Technical Migration of Exports in Clean Energy Goods: The Indian Paradigm

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Abstract:

Climate change has emerged as the greatest threat to survival in the 21st century. As emissions continue to rise, the last decade (2011-2020) was the warmest on record. Consequences of such drastic shifts in global temperatures are far reaching such as intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms and declining biodiversity. This has resulted in increased awareness and rapid response from the global community over the past 2 decades. Several notable multilateral agreements such as Kyoto Protocol, UNFCCC, Montreal Protocol, and Paris Agreement have sought to limit global emissions, enhance responsibility-sharing and improve climate financing infrastructure. Mitigation and adaption via shift to alternate sources of energy have been highlighted as vital action points for policy-makers across the world. The development and trade of renewable energy products has positive implications in this regard. This paper seeks to evaluate the trend in exports of such goods over the past decade, and evaluation of their technical embodiment. While linkages between exports and economic growth have been established empirically by several studies, academic focus has shifted towards analysing the technological efficiency of exports basket. Further, effective action against climate change largely depends on ability to innovate and develop means for sustainable development. The following sectoral analysis will make use of product and export efficiency parameters (PRODY, EXPY, SI) as well as will attempt to classify the products baskets under different grades of technical sophistication. This is followed by assessment of India's position and subsequent comparison with other market participants. The discussion concludes with a result summary and goal-oriented policy prescriptions.

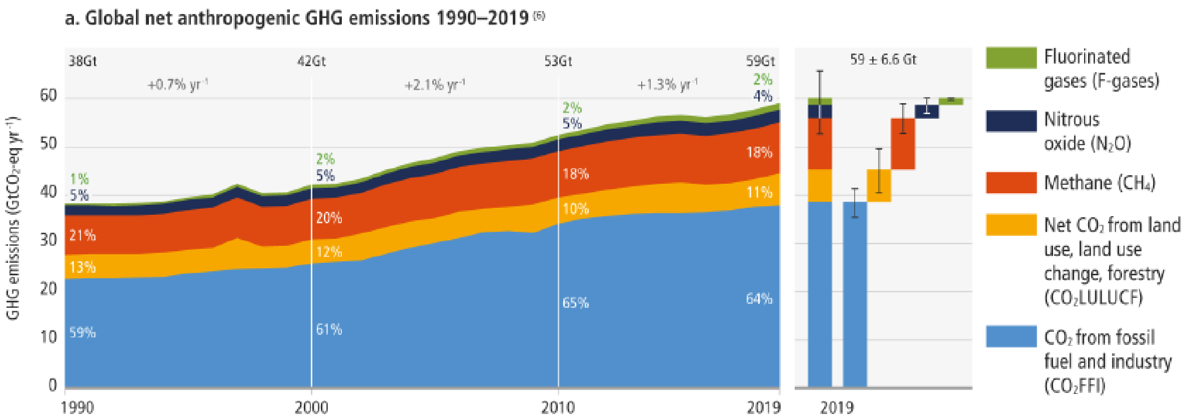
1. Introduction

United Nations has defined Climate Change as long-term change in temperatures and weather patterns. These shifts may be due to natural or man-made causes but since the 1800s, human activities have been the main driver of climate change, primarily due to burning of fossil fuels like coal, oil and gas.

The 6th Report of Intergovernmental Panel on Climate Change [I] stated that Net Anthropogenic greenhouse gas emissions (i.e. gross releases minus removal by anthropogenic sinks for UNFCCC specified gases) have increased since 2010 across all major sectors globally, with a rising share attributed to urban areas. Figure 1 maps the greenhouse gas emissions from 1990-2019, depicting a steady rise. *'Emissions reductions in CO_2 from fossil fuels and industrial processes, due to improvements in energy intensity of GDP and carbon intensity of energy, have been less than emissions increases from rising global activity levels in industry, energy supply, transport, agriculture and buildings.'* [I] Further, in 2019, roughly 50% of total net anthropogenic emissions were from Energy Sector (34%) and Industry (24%).

Figure 1 *(Source: 6th IPCC Report- Summary for Policymakers)*:

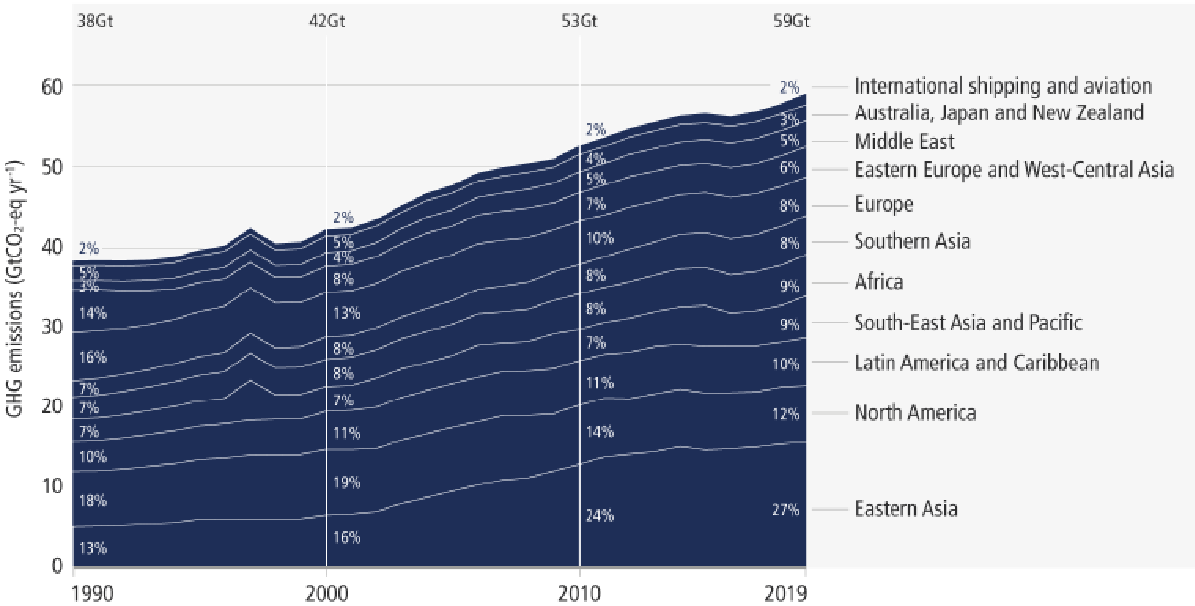
Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.



Country-specific contribution to these emissions is also varied across income and developmental levels. Nations at similar income levels have also shown differential net emissions and responses thereof. Figure 2 shows distribution of the global emissions based on geographic regions. The 6th IPCC Report [I] explains that countries with low emissions lack access to modern energy services i.e. clean and affordable energy services for personal and economic purposes. This is critical since improvement in living standards and promoting development is contingent on following a sustainable growth path.

Figure 2 *(Source: 6th IPCC Report- Summary for Policymakers)*:

a. Global net anthropogenic GHG emissions by region (1990–2019)



Moreover, at least 18 countries have shown sustained greenhouse gas emission reductions for longer than 10 years which has been linked to decarbonisation in energy production, energy efficiency gains, and energy demand reduction. Adoption of Renewable Energy (RE) in this context is another facilitating factor. RE or Clean Energy originates from natural sources/ processes that are replenished within the human timescale. [II] International Renewable Energy Agency (IRENA) considers 6 sources of RE which are, Bioenergy, Geothermal, Hydropower, Ocean, Solar, and Wind.

