect is that whenever we talk of sustainability is the save the mineral resources, our metallic resources, metallic or nonmetallic resources for our future generation. Because what we exploit today is depleted and is not available for our future generation that is sometimes would look going in favor of deferral.

But if you look at that there are countries which make substantial progress in setting up a wide range of industrial activities, but yet to reach a mature stage starting out with the known resource base and pleads for preserving for future growing needs of domestic industry, for example, this would an argument which will go in favor of deferral.

Let us say that there is a country because most of our mineral economic analysis that we make in relation to many of the mineral producing countries is always with a history or the back up of their political setup. For example, many of the countries who are under colonial rule and they become free or they become independent or there are many kind of coming over from some political turmoil, and then restructuring of the political system of the country and from that everything seems to be starting from the scratches and development of many of the things as if it is from the beginning.

So, say for example, if some of the country has a substantial progress in setting up a wide range of industrial activities, but yet to reach a mature stage would not like to exploit its mineral resources. And would like to wait and would plead for preserving for the future for the time that there is a proper risk structuring or the industrial set up would reach a

mature stage. But there could be some counter arguments for such kind of arguments in favor of deferral. Say for example, sometime in the 40's; in the 30's and 40's the iron ore in Australian reserve was possibly about something about 400 million tons.

And the Australian government decided or put a call on the export of iron ore. So, when there was no demand or no export of the iron ore; there was no much of a demand for its further growth of reserve or the further growth of the resources of that particular country. So, as and when sometime during the 60's when this policy was relaxed and the iron ore export was again allowed by the government, the exploration the further exploration activities went up to such an extent that from 400 million tons; it went up to around 40, 42 billion tons of reserve of iron.

Similarly in case of uranium in Canada; the Canadian government also decided to slow down or to put curve on the export. Even in the later part there were discovery of many of the rich uranium resources in Canada, but the government could not make the proper benefit out of these increased resources of very high rich, very high grade uranium ore.

Similarly the situation in Venezuela; so this tells us that if there is deferral there it does not do any good rather an exploitation of the mineral resources also helps or triggers further exploration and increase of the reserve and that particular mineral rich country gets the full benefit out of it. So that is the examples or the additions to reserve Australia iron, and the Canadian uranium.

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Economic Development and Timing of Exploitation of Mineral Resources

- Additions to Reserve (Australian Iron and Canadian Uranium)
- Widespread misunderstanding of reserve
- Multiple of 30 concept
- Australian Iron Ore Resource in 1940s – 400 million tonnes – embargo on export – abolished in the 70s – reserve increased to 17 billion tonnes by 1987
- Canadian Uranium reserves increased without the Government getting the benefit of the extraordinary Uranium boom of 1970s

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The mineral resources as and when they discovered, their exploitations also starts. The revenue that is earned through the exploitation of this mineral resources, it always helps or enhances the further exploration and addition of reserve and the both cases in Australian iron and Canadian uranium can be taken as example where the Australian iron story is that they could export their iron ore and got get the benefit; whereas, the Canadian uranium, the country could not get the full benefit of the increase in this reserve the very high grade iron uranium ore.

Now in this context, , the figures that was given here that is Australian iron ore resource in the 1940s where about 400 million tons. There was an embargo on the export and that embargo was abolished in the 70s. And then the reserve increased from 400 million tons to 17 it is not 40 to as I stated it is about 17 billion tons of iron ore. By the time it was 1987 of course, the present figure is not available with me now. The Canada and uranium reserve also increased without the government getting the benefit of the extraordinary uranium boom of the 1970s.

Now in this context there is a widespread misunderstanding that what should be the reserve because whenever there is a discovery of an ore body it is believed that a time period of about multiple of 30 concept, means it should be kind for a 30 years period of time for which the mineral reserve resource should be there not beyond that which also would then argue in favor of deferral, or in favor of slowing down of the exploitation. But in that analysis which we have seen we will not do any good to the economic growth of the country.

