Critical raw materials result in substantive technological and economic catch-up for the global south: Setting the scene for a deeper Socratic dialogue

The debate on sustainable economic development is increasingly focused on the widescale deployment of carbon neutral energy sources to drive the future energy systems. Renewable energy technologies such as hydropower, solar, wind, geothermal, fuel cells and bioenergy, among others, are indispensable to mitigating the impact of anthropogenic global warming while concurrently addressing the energy poverty faced by many countries in the global south. The transition to clean energy generation and storage systems is metal and mineral intensive and will require a substantive but sustainable supply of many of these critical metals and minerals. For example, metals and minerals such as lithium (Li), nickel (Ni), cobalt (Co), manganese (Mn), and graphite are irreplaceable in battery energy storage systems while rare earth metals are critical in the manufacture of high-performance magnets needed for wind turbines and electric vehicles. Likewise, industrial metals such as aluminium (Al) and copper (Cu) are irreplaceable in electricity generation and distribution systems. According to the International Energy Association (2021), electric vehicles require approximately 53 kg Cu, 9 kg Li, 40 kg, 25 kg Mn, 13k g Co, and 66 kg graphite per vehicle, compared to 22 kg Cu and 11 kg Mn in conventional vehicles. In the Minerals for Climate Action report (Hund et al. 2020) compiled by the World Bank Group, it is estimated that the production of critical raw materials (CRMs), such as graphite, lithium and cobalt, will increase by 500% by 2050 to meet the growing demand for clean energy technologies. This giganteum increase in demand in CRMs will create unprecedent opportunities for industrialization to resource-rich countries through exports and localization of value-added manufacturing activities.

Similar to a lot of other countries in the global south, Southern African states are either least developed or middle-income countries with ambitions to escape the poverty trap and catch up with more advanced economies. Contrary to these long-held ambitions to upgrade their economies, the GDP for most countries in sub-Saharan Africa has contracted over a protracted period of time and continue to face unprecedented challenges in transitioning from an economy driven by the exports of low value mineral commodities to manufacturing and knowledge driven economies. Being high value and high impact, clean energy technologies naturally present windows of opportunity for technological and economic upgrading to resource-rich countries such as South Africa. Although often associated with high risk and a high degree of uncertainty, clean energy technologies are characterized by high radical novelty, fast growth, and relatively high economic impact, with significant potential in creating new industries and/or transforming existing ones (Rotolo et al. 2015). There is indisputable evidence that, if managed properly, emerging technologies can indeed result in sustained technological and economic growth, and ultimately, lead to economic catch-up by the countries in the global south.

Economic scholars define 'catch-up' as a process by which a developing country narrows the income gap ('economic catch-up') and increases its technological capabilities ('technological catch-up') relative to frontier countries (Lee, 2013; Lee, 2019). When combined, technological and economic catch-up thus refers to the ability of a developing economy to grow faster compared to frontier economies and eventually reaching similar levels of technological capabilities and per capita income. Thus, in order to reduce the technological and income gaps relative to frontier economies, developing economies must attain and sustain both technological capabilities and income growth more rapidly than the advanced economies. Technological catch-up, which itself is a function of the specific technological strategies adopted as part of the growth strategy, logically precedes economic catch-up. Although 'technological catch-up' and 'economic catch-up' are not identical, they are closely related to each other in such a way that technological catch-up precedes or leads to market or economic catch-up (Lee, 2013).

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Two main models have been proposed to explain catch-up trajectories, namely, path-following (also known as flying geese) catch-up, and leapfrogging catch-up, with the latter form occurring following a stage-skipping or path-creating strategy (Lee, 2013; Lee, 2019). The path following catch-up is a linear and cumulative process whereby the latecomer follows the same technological trajectories taken by frontrunners. In this case, the latecomer moves along the same path, but faster by taking advantage of historical factors such as the maturity, declining costs, and ubiquity of technologies and technical knowledge (Lee, 2013). The leapfrogging model is more complex and occurs when a latecomer bypasses traditional stages of development to either jump directly to the latest technologies (stage-skipping) or explore an alternative path of technological development involving emerging technologies with new benefits and opportunities (path-creating) (Lee, 2019; Yayboke et al. 2020). This form of catch-up often occurs when technologies are shifting towards new technological trajectories, which allow the latecomers to reduce the technological gaps by skipping the older generations to adopt the next generation and cost-efficient technologies. This may, however, depend on a number of factors, such as market availability, cost of next generation of technologies, and/or the willingness of incumbents to share their proprietary technologies (Lee, 2013; Lee, 2019; Yayboke et al. 2020).

Regardless of the leapfrogging model adopted, the ability to catch up is dependent on the windows of opportunity arising from the emergence of new technoeconomic paradigms (Perez and Soete, 1988; Lee and Malerba, 2017). The emergence of radically new technologies, for example, offers latecomers the window of opportunity to leapfrog the incumbents whose technological capabilities and investments are locked into older technologies, limiting their agility to mitigate against the destructive potential of new technologies and products. In contrast, latecomers are able to leapfrog older technologies, bypass sunk investments in previous technology systems, and adapt new and emerging technologies to assume control of markets and thus outcompete the incumbents (Lee and Malerba, 2017). Shorter cycle technologies also present windows of opportunity to latecomers by reducing reliance on old and existing knowledge bases characteristic of longer cycle, often capital-intensive technologies, often dominated by incumbents (Lee, 2013). Complimentary to emerging and shorter cycle technologies, radical changes in demand conditions, business cycles, and/or abrupt changes in markets, such as those presented by the clean energy transition, also increase the ability of agile latecomers to enter new markets, catch up, and leapfrog the incumbents (Lee and Malerba, 2017). The success to catch-up by leapfrogging also depends on the regulatory and institutional framework. Most importantly, deliberate government policies through strategic mission-oriented industrial policies and R&D programs can shape the rate of innovations and accumulation of technological capabilities by domestic firms (Mazzucato, 2018).

Obviously, the ability to catch up is not a free ride, but rather, depends on a number of deliberate efforts and strategic interventions. The answer to sustained catch-up and growth lies in the ability to build technological capabilities, which in this context, can be defined as the ability to effectively assimilate, use new and existing knowledge to create new technologies, products and processes, and to acquire and commercially exploit new knowledge and skills (Lee, 2013). Purposive efforts to build technological capabilities at macro-scale can thus significantly increase the national absorptive capacity to assimilate technologies and knowledge developed by frontier economies (Kinoshita, 2000). Although the importance of national absorptive capacity in technology transfer is widely accepted, very few case studies are available to demonstrate its linkage to sustained technological and economic upgrading in most resource-based economies.

To conclude, the vast majority of literature and policy statements clearly articulate the high technological and economic importance of critical raw materials to the clean energy transition. Most notably, the emerging discourse on net zero transition has mostly focused on the critical roles of resource-rich countries from the global south derisking supply chains for these critical raw materials, which in my view, would only function to exacerbate the current 'pit to port extractivist' strategies being employed by most developing economies. In my mind, there is no doubt that the clean energy transition presents windows of opportunity for technological upgrading and industrialization through localization of value-added manufacturing activities. These issues definitely warrant further debate, and it is prudent to explore the macro-level linkages and challenges, and most importantly, the potential industrial policy tools available to increase the localization of manufacturing capabilities by resource-rich countries.

President's Corner *(continued)*

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