From 2010-19, global reductions in greenhouse gas emissions have been supported by reduction in unit costs of solar energy (85%), wind energy (55%), and lithium-ion batteries (85%), and large increases in their deployment. [I] Public funding for R&D, adoption subsidies and technology diffusion have been major policy tools for transitioning from fossil-fuel based consumption to cleaner alternates. However, lack of domestic enabling environment, institutional and infrastructural bottlenecks, dependency on foreign know-how and investments have limited this transformation for low-income, developing regions. In such environment, making a shift from conventional to green energy use will cause large scale disruptions in manufacturing, consumption activities and income.

Thus, there exist two seemingly disparate goals- shifting to RE and achieving economic growth. Over the past few years, this economic growth has been stagnating across the income spectrum. With constrained fiscal capacity of government, and uncertainty in consumption and investment, the impetus has shifted to the foreign sector for propelling growth. While growth does not necessarily translate into development, it is pertinent for achieving eradication of poverty, addressing needs of a rising population, catalysing wide-spread improvement in quality of life as well as expanding the available financial space for public expenditures. Sustainable energy security is one of the indispensable pillars of such development agenda. Consumption per capita of Primary Energy[1] in 2020 for India stood at 23.2 Gigajoules per capita in comparison to 265.2 Gigajoules per capita for USA and 101.1 Gigajoules per capita for China for the same year [III].

From above, it may be argued that there exist expansion possibilities in wide-spread generation and per-capita energy consumption for India, through holistic and sustainable means. This paper focuses on equipment/ products of such RE generation, the level of technology embodied within and implications for gains realised from such exports.

Efficiency, which has been considered of the technical variant for the purpose of discussion under this paper, has generally been analysed in terms of production abilities. Hausmann et al. [2007] [VII] had extended this premise to the context of exports. The formulation and evaluation of efficiency parameters, as considered by the above authors and adopted in this paper, follows from the fact that a country may be reasonably expected to export a good in which it has the highest efficiency/ expertise/ proficiency in order to maximise its returns. Thus, efficiency of the export basket has been considered as reflective of domestic competence in producing the basket's goods[2]. From this, the concepts of product and country efficiency are derived for analysis.

Economic theory and empirical analysis have revealed that the impact of various products on economic performance and gains is differential. Since the resource constraint is binding in economic activities (production, sale, reinvestment), efforts must be focussed towards incentivising production of growth-enhancing goods. The motivation of using measures to compute technical sophistication is to guide policy prescription and establish a positive role of government policies in specialisation of such higher productivity commodities.

The rest of the paper will proceed as follows: Section 2 will focus on establishing the methodology, working equations and data sources, Section 3 will depict the results which follow from the mathematical exercise, Section 4 will analyse these results in detail for India, Section 5 will look into performance of other nations and Section 6 will conclude the findings of the paper.

2. Methodology, Parameters and Data

i. Methodology

Inclusion of Products: The primary task in calculation of technical efficiency in production of export goods for a given nation requires identification of relevant goods (products) forming the export basket. In the case of Renewable Energy Products (REPs), the definition of such products is important to avoid inclusion of general-use equipment in the evaluation. For the purpose of this paper,

[1] Primary energy comprises of commercially traded fuels, including modern renewables used to generate electricity.

[2] See Empirics under Hausmann et al. [2007] [VII] for detailed elaboration.

Green/Renewable Energy products are those which are used in production of/manufactured by employment of renewable energy. This is in line with the understanding evolved through previous literature in this field[3].

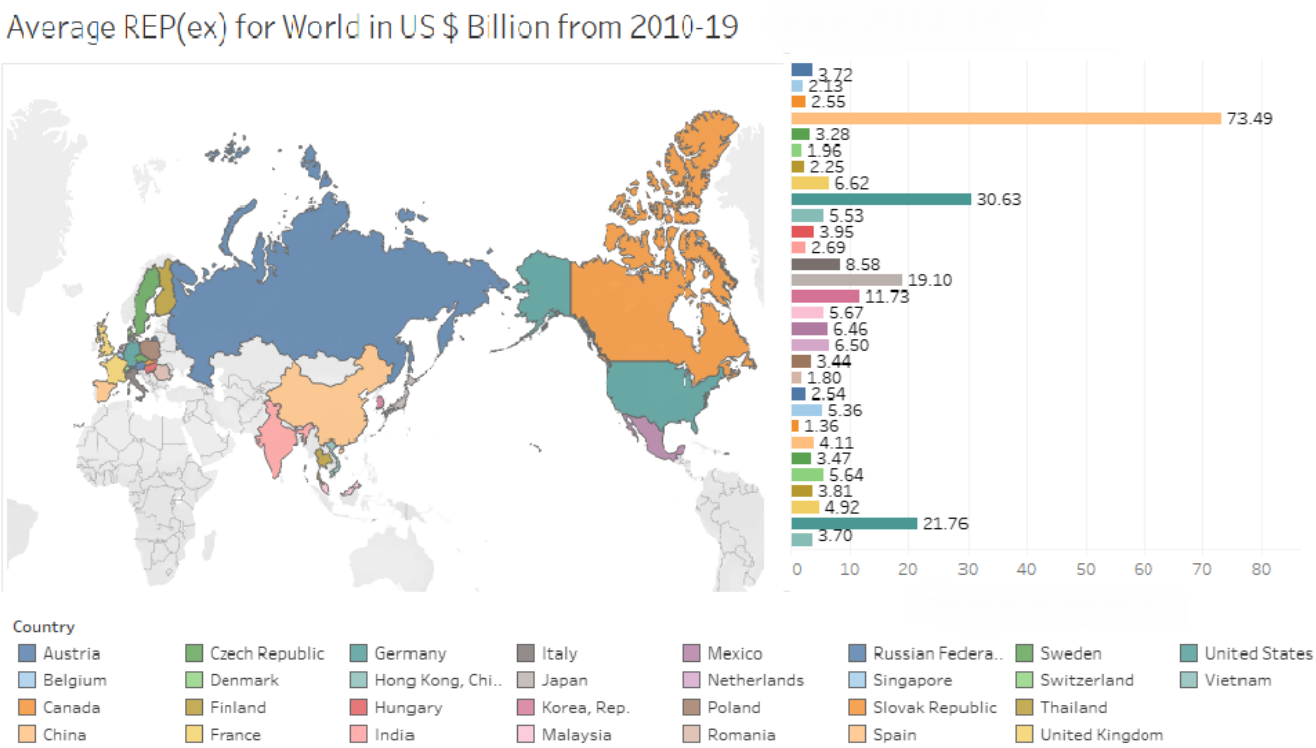
For inclusion of products concerning RE, the author has used HS 6 level of disaggregation of HS 2007 international trade standard. Fu et al. [2013], in their analysis on a related matter, had utilised HS 4 level of disaggregation for evaluation of export competitiveness of China [IV]. This was refined by Cao et al. [2018] [V] to select products at HS 6 level and classify them into 4 broad groups. In this regard, it is pertinent to mention that there is no single uniform or exhaustive list of products that can be included for such studies, and the dynamic definition of REPs allows for certain subjectivity in selection. Thus, the author has maintained the categorisation of REPs as by Cao et al [2018], but has expanded the product base from 28 to 43 products (Table A1) to attain a representative product sample for the sector[4]. Certain 4 digit HS product codes have been included to imply that the entire range of products under HS 6 Level of disaggregation of that 4 digit code are included in the REP list.