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Economic Development and Timing of Exploitation of Mineral Resources

- New Technology (Swedis Iron Ore Example)
- Waiting for an appropriate industrial framework (Papua New Guinea copper, Namibian mineral resources and Nigerian Uranium)
- Deferral to avoid depressing mineral prices (applicable to large deposits particularly where a price fall is expected) (Carajas Iron Ore, Brazil and Escondida Copper, Chile) (price elasticity of demand versus supply)
- Delaying projects to strengthen monopoly profits (cartelization – does not last for more than 3 to 5 years) (consumers find alternatives)

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And there are also issues or arguments which can go against the deferral say for example, new technology before the bulk transportation facility of the iron ore that are available in plenty in countries like Brazil, India, Australia that were available. The Kiruna type iron ore in Sweden was actually the major iron ore source of iron ore in Europe.

And the example can be sited like this so by exploiting the iron resources which were available in the Kiruna type iron ore in Sweden had it been deferred for with any of the arguments of saving for the future or any other argument or Hotelling rule then Sweden would not have been able to get the full benefit of its iron resource.

Because had it kept saved for the future or deferred the exploitation of the iron resources those resources would have been rendered as useless without any value once the huge iron ore from the banded iron ore formations in countries like Brazil, Australia or India were available and bulk transportation facilities and export were promoted all around the world.

One of the other arguments in favor of deferral is for waiting for an appropriate industrial framework the point, that we were discussing about that the country might not have reached to a proper framework for its utilization of the mineral resources.

The example is taken from the Bougainville copper mine in Papua New Guinea and the Namibian mineral resources and Nigerian, uranium are taken as example that possibly a

deferral of the mineral resources could be favored that let us wait till the country attains a particular level of maturity in its industry, and its organizational framework, its legal and many of the other things, political stability, and then only start exploiting the mineral resources.

But in the ultimate analysis that also comes out to be untrue in the sense that even if a particular country will be in kind of a state of an unprepared state, but only if it starts the exploitation of the mineral resources that only will have a binding on the faster or expedite the in the proper organization of the industrial framework.

And all other supportive machinery for the exploitation of this mineral resources and the country will get the full benefit of exploitation of the mineral resources, but if it is deferred then the growth will also be slowed down, and it will take much longer time for the particular thing to happen, for example, a maturity industrial framework or its political stability or other supportive machinery. Sometimes deferral in the exploitation of the mineral resources is argued to avoid depressing mineral prices.

So, this is applicable to large deposits particularly where a price fall is expected. This example is taken from the Carajas iron Ore Brazil, and the Escondida copper Chile. Just before the discovery of this Escondida copper Chile was already producing copper in huge quantity. And it was apprehended that if this particular mine would come into existence then there could be a fall in the price of metal by certain amount, say some marginal decrease in the cost of the copper, because the supply will become very high at a particular point of time. So, on this situation for example, there is a discovery of a large deposit of the size of Carajas iron ore in Brazil or the Escondida copper in Chile.

One would always argue that well if this exploitation is deferred then it would possibly not have that kind of a fall in the price. So, the total revenue that could be earned by that particular deposit could possibly be high. But in this case also when the proper calculation is done and one of the important fact is that whenever there is a large deposit to be mined, it is always thought in terms of a longer period of time for exploitation in terms of 30, 40, or 50 years.

And the economic situations for example, the demand in the price or fall in the demand are always short shorter terms. And when the total amount in terms of the tonnage of the total metal to be produced and marketed when it comes, it is observed that this type of

apprehensions are also not justified. Rather it is always argued that deferral of this kind of resources would not do any good to the economy of the country. These are the two examples which could be supply.

So, the price elasticity of demand; sometimes it is observed that the elasticity is not that with respect to supply. For example, if a particular metals supply to the world increases it does not make the price fall immediately that elasticity behavior which is studied by the metal price cyclicalities and the elasticity that is what is observed.

So, under those kinds of situations one can argue that even if there are discoveries of large deposits they should be exploited as and when they discovered and the apprehensions that the price will fall and the particular deposit will not be able to earn the revenue as expected is not quite justified. Sometimes there are arguments the delaying of the projects to strengthen monopoly profits. This cartelization does not last for more than 3 to 5 years. So it is exactly in the context of cartelization.

For example any one take the example of OPEC or take the example of international association or something like that. Let us defer production of this particular metal so that we could have the monopoly in the world market.

Now the arguments which go against such kind of deferral with the intention that a particular mineral producing country will be able to exert a monopoly is also not quite right. Because of the simple reason that such kind of cartelization can only last for a very short period of time of 3 to 5 years not more than that. Because, by that time the world consumers, the countries which would be looking for import of that particular metal or utilizing that particular metal in any industry will always look for some alternatives and this kind of monopoly will not actually be successful.

