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CONCLUSION

Some observations from my experience

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Shakespeare's Hamlet observed: "Use every man after his desert, and who should 'scape whipping?" (*Hamlet. Act II, Line 561*). I am flattered and humbled that Magnus Ericsson has not assigned me that fate, but has instead prepared this special edition of Mineral Economics in my honour. I am very grateful indeed to all my friends and former colleagues and students who have contributed papers and notes in support.

Unfortunately I have not been offered the option of following the invaluable maxim that if you have special nothing to say then say nothing.

Accordingly I shall start with some broad observations on lessons I have acquired during my working life. Rather like Caesar's Gaul my professional life in the mining and metals industry has fallen into three parts. In July 1971 I was a refugee from a decade working in the declining UK chemical industry which I had entered on leaving university. I joined Rio Tinto as an economist, knowing virtually nothing about mining and metals, but realised very quickly that I needed to learn as much as possible about it. I think I did. Some happy and rewarding twenty five years later I decided to retire early as incessant foreign travel was becoming tiresome and I did not wish to cultivate a heart attack. I was very fortunate that I had many opportunities for close involvement in many industry organisations and for fruitful contacts with academics and government officials throughout my time at Rio Tinto.

The second and third parts of my career, if it can be described as such rather than as a series of happy accidents, grew out of those contacts. In 1988 Christopher Green, then the chairman of the newly reconstituted London Metal Exchange, asked me to become one of its four invited directors. After some demur I agreed, little realising that I would be an LME Board member for twelve years and would still be involved with LME committees today. This involvement opened up completely different and fascinating perspectives on the metals industry from those seen from within the mining industry.

One of my functions during my time at Rio Tinto was to talk about various aspects of the mining industry at conferences and symposiums, including inter-governmental organisations. It was through these that I came into contact with Thomas Walde, and slightly later Chris Rogers, of Dundee's Centre for Energy and Petroleum and Mineral Economics. I was initially invited to give a couple of talks to students, and after I had retired was inveigled into taking over Chris's graduate module on Mineral Economics and Resources Policy. Hence the third part of my career, which I fulfilled for about twenty five years, finally giving up in the face of on-line teaching during the Covid pandemic.

First I apologise at the outset if some of some of my remarks repeat comments made by Fred Wellmer in his article in his special edition of Mineral Economics (Friedrich-W Wellmer, What we have learned from the past and how we should look forward. Mineral Economics, Volume 35, Numbers 3–4, pages 765–795, December 2022, Springer). It should be unsurprising that two octogenarians who have been involved in the mineral industries for many years have similar messages. After all, "the thing that hath been, it is that which shall be; and that which is done is that which shall be done: and there is no new thing under the sun. Is there any thing whereof it may be said, See, this is new? It hath been already of old time, which was before us."". (*Ecclesiastes or The Preacher, Chap. 1. Verse 9 and 10*).

It is always dangerous to assume that the present generation has all the answers and that previous generations were naïve or unfeeling. Previous generations have had to grapple with similar problems to those facing the present one, even if the emphasis changes and new facets present themselves. There are fashions here as in everything else. The present focus on the ESG aspects of the industry is important, but that is only part of the industry's responsibilities. Its basic function is to create wealth by finding and extracting the mineral resources required to support industry and commerce. It needs to do this in as economically efficient a

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manner as is consistent with respecting its workforce, the environment and society. It exists in a global marketplace that both conditions and constrains its operations. Its ability to discharge its various responsibilities depends on its profitability as without that nothing is really sustainable.

There is a perpetual tendency to underestimate the power of the price mechanism in balancing supply and demand over the medium to long term. That tendency is most pronounced amongst politicians and public commentators. Mining is a cyclical industry in just about every respect and surpluses or shortages carry the seeds of their own demise. These seeds may sometimes take a long time to germinate but they invariably do. Even apparently well-established trends never continue indefinitely but are subverted by their own contradictions or by unforeseen events.

It is as well to be sceptical about projections of continuing rapid growth of demand or of severe persistent shortages. Trends, however seemingly well established, rarely last indefinitely. It is often overlooked, especially in public discourse, that very few mineral products are demanded for themselves but for their properties in use. Most can be substituted in most uses either by other materials or by different ways of satisfying the same end. Projections of demand seldom take sufficient account of potential substitution, whether induced by relative price movements or by technical change. The latter can be dramatic over time, wiping out major uses of a material and creating new ones. Many projections of demand have too narrow a focus and overlook the broader environment in which that demand exists.

Turning to supply, it is a truism that mineral resources are ultimately finite. For nearly all minerals that is of little operational relevance. Exploration for undiscovered resources and development of unexploited deposits may at times be insufficient to support adequate production to satisfy near-term demand. In the longer term, however, changes in technology and prices will elicit additional mine development. Many of the political, environmental and social impediments to mine development are man-made and tend to weaken or vanish in the face of changing societal needs. Admittedly this does not always happen rapidly or smoothly enough to avoid price dislocations but those are the triggers for change.