Inclusion of Countries: The annual export data of the world (country-wise) for the above selected 43 products was studied for the period 2010-19. A total of 174 countries/ regions exported REPs during the given time period. These were ranked in descending order and it was observed that top 30 countries accounted for roughly 94% of the world exports in REPs from 2010-19. For the purpose of this paper, this set of 30 nations have been considered as a representative proxy of the world. Their average trade (export) values in $ Billion from 2010-19, have been listed under Table A2 and a graphical representation may be seen below (Figure 3). China stood at the top rank with annual average export value of $ 73.49 Billion, and India was ranked at 23rd position with an annual average of $ 2.7 Billion. Interestingly, Germany and USA were ranked 2nd and 3rd respectively in the above Table A2 (with difference of $ 9 Billion in their annual averages), while the difference between 1st and 2nd ranks was worth $ 42.85 Billion, depicting wide variation among top nations in their export shares of REPs.

[3] Cao et al. [2018] defined REPs as equipment and related products that provide services for the efficient use of RE, and the development of RE industries.

[4] EXIM Bank's Occasional Paper - New Renewable Energy in India: Harnessing the Potential [2013] [VI] has been used for reference as well to identify relevant renewable energy products. However, the HS 6 digit codes for most of the products have been revised since the publication of the above mentioned paper and product codes used in this document may not match with the Occasional Paper.

Figure 3 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:



Use of GDP per capita: For calculation of PRODY$_k$ values for each product (explanation of preference of this parameter over others has been given in subsequent sections), the author has considered GDP per capita data (PPP) at 'Constant 2017 International $' standard. Hausmann et al. [2007] [VII] had computed PRODY$_k$ values '*using both PPP-adjusted GDP and GDP at market exchange rates*'. They had found similar results for both measures and concluded that there does not exist a '*substantive difference*' between them.

ii. Parameters for computation of Technical Sophistication

(a) Estimation of PRODY$_k$: Product efficiency parameter or PRODY$_k$ for a given good 'k' was introduced by Hausmann et al. [2007] [VII]. As can be observed from its equation given below, it builds upon the Revealed Comparative Advantage Index (RCA) of Balassa [1965] [VIII] and seeks to improve the previous indices developed by Michaely [1984] [IX] and Lall et al. [2006] [X]. Hausmann's measure utilises RCA as a weight to ensure that size of a nation has no bias in ranking the products. Michaely's index suffered from bias with respect to level of development and was constructed at a low level of aggregation, while Lall's index proposed aggregation of countries into different income groups with loss of precision and country-specific analysis[5].

[5] Interested readers may refer to Huber, S. Indicators of Product Sophistication and Factor Intensities: Measurement Matters. *Journal of Economic and Social Measurement, Vol. 42, No. 1, pp. 27-65, 2017* for critical evaluation of these indices. Interestingly, Huber [2017] [XI] in this paper proposes a stylised indicator to replace PRODY$_k$ in the form of Controlled PRODY$_k$ or CPRODY$_k$, to overcome the former's drawbacks.

The main criticism for Hausmann's measure is that is faces the problem of double counting inherent in Balassa's measure [VIII]. To address this, Vollrath [1987] [XII] introduced amended versions of RCA which were discussed by Shirotori et al. [2010] [XIII] in terms of evaluation of $PRODY_k$. Additionally, literature says that very small countries distort $PRODY_k$ values, but this can be safely ignored for this paper since it considers a pool of 30 developed and developing nations with significant share in world trade and output.

Despite the above constraints, $PRODY_k$ is still widely used due to its convenience and availability of data. Furthermore, it has been observed that Vollrath's [1987] [XII] amendments yield similar results as the original $PRODY_k$, thus allowing researchers to use the latter [XI].

The $PRODY_k$ index is given as follows (E1):

$$PRODY_k = \sum_j \frac{(x_{jk}/X_j)}{\sum_j (x_{jk}/X_j)} Y_j$$

Where,
(x_{jk}/X_j) refers to value share of kth product of jth nation in the total exports of jth nation,
$\sum(x_{jk}/X_j)$ aggregates the value shares of the product across all countries,
Y_j is GDP per capita data (PPP) at 'Constant 2017 International \$' standard.

From above, it is evident that higher weights are assigned if the export commodity constitutes a larger share of a country's export basket. While the above indicator was developed to analyse technical content of a given country's export product (through use of panel data), its adoption for sectoral analysis (for instance, REPs in this paper) requires certain modifications. In light of above, it is quite probable that Cao et al. [2018] [V] had redefined X_j to incorporate such sectoral adjustments for their study. They had considered X_j to denote *total exports of the REPs of a nation in comparison to its definition in the original Hausmann's equation (see Box 1).*

However, this paper has retained the $PRODY_k$ form given under E1 for the purpose of calculations and interpretation of $EXPY_j$ has been modified to address requirements of this sector-specific scrutiny (discussed in subsequent sections).

Box 1: Methodology of Cao et al. [2018] [V] and caveats in using STATA

Huber [2017] [XI] in his remarkable paper on amendments in $PRODY_k$, had introduced the user-written program code for STATA to calculate $PRODY_k$ and $EXPY_j$ indices. This program and other sample files are available in the Statistical Software Component (SSC) Archive [XIV].

The program allows researchers to calculate the parameters in simple steps and is highly convenient and simplistic in its use. Furthermore, it allows for computation of different versions of the technical sophistication parameter [such as timevarying, Hausmann et al. [2007], Lall, Mic].

However, a key limitation of this program is that it was written for country-wide analysis and its application at sector level requires certain qualifications. In other words, the program does not include total exports of a country k (i.e. X_j in Hausmann's formula) as a separate variable, but uses the sum of all products specified in the data set as X_j. Though Cao et al. [V] have refrained from mentioning the calculation aspect of their research, the modification in the definition of X_j in that paper hints towards the liberal use of Huber's STATA code for deriving results.

Furthermore, the Trade Policy Analysis publication by UNCTAD and WTO [XVI] had also written a series of do-files for STATA computation of $PRODY_k$ values. As in the case of Huber [2017] [XI], this too suffers from the same limitation in application to sectoral cases (see Appendix).

In order to address the above modification, $PRODY_k$ may be computed using manual calculations to get values as under Hausmann's equation. An alternate approach can be undertaken by application of filters for sector-specific products, once $PRODY_k$ values for all products is estimated in STATA. However, at HS 6 level of disaggregation, this may be considered as a cumbersome and tedious exercise. Thus, this paper has taken recourse to the first method and adjustments to account for REPs sector have been made in other indices.

(b) Classification of $PRODY_k$ values: For effective comparison of $PRODY_k$ values for different products, these need to be illustrated across a given spectrum of finite length. Various classification methodologies have been evolved through the literature[6].

This paper uses 'Equalisation Technology Classification' methodology introduced by Cao et al. [2018] [V]. The choice of classification is subjective and the above-mentioned method has been adopted due to its simplicity and equal-sized intervals. This allows for distribution of appropriate products in a homogenised manner. This can be explained as follows:

- The largest and smallest PRODY values for a given year (across all products) are denoted as t_n and t_1.
- Let 'm' denote the number of intervals/ categories for product classification.

[6] Interested readers may refer to Cao et al. [2018] [V] for information about other classification techniques and relevant papers.

- Then, "PRODY value difference of the adjacent technology grade products, D" is defined as follows (E2):

$$D = \frac{t_n - t_1}{m}$$

- The criteria for m intervals is calculated as (Table 1)

Category	Interval Range
High Technical Complexity Products	PRODY ≤ t_1 + D
High- Medium Technical Complexity Products	t_1 + D ≤ PRODY ≤ t_1 + 2D
Medium Technical Complexity Products	t_1 + 2D ≤ PRODY ≤ t_1 + 3D
Medium- Low Technical Complexity Products	t_1 + 3D ≤ PRODY ≤ t_1 + 4D
Low Technical Complexity Products	t_1 +4D ≤ PRODY

The above categories correspond to the descriptive explanations as listed in the table. This allows for easier interpretation of the results and formation of above classification is intuitive since higher $PRODY_k$ values express higher level of technical sophistication.