So, the ground that deferral would be advisable in such kind of a situation is also not right and could be refuted. So, taking all these points the conclusion is that for the proper return or the proper economic development for minerals from the mineral resources it would be advisable to exploit the mineral resources as and when the ore body or the mineral deposit is discovered.

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Mineral Resources in National Economy : Two Contrasting Cases

- The Bolivian Mining Crisis (Jordan and Warhurst, 1992)
(Was the Tin market crash OR the corporate behavior of COMIBOL the culprit???)
- The Success Story of Botswana

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So, to conclude we will just discuss; this possibly will remain as case histories. One cannot say that whether such kind of cases will recur in future or at least it's worth discussing and to pick up the points which can be taken as takeaway points for deciding the mineral policy or, the economic policy from the mineral resources.

There are two contrasting cases here one is the Bolivian tin. We all know that once upon a time the tin resources of Bolivia and the production of tin that was coming out from Bolivia was all mostly one-fourth of that of the whole world. However, this small country actually never could get the economic benefit out of the tin resources, but on the contrary was actually had to face a crisis which is very well referred to as the Bolivian mining crisis.

The little bit of its historical background for that is the Bolivian became kind of a country after a lot of political turmoil round about sometime around 1950 when its tin resources was almost like one-fourth of that of the world.

By the time it was 1985, it came to a virtual state of collapse and the organization which was named COMIBOL; it is kind of a statutory or a kind of a body which would be comparable to any public sector unit in a country like India was given the responsibility of the management of the tin resources of this country.

Now instead of that what exactly happened is that, many of the factors worked for the Bolivian mining crisis. One was of course, the decreasing or the falling price of tin in the world market, but then a rise or a fall in any of the metal market in the international market, the countries national economic policy of the mineral policies should be such that it should not get affected or it is a kind of the economic status should not be should not be allowed to deteriorate.

Whereas what happened in COMIBOL was that the government was not utilizing any of the revenues that is earned by export of the tin to any other well generating sector in the country, rather the entire earning from this export of tin was actually can be called as squandered.

And was more for situations like by spending more on the salary or the other kind of comfort of the miners and it is increasing all the revenue that is earned from the export of this mineral, if we could if we could put it in this way that not a single, not even a very negligible fraction of that was actually reinvested in the mineral sector for the development or for the augmentation of the reserve or increasing of the reserve or development in the quality of the production. On the contrary with decreasing quality of the ore,

the cost of production of the tin recovery of the tin went up and then it acted in such a way that it was a twice double disadvantage with the tin price falling in the market; as well as the cost of production of the tin as well as the recovery cost with no developmental activity in terms of the infrastructure machinery which was all being imported.

So, other than the fact that this earning that was made from the export of this tin, the rest all economy of the country depended on import. So, there was a huge imbalance between the export and import and the economy of the country fell to such an extent that inflation went up by 400- 500 percent. And there was also the political setup of the country the policies and more and more of authority on the COMIBOL to spend more on the on the on public or on the non resource generating sector actually caused all the collapse of this particular mineralized country.

So, it is not exactly the fall in the price of tin in the international market that was not responsible for the crisis of the Bolivian mining or the virtual collapse of this COMIBOL

which was actually responsible for the mining of the important metal tin in such a tin rich country. On the other hand there is a very good success story of the country of Botswana which is endowed with a good reserve of diamond and it also started as a country with a very poor economy in the beginning.

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Sustainability of Mineral Resources : Some General Concerns

- By omitting mineral depletion, the national accounts provide a distorted picture of a country's economic health: the accounts record mineral exploitation as a contribution to GDP and income, but do not record the simultaneous loss of wealth due to depletion. Environmental accounts, properly constructed, correct this omission by estimating the economic value of the mineral assets and the cost of depleting minerals, thus providing a more accurate assessment of economic performance and sustainable development (United Nations, 1993b, 2001).
- Sustainable development requires that depletion of mineral assets be offset by a compensating increase in other forms of capital. The transformation of mineral assets into other forms of capital raises two related issues: what share of the resource rent generated by mineral extraction should be reinvested to offset depletion, and are the alternative investments as productive as the mineral assets they replace?