The present furore over 'critical minerals' epitomises some of the weaknesses in public policy on minerals. Present concerns about 'critical minerals' mirror a previous generation's worries about 'strategic minerals'. Most mineral products are 'critical' or 'strategic' in some uses, but they are also substitutable in most. For several decades users throughout the world were happy to rely on cheap supplies of minerals from China. Higher cost mines elsewhere were unable to compete and closed down, whilst there was little incentive, or apparent need, to explore for deposits elsewhere. In consequence China came to dominate the supply of many minerals.

Changes in perceptions about the desirability or reliability of dependence on China have caused something akin to panic about mineral supplies in western nations. That panic has been accentuated by projections of the likely demands created by the de-carbonisation and electrification of the global economy. My earlier comment about the need for scepticism is especially relevant here. There will certainly be lags before exploration is revitalised and new mines and processing facilities are brought into being, but continued scarcity is unlikely, even in the doubtful event that demand rises in line with present projections. Naturally the prospect of governmental support and subsidies encourages many companies and organisations to climb aboard the 'critical minerals' bandwagon. 'Put not your trust in princes' is, however, always sound advice for mining companies. In due course productive capacity will tend to meet and even outstrip supply. Also governmental priorities are liable to change and subsidies or other assistance withdrawn at short notice. High cost operations can become exposed to the cold winds of competition. Economic welfare and security are poorly served by fostering domestic production of mineral materials almost regardless of cost.

This leads on to the dangers inherent in consensus forecasts. When nearly all forecasters converge on very similar projections it is well to be cautious. There is some wisdom in crowds, but not all conventional wisdom is wise. Following the crowd may provide an alibi for error, and it is more comfortable to be wrong in company than alone. Nonetheless, there should be room for a variety of independent commentators, both idiosyncratic and conventional. In recent decades the number of genuinely independent analysts, both within mining and metal companies and more generally, has dwindled. The mining industry has always been a dedicated follower of fashion, but undue dependence on a small coterie of analysts can reinforce a herd mentality and accentuate the investment cycle that is one of the mining industry's enduring characteristics.

One abiding danger is the tendency to base longer term price forecasts on the requirement to cover the full costs of those marginal projects seemingly needed to meet expected demands. Obviously investment will be constrained and output will tend to stagnate if the mining industry fails to cover its cost of capital. The industry's capital cost are not, however, the same as the after-tax rates of return that major mining companies hope to achieve on new projects. Those are often ambitions that allow for the possibility that some projects will fail. They also tend to be substantially higher than the returns acceptable to many investors in the industry. More importantly, they are ex-ante forecasts, which do not fully allow for the behaviour of competitors,

for the lumpiness of capacity changes or for fluctuations in demand. Once a mine has been constructed its long run full costs become of academic interest, and its short-run marginal costs, which are much lower, become the relevant magnitude. Given their heavy burden of fixed costs, mines will tend to produce as long as such costs are covered, and in many instances they will continue for a considerable period when prices fall even lower. In consequence ex-post prices tend to fall short of expectations.

The time horizons of companies, investors, financial institutions and governments appear to have shortened considerably since I first entered the industry. Governments are strongly influenced by the electoral cycle, and company managements by the next set of financial results. Many financial institutions are mainly concerned with short-term returns rather than longer-term wealth creation, and company directors and executives have relatively brief sojourns in office. Twenty four hour news cycles and the demands of social media increase the pressures for speedy reactions and rushed decisions where careful balanced judgements may be required. This is to the detriment of sound planning and investment decisions in an industry with lengthy project lead times, long lived assets and extended payback periods. Short-termism has been a large contributor to western countries' present dependence on Chinese minerals. It is, of course, easy to grumble about all this, but very difficult to change it.

Much of the academic world is no less driven by appearance and perception rather than underlying reality than any other sector. Many papers (obviously including this one!) add little to knowledge but there are strong incentives to publish, often regardless of quality. Such papers are often adorned with bibliographies including extensive references, which are often marginally relevant. How much each reference has been read is sometimes open to question.

There is a serious point involved here. All too often authors quote statistics or analyses from other papers without thoroughly checking their accuracy or veracity. No matter how distinguished an author, their grasp of the true value of the statistics they quote may be tenuous. Most statistical sources contain caveats or qualifications to their data, but these often get lost in translation. Moreover, some widely quoted numbers have little firm foundation, as perusal of their initial source would quickly disclose. Once an error has been published it may acquire the status of holy writ and never be properly challenged. In short it is always best to go back to the original sources. That is particularly important where mathematical or statistical models are being constructed as their foundations may be too shallow to support their conclusions, no matter how elegant their mathematics or rigorous their reasoning. The devil truly does lie in the detail even if such detail appears boring and mundane.

Reverting to my introductory comments, I greatly appreciate this opportunity to express my sincere thanks to all those who have worked with me over the past sixty plus years. They have contributed in no small fashion to anything I have achieved in my various roles. It is perhaps fitting to end as I began with a quotation from Shakespeare: " Our revels now are ended… We are such stuff as dreams are made on, and our little life Is rounded with a sleep." (*The Tempest, Act IV, Line 148).*