(c) Estimation of $EXPY_j$ and subsequent normalisation

In conducting the empirical analysis, Hausmann et al. [2007] [VII] had introduced the parameter of $PRODY_k$ for calculation of the export efficiency of a given country. Alternately, $EXPY_j$ has been formulated to reflect the '*productivity level associated with a country's specialisation pattern*' Hausmann et al. [2007] [VII]. The rationale given for linking productively with export efficiency is as follows: '*Focusing on exports is a sensible strategy since θ_{max} refers to the most productive goods that a country produces and we can expect a country to export those goods in which it is the most productive. Besides, we have much more detailed data on exports across countries than we do on production.*' Hausmann et al. [2007] [VII].

Following this, $EXPY_i$ or the efficiency of a nation i for its export basket can be formulated as follows (E3):

$$EXPY_i = \sum_l \left(\frac{x_{il}}{X_i}\right) PRODY_l$$

Where,

(x_{il}/X_i) refers to value share of lth product of ith nation in the total exports of ith nation,

$PRODY_l$ refers to the product efficiency value of lth product.

This implies that higher $PRODY_l$ values and higher share of that lth product in a nation's export basket result in higher $EXPY_i$, or alternately, the more technically sophisticated are a country's export, the higher will be its $EXPY_i$.

Herein comes the slight modification as required by sectoral considerations. Since the premise of this paper is to analyse only the REPs sector, the $PRODY_k$ values have been computed exclusively for a selected group of products (see Table A1). Consequently, computation of $EXPY_i$ will employ only these specific $PRODY_k$ values from the entire range of possible $PRODY_l$ values (given, $k \subset l$).

Thus, E1 for $PRODY_k$ can be reinterpreted as parameter of product technical complexity for REPs (where k=1, 2…n REPs) and $EXPY_i$ (E3) will then reflect the export efficiency of a nation i (where i=1, 2….m nations) in REPs only.

Fortunato et al. [2014] [XV][7] went a step ahead and normalised the $EXPY_i$ values for a range of countries over a period of time. Since this manuscript works on a panel data, this method is especially useful is comparing efficiency-centric export performances across time and nations and deriving valuable insights for future policy actions.

The above mentioned normalisation has been explained in terms of a Sophistication Index (formulated by Fortunato et al. [2014] [XV]) as follows (E4):

$$SI_{jt} = \frac{EXPY_{jt} - EXPY_t(Min)}{EXPY_t(Max) - EXPY_t(Min)} * 100$$

Where,
$EXPY_{jt}$ refers to EXPY value for jth nation in t year,
$EXPY_t$ (Min) refers to minimum EXPY value across given set of nations in t year,
$EXPY_t$ (Max) refers to maximum EXPY value across given set of nations in t year.

As can be seen from above, the index ranges from 0 to 100 with 0 denoting the worst performing nation and 100 denoting the best performing nation in terms of export efficiency in year t.

iii. Data Sources and Selection

The raw data for REP(ex) has been extracted from WITS database (UN COMTRADE) through 'Advanced Query' feature, in US $ Thousand. For convenience in interpretation, this has been converted in US $ Billion, though the ratio in the applied equations is unit-free. The HS standard considered for this paper is 2007 and product codes are at HS 6 level of disaggregation.
The dataset for GDP per capita data (PPP) at 'Constant 2017 International $' standard has been extracted from the World Bank database (WDI).

[7] The said paper is quite useful in explaining the middle-income trap with respect to export performances of countries. This builds upon the existing developmental theories and establishes wide-ranging impact of the trap.

3. Results

i. <u>Average $PRODY_k$ values from 2010-19 for the selected REPs</u>

$PRODY_k$ values for all years (2010-19) for the 43 REPs were computed and average figures are given under Table A3. The range for the given dataset was [54932, 26112] for solar-powered wrist-watches and wood, sawdust, scrap respectively. As the theoretical framework suggests, higher $PRODY_k$ suggests higher level of technical complexity of the product (assuming they are exported by high-income countries), the range discussed above is intuitive and self-explanatory.

ii. <u>Classification of $PRODY_k$ values based on Equalisation Technology Classification Method</u>

Following i., the results (average values of $PRODY_k$) were categorised based on E2 with D= 5764.165. The categories and their respective bounds have been defined as follows (Table 2):

S.No.	Technical Classification Category	Calculations	Dimensions	Colour code of REPs under each category	Number of Products
1	High	-	t_i >49,168.22	Green	2
2	High-Medium	49,168.22	43,404.06< t_i <49,168.22	Purple	9
3	Medium	43,404.06	37,639.89< t_i <43,404.06	Pink	17
4	Medium-Low	37,639.89	31,875.73< t_i <37,639.89	Blue	13
5	Low	31,875.73	t_i< 31,875.73	Yellow	2

Where,
t_i= PRODY value of ith product

Details of different products under each group are given in Table A4. As can be inferred from Table 2, major portion of products are concentrated in middle 3 categories with 'Medium Technical Complexity Level' having the highest number of REPs.

iii. <u>Average $EXPY_i$ in REPs from 2010-19 for "World" and Sophistication Index</u>

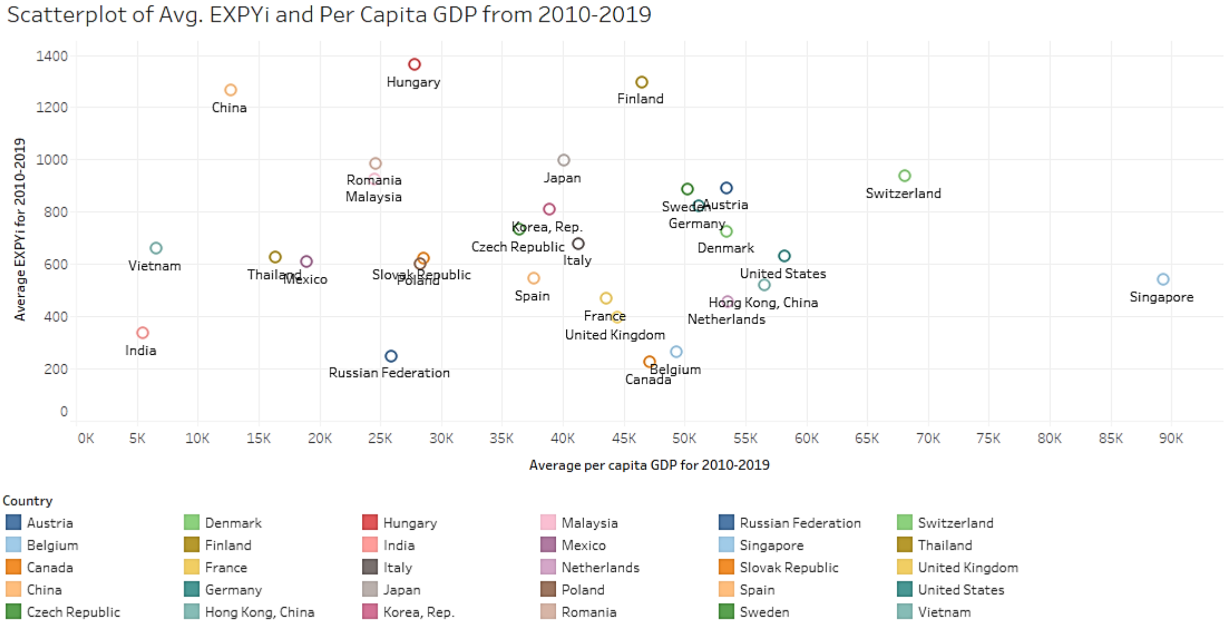
The average $EXPY_i$ for REPs for the world (Top 30 REP(ex) nations) have been computed as per E3 and summarised in Table A5. Further, Sophistication Index for ith country has been tabulated in Table A6, by normalising $EXPY_i$ values for each year (following E4).