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So, what exactly is the difference? So, to appreciate that let us look at some points that what is actually the sustainability of mineral resources. By omitting mineral depletion the national accounts provide a distorted picture of a country's economic health. The accounts record minerals protection is a contribution to GDP and income, but do not record the simultaneous loss of wealth due to depletion.

So, this loss due to depletion has to be very properly accounted, the environmental accounts properly constructed, correct this omission by estimating the economic value of the mineral assets and the cost of depleting minerals thus providing a more accurate assessment of economic performance and sustainable development.

Because the gist of it is that whatever is being exploited is depleted. So, if it is not being replaced or some other kind of wealth is not being generated in that process, then it will definitely lead to a virtual a situation of collapse like Bolivian mining crisis and will not be sustainable.

So, sustainable development requires the depletion of mineral assets we offset by a compensating increase in other form of capital which is actually very important. The transformation of mineral assets into other forms of capital raises two related issues; the what share of the resource rent generated by mineral extraction should be reinvested to offset the depletion and are the alternative investments as productive as the mineral assets they replace.

So, these are the two issues that whatever is earned as revenue or what we call as rent from the mineral resources by utilizing in domestic industry or exporting. They have to be reinvested to offset this depletion and what are the investments of alternatives which should be as productive as the minerals asset they replace?

Definitely one of the things is that to reinvest in the mineral sector itself to augment the reserve. And also a contrary to what happened in Bolivia that most of their technology of the mining, the of the processing of the tin, the equipment, the machinery that they were using they were all not getting properly maintained.

Because of no part of the revenue that is earned from the mineral resources were actually spent on them, and also simultaneously it could not compete with other countries which came up with higher better technology of production of this particular metal at a lower cost and also the recovery.

So, Bolivia was in the kind of a turbulence facing all odds at the very same time with not spending any of its revenue in the mineral sector, increasing cost of production of metal, fall in the international price and not being able to compete with other countries in the international market so led to the collapse of that.

So, in contrast to that as a country Botswana because of its very well formulated economic policy, and conversion of the mineral wealth to other type of wealth, in capital investment, in foreign assets actually prospered much more.

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• Researchers have found that, as a group, resource-rich developing countries have performed worse, economically, than resource-poor developing countries over the past 30 years, a phenomenon known as the "resource curse"

• Government can use mineral revenues in a combination of four ways:

- 1. Invest in foreign financial assets
- 2. Invest in infrastructure and human capital
- 3. Fund public consumption
- 4. Fund private consumption by returning some of the revenues to citizens

One of the world's poorest countries at independence in 1966, Botswana has done remarkably well in using its mineral wealth to transform the economy, joining the World Bank's category of Upper-middle-income countries in the 1990s. Botswana is an excellent model for resource-rich economies, escaping the 'resource curse' through prudent macroeconomic management. It devised its own rule-of-thumb for reinvestment of mineral revenues to offset depletion, the Sustainable Budget Index, which requires that all mineral revenues be reinvested. In the process Botswana has achieved remarkable improvements in infrastructure, human capital, and the basic services supplied to its population

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And so in this context sometimes it is told that actually the resource rich developing countries have performed worse economically, than resource poor developing countries over the past 30 years, a phenomena known as the resource curse. Because sometimes we ask ourselves the mineral resources that we have, is it a boon or a curse to us. So, it actually becomes a curse like what happened in Bolivian crisis that the mineral resources could not be utilized in a sustainable manner.

So, the government can use mineral revenues in a combination of four ways; one is the invest in foreign financial assets which Botswana could do it in a very efficient way. And also spending more on the mineral sector because Botswana is primarily diamond producing and endowed with a huge resource of diamond

and the diamond resources also further increase to the reserve and invest in infrastructure and human capital. There are other ways like fund public consumption and which is of course, not well generating, but still is very much required, fund private consumption by returning some of the revenues to the citizens.

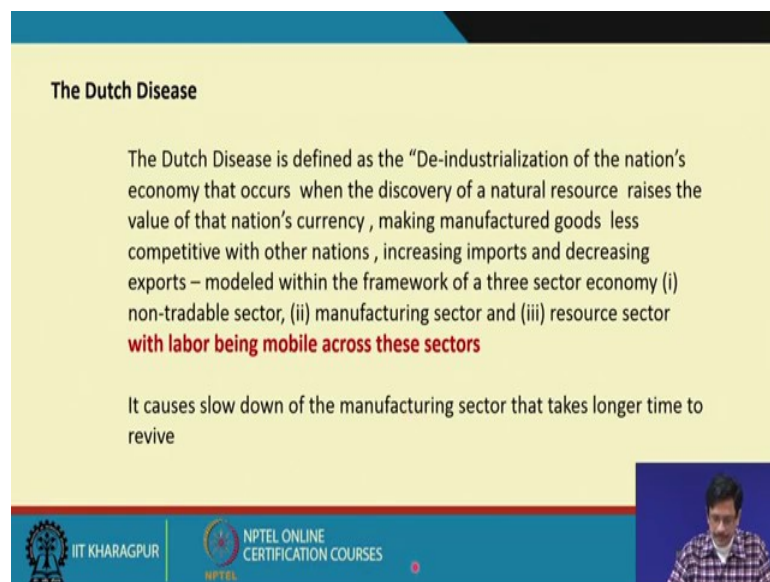
So, Botswana's case was one of the poorest countries in the world after independence in 1966. Botswana has done remarkably well in using its mineral wealth to transform the economic, joining the World Bank's category of upper middle income countries in the 1990s within a short period of 24 years.

Whereas, in contrary the Bolivian, from 1950 to 1985 it came to a situation of a virtual collapse and of course, the exactly the present state of affairs is not very well known. Although there are many rescue strategies built up like inviting foreign companies to again come and invest in the mineral sector, improved the technology and so many things.

So, Botswana is an excellent model for resources economies, escaping the resource curse through prudent macroeconomic management. It devised its own rule of thumb of reinvestment of mineral revenues to offset depletion, the sustainable budget index which requires that all mineral revenues be reinvested.

In the process Botswana has achieved remarkable improvements in infrastructure, human capital, and the basic services supplied to its population. So, these are some of the learning things and its basic insight into when we are studying a subject like mineral economics, to have in our mind that how a proper economic policy will make a country get the full benefit out of its mineral resources and a faulty policy can lead to its virtual collapse.

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The Dutch Disease

The Dutch Disease is defined as the “De-industrialization of the nation’s economy that occurs when the discovery of a natural resource raises the value of that nation’s currency, making manufactured goods less competitive with other nations, increasing imports and decreasing exports – modeled within the framework of a three sector economy (i) non-tradable sector, (ii) manufacturing sector and (iii) resource sector **with labor being mobile across these sectors**

It causes slow down of the manufacturing sector that takes longer time to revive

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So, in this case I will just conclude with a very interesting thing which is called the Dutch disease. So, Dutch disease is defined as the deindustrialization of the nation’s economy that occurs when the discovery of a natural resource raises the value of that nation’s currency, making manufactured good less competitive with other nations.

So, what happened is suddenly if a particular mineral or, natural resource like what had happened in Netherlands that from the name is derived as a Dutch disease; suddenly was found to be endowed with a huge reserve of natural gas. So, that is to be exported to the other part of the world and huge amount of foreign currency is earned in that process. What it will do is it will make the manufacturing sector go down. So, now what happens is what will happen is if that particular natural resource gets depleted the manufacturing industry will always take more time to recover and get back to its original form.. So, by the process of earning of huge amount of foreign currency and the manufacturing goods, it will become less competitive in the world market and it will be increase the imports.

Because the nation's economy is strong so it would rather becomes more beneficial for the country to import many of the other things for the manufactured items rather than to manufacture them in their own country which will be more expensive. And in that case the manufacture sector will sector will get neglected and there will be decreasing exports. So, so this Dutch disease is actually modeled with the framework of three sector economy there is the non tradable sector, manufacturing sector, and a resource sector with the labour being mobile across these sectors.

For example, if the labour that is employed in the manufacturing sector is there is a sudden boom in the natural resource sector the labour will move there and it will be difficult or it will at least take more time for the manufactured sector to again come back to its original shape once the natural resource sector will become less prominent or would become less significant in terms of the earning of the foreign exchange. So, it causes slowdown to the manufacturing sector that takes longer time to revive.

So, with this I would like to conclude the discussion on several aspects of mineral economics, and as I have stated in the beginning it is a very interesting very vast topic which could possibly merit a full lecture series like the one which we have taken up here. But it definitely constitutes a very essential component of mineral resources and as I have said that as geologists we do have a certain amount of responsibility and we also do need to learn this subject well, understand the intricacies, so that we could also contribute.

Thank you so much.