From Table A6, highest average SI (=93.52%) was for Hungary and lowest (=6.01%) was for Canada. India stood on the lower end of the spectrum at 27th rank with average SI of 14.52%.

iv. Mapping $EXPY_i$ against GDP per capita

Figure 4 depicts a scatterplot of average $EXPY_i$ and Per-Capita GDP for the given time reference. While the relationship between these 2 variables is by construction as well, Hausmann et al. [2007] [VII] have found that countries which perform better in $EXPY_i$ than predicted by their Per-Capita GDP have shown rapid economic growth in subsequent years. This validates their claim that the efficiency parameter for a country's export basket is a strong indicator of growth. Most of the countries are concentrated in the middle of the graph, with certain outliers such as Singapore, Switzerland, Finland, Hungary, China, Vietnam, and India. China, Hungary and Vietnam, Romania, Malaysia show better performance in $EXPY_i$ over Per-Capita GDP and opposite is the case for Singapore. India performed poorly in terms of both parameters on an average, implying latent potential in manufacturing high- value added products.

Figure 4 *(Source: Raw Data from WITS database (UN COMTRADE), World Bank database (WDI) and Author's own calculations)*:



4. Analysis and Evaluation for India

Figure 5 depicts the total REP(ex) across all 43 products for India from 2010-19 in US $ Billion. These exports rose steeply during 2017-19. This is in tandem with the movement of total exports basket of India during the same period, though growth in former has been comparatively faster in the last 2 years.

During 2010-19, the top 5 products exported by India under REP category (roughly 60% of total REP(ex) in this period) are as follows: Electrical Static Converters (850440) [Medium Technical Complexity], Electric Motors and Generators (spl. category) (850300) [Medium Technical Complexity], Pumps and Compressors; for air, vacuum or gas (841480) [Medium-Low Technical Complexity], Photovoltaic Cells (854140) [Medium-Low Technical Complexity], Electrical Transformers, Static Converters and Inductors (850490) [Medium Technical Complexity], in descending order. During the period, exports of PV cells have fallen except for a rise in the last year. Pumps, compressors and electrical transformers have converged to similar levels by the end of 2019. Only electric static converters have shown significant improvement in export numbers, with electrical motors and generators (spl. category) reporting sharp upward trend from 2018.

The top 5 REP(ex) destinations for India are as follows: USA, China, France, Germany and UAE, in descending order. These destinations constitute approximately 35% of total REP(ex) to all countries, indicating that India performs better in geographical diversification in comparison to product diversification.

Figure 5 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:

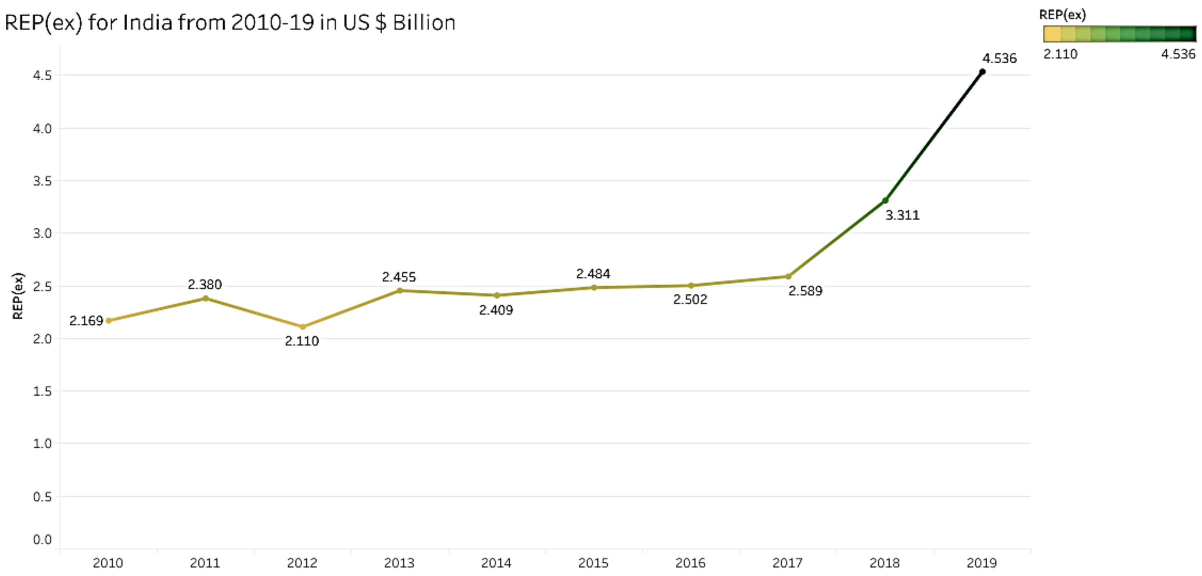


Figure 6 represents the values of EXPY in REPs and Sophistication Index for India from 2010-19. Average figures for India stood at 335.37 and 14.52% respectively for the given time period. By and large, EXPY for REPs and SI have followed a similar path, with the difference that SI shows greater volatility (for instance, SI fell sharply from 15% in 2016 to 6% in 2017 while EXPY in REPs fell marginally from 360 to 344 during the same period). This may be explained by the computational methodology for SI which considers the relative position of a country's EXPY value with respect to other countries constituting the "World" group in a year.

EXPY showed a falling trend till 2014, after which it picked up to attain a maximum value of 434 in 2018 and fell slightly to 412 in 2019. The peak in 2018 can be attributed to increase in total REP(ex), as well as Y-O-Y increase in exports of high and medium technical complexity products (i.e. higher $PRODY_k$ values). The decline in EXPY in REPs for 2019 despite robust growth in total REP(ex) compared to total export basket has primarily been due to Y-O-Y decline in $PRODY_k$ values in most of the products in the selected group. Since $PRODY_k$ requires weighted average of per-capita GDP, it has been observed that the latter has declined in 2019 vis-a-vis 2018 for almost all economies in the "World" group. Consequently, in general, EXPY in REPs for 2019 has decreased for most countries in this group.

Figure 6 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:

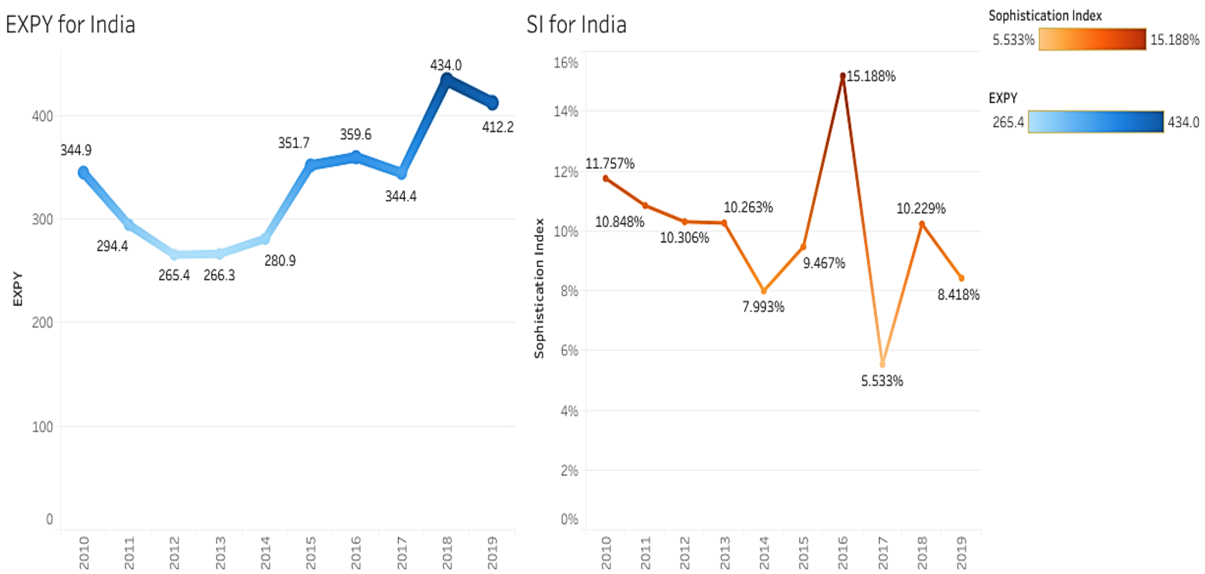


Figure 7 depicts the central theme of this paper. Based on total REP(ex) under various product categories for 2010-19, the actual relative shares of export value for different technical sophistication levels in the total REP(ex) for each year has been illustrated in the representation below. Further, the percentages on the left side of the line graph denote the proportional share of each complexity category based on the number of products classified at each level.

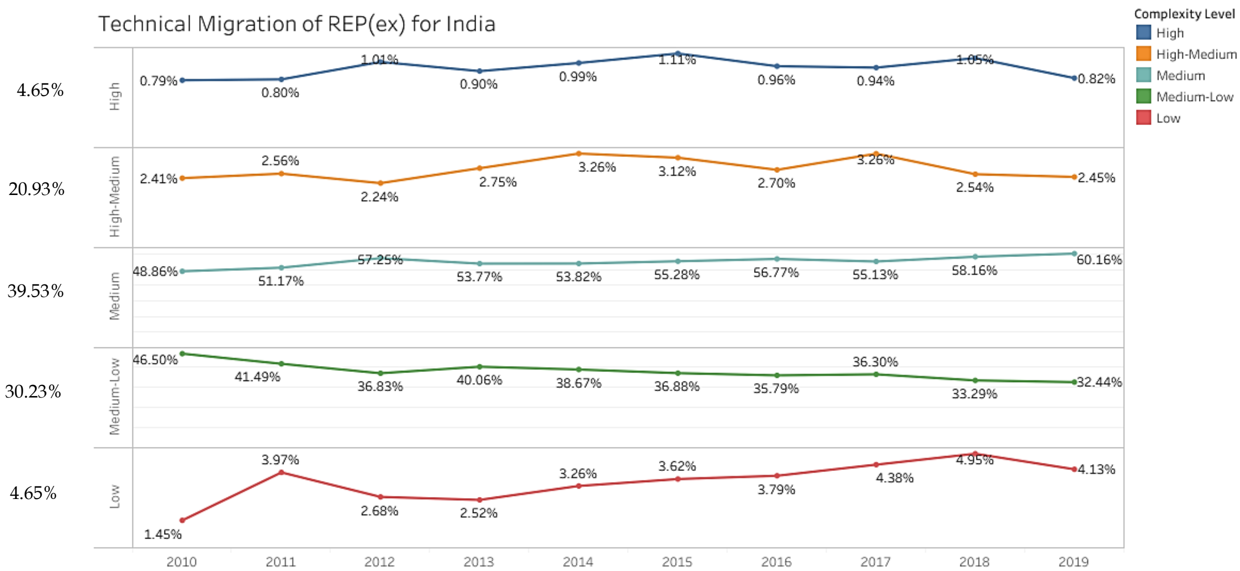
For India, roughly 55% of REP(ex) belong to Medium Technical Complexity Level. This is almost 1.5 times higher than that warranted by the proportional share of this category. The second highest share of REP(ex) fall under Medium-Low Complexity Level with an average value of 38% (and, 30% as per proportional share). Broadly, over the span of 10 years, with expansion in total REP(ex), only the share of Medium-Low Technical Complexity products have shown a consistent decline, while Medium Technical Complexity level has witnessed a steady growth in its relative share.

However, on the down side, the shares of High and High-Medium Complexity Levels have been stagnant over the past decade, interjected with brief periods of improvement. Unfortunately, there has not be sustained growth in these shares for a longer duration. Moreover, the products under above-mentioned 2 categories form a despairingly lower share in the overall REP(ex) (an average of 0.94% for High and 2.73% for High-Medium) than the portion stipulated by their product count (i.e. 4.65% for High and 20.93% for High-Medium).

The only sophistication categories where Indian REP(ex) performance corresponds to their counterpart proportional shares are Medium-Low and Low Technical

Sophistication Levels. While the trend for Medium-Low category shows a steady fall over the time period, the situation is unfortunate in the case of Low category. Contrary to expectation of improvement in technological capabilities over the years, the share of Low Technical Complexity products have increased swiftly from 1.45% (in 2010) to peak at 4.95% (in 2018). While there has been a definite decline in Medium-Low category product share, its impact is ambiguous from the above discussion since it is unclear which category has occupied the vacated product space (Medium or Low?).

Figure 7 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:



5. International Performance and Peer Comparisons

For comparative study, the author under this section looked at a few benchmark cases for drawing reference, and then proceeded to analyse the performance of emerging peer countries. As evident from the following discussions, the countries that had been the top performers at one time, have faced a consistent decline in the technical sophistication of their REP(ex). This suggests an ample, growing space in international market and technology-based learning for fast-moving economies in this sector.

i. Benchmark Nations

Figures 8 and 9 map the movement of total REP(ex) and Sophistication Index, respectively for a specific group of nations from 2010-19. The choice of nations considered here is based on average GDP per capita data (PPP) at 'Constant 2017 International $' standard from 2010-19, with top 10 nations (excluding Hong Kong SAR, see Box 2) as Benchmark Nations. Since the premise of this paper rests on effective transformation of high income and technological know-how into high sophistication level REP(ex) performance, the above metric may be considered justifiable for the purpose of analysis.

With the exception of Netherlands, which has revived its REP(ex) progressively from 2015, all Benchmark Nations have witnessed decline or near stagnation in their total REP(ex) during 2010-19. More importantly, the analysis of Sophistication Index depicts a broadly continuous fall (with one major outlier in 2016, where certain nations experienced a sharp increase). Since SI is constructed in a relative sense, this implies that for Benchmark Nations, export efficiency in REP(ex) has suffered sharp decline from 2010-19.

Figure 8 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations):*

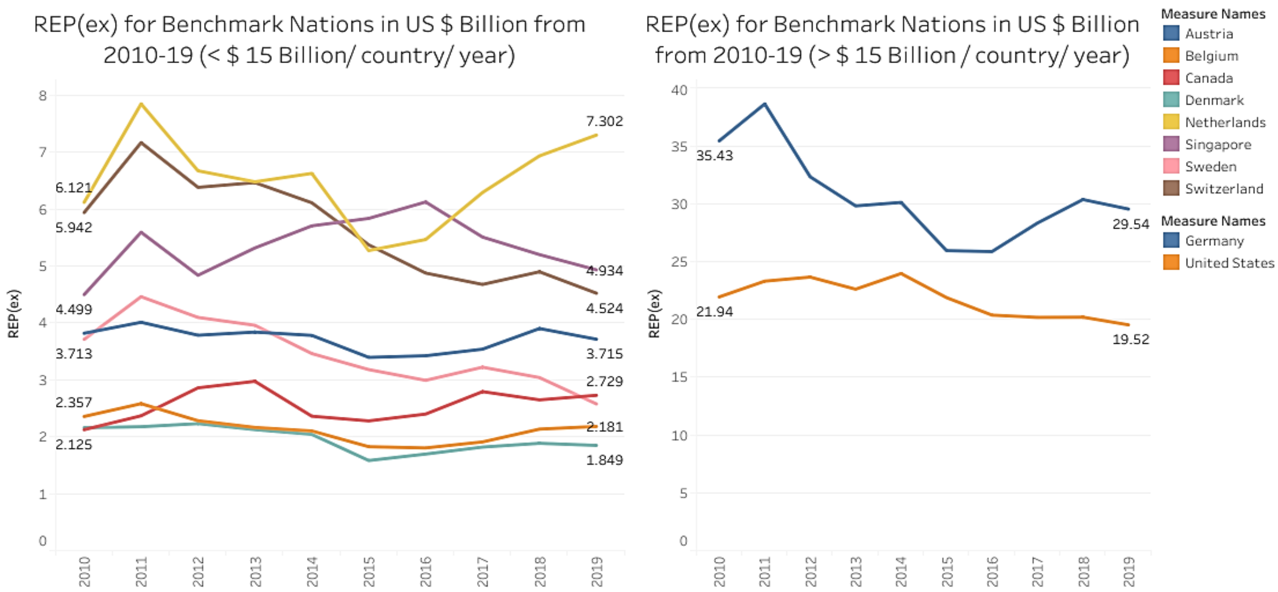
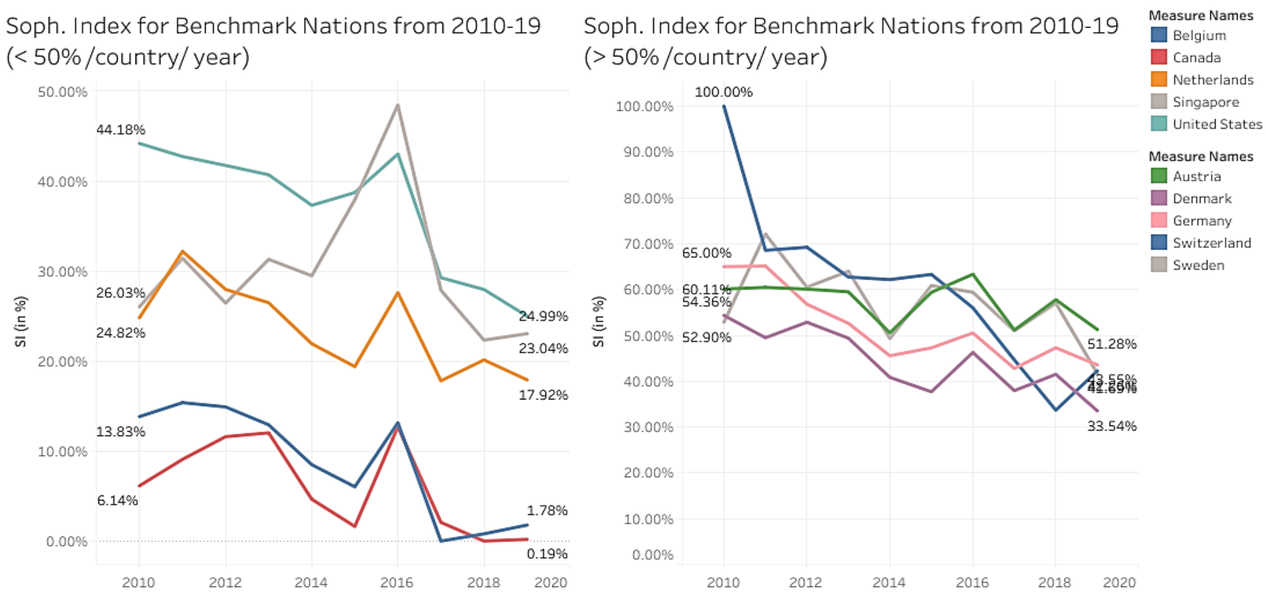


Figure 9 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations):*



Box 2: The special case of Hong Kong

Analysis of Hong Kong SAR presented a confounding case while consideration of REP(ex) of top 30 nations for the period 2010-19. The tables below refer to the total exports, total REP(ex) of Hong Kong for respective years.

Table B2.1: Total Exports of Hong Kong SAR in US $ Billion (2015-19)

Source: Raw Data from WITS database (UN COMTRADE)

Year→	**2015**	**2016**	**2017**	**2018**	**2019**
Total Exports to World	11.90	25.53	549.86	569.11	535.71
Exports to Top 3 Partners					
China	6.88	14.66	297.81	314.29	296.07
United States	0.46	0.69	42.42	45.87	39.12
India	0.08	0.28	21.07	17.90	15.49

Table B2.2: REP(ex) of Hong Kong SAR in US $ Billion (2015-19)

Source: Raw Data from WITS database (UN COMTRADE)

Year→	**2015**	**2016**	**2017**	**2018**	**2019**
Total Exports to World	0.059	0.048	18.502	18.925	17.568
Exports to Top 3 Partners					
China	0.054	0.044	8.048	8.541	8.037
United States	0.002	0.001	2.870	2.668	2.139
Japan	0.000	0.000	0.952	0.897	0.887

As can be seen from above, Hong Kong's export basket expanded steeply between 2016 and 2017 (roughly 21 times increase y-o-y). This was reflected in substantial growth across all Standard Product Groups in its exports. *What happened to Hong Kong in this period?*

It will helpful to know a little background first.

Hong Kong Special Administrative Region of the People's Republic of China is a city and special administrative region of China on the eastern Pearl River Delta in South China. It was established as a British Colony in 1841 and was later transferred to China in 1997. It is one of the 2 SARs of China (the other being Macau) which maintains separate governing and economic systems from that of mainland China under the principle of "one country, two systems [XVII]. Moreover, both Hong Kong and China remain individual members of the World Trade Organization (WTO).

It is a capitalist, service-led economy characterised by low taxation, free trade and minimal government intervention in the market. On the economy front, the city has excellent transportation, port and logistics infrastructure for international cargo, enabling its role as an entrepôt [XX]. It offers as a platform for Mainland China companies to enter regional and global markets. Further, Hong Kong is part of the Maritime Silk Road of China which allows for greater connectivity and free movement across a vast area.

The signing of Closer Economic Partnership Arrangement (CEPA), 2003 and its subsequent amendments also facilitated free trade and cross-boundary investment between Mainland China and Hong Kong [XVIII] [XIX]. More importantly, since CEPA is nationality neutral, overseas-based companies incorporated in Hong Kong can enjoy the full benefits of CEPA.

Despite this, the above does not entirely explain the puzzling scenario of 2016-17. This is explained *by classification of exports data*. The tables below depict gross exports, re-exports and exports of Hong Kong for 2015-19 under various heads.

Table B2.3: Total Exports of Hong Kong SAR in US $ Billion (2015-19)

Source: Raw Data from WITS database (UN COMTRADE)

Year→	**2015**	**2016**	**2017**	**2018**	**2019**
Re-Exports	498.65	491.06	-	-	-
Exports	11.90	25.53	549.86	569.11	535.71
Gross Exports	510.55	516.59	549.86	569.11	535.71
=SUM(Exports, Re-exports)	510.55	516.59	-	-	-

Table B2.4: REP(ex) of Hong Kong SAR in US $ Billion (2015-19)

Source: Raw Data from WITS database (UN COMTRADE)

Year→	**2015**	**2016**	**2017**	**2018**	**2019**
Re-Exports	18.539	17.294	-	-	-
Exports	0.059	0.048	18.502	18.925	17.568
Gross Exports	18.598	17.342	18.502	18.925	17.568
=SUM(Exports, Re-exports)	18.539	17.294	-	-	-

Gross exports include Exports (goods produced and exported by a nation) and Re-Exports (exports of foreign goods in the same state as previously imported without substantial transformation (UN)). For the purpose of this paper, the author has considered 'Exports' data (to consider only domestic capabilities in production of a good), which excludes the Re-exports. However, in the case of Hong Kong, the UN COMTRADE database did not separately classify re-exports post-2016. This resulted in inclusion of Re-Exports under the Exports head (and consequently Gross Exports and Exports are equivalent for 2017-19 in the data above, leading to a very high jump in the Exports figures). Even for the period before 2016, Re-Exports constitute a majority share of the Gross Exports (over 97.4% of total exports in 2015 [XX]) with a meagre portion of Exports, and it may be considered to hold true for later years as well. This validates the functioning of Hong Kong as a "centralised location for trade, where traders specialise in matching buyers and sellers from different foreign economies", as described by Jones et al. [2020] [XX]. Further, independent analysis of Gross Exports data from above data shows low y-o-y growth (only 0.07 times from 2016 to 2017). Thus, data deficiency has incorrectly exaggerated the export figures for Hong Kong SAR.

Due to lack of alternate data, the above figures have been considered for Hong Kong since its exclusion will not yield representative results. However, since this transcript is concerned with addressing the domestic potential to produce technically sophisticated products in RE, the author has refrained from analysing Hong Kong's REP(ex) for international comparison purposes.

ii. <u>Emerging Producers</u>

This is in contrast to the case of Emerging Producers, with corresponding analysis in Figures 10 and 11. Sustained growth has been observed in absolute numbers for the given nations in their total REP(ex) from 2010-19. This rise has been sharpest for the case of Vietnam, which has emerged as a strong competitor of India in merchandise trade across various sectors. Moreover, since the withdrawal of China from the forefront of Manufacturing Hub, the Asian group has demonstrated immense potential in catering to the global manufacturing demand in a variety of products.

In terms of Sophistication Index, while the rise has not be as steep as under REP(ex), there has been consistent improvement in the relative position of these Emerging Producers from 2010-19, except for decline in the last year of the time period.

<u>Figure 10 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:</u>

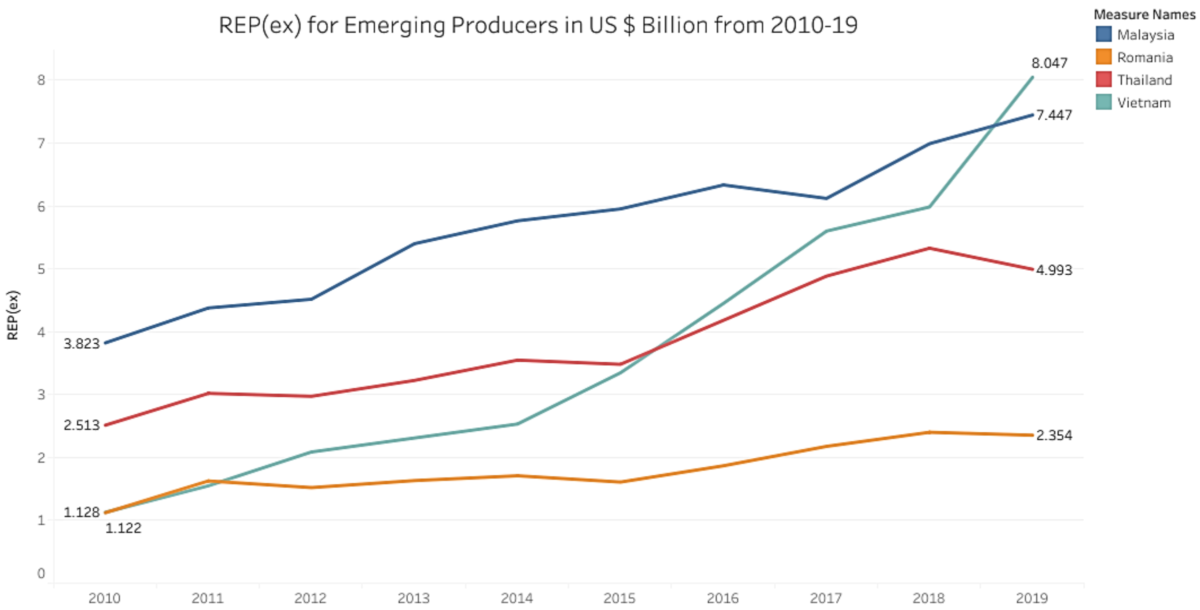
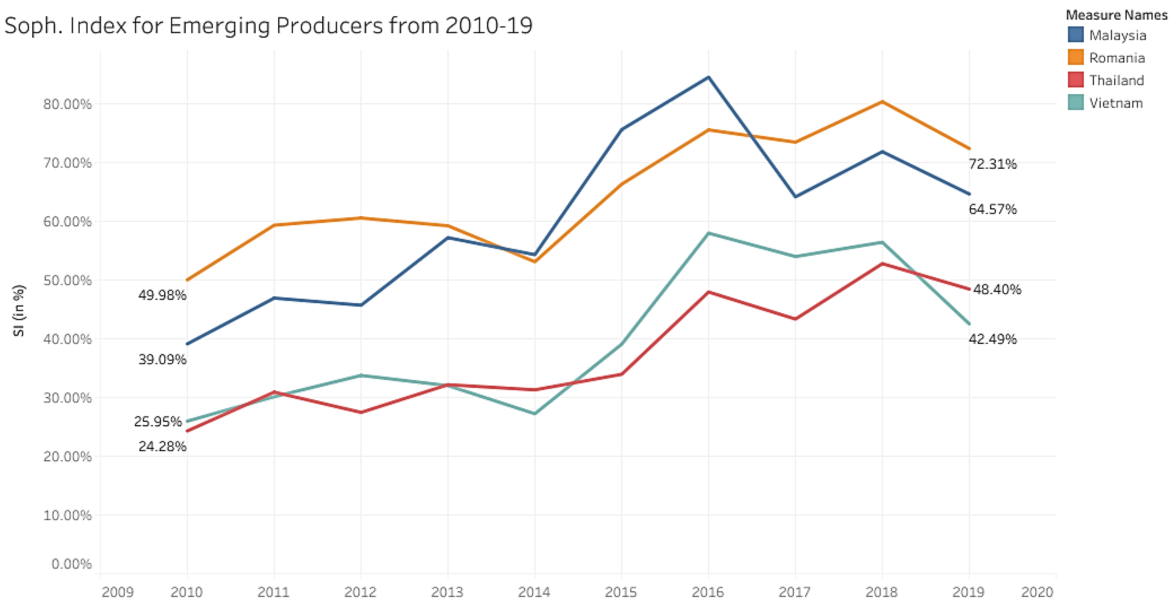


Figure 11 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:



Box 3: What's up with Vietnam? [XXI] [XXII]

After the end of Vietnam War (between Communist North and Capitalist South) in 1975, the Vietnamese economy was in shambles. After series of failed steps to improve economic growth, production and social indicators, the communist government of the nation initiated socialist-oriented market economic reforms known as "Đổi Mới". These reforms marked the beginning of Vietnam's journey as a probable 'China plus One' contender.

Figures B3.1 and B3.2 depict the GDP per capita, exports as % of GDP and Change in composition of Vietnam's Exports. These variables have been on considerable rise as well as there has been a definite shift from primary to manufactured exports during the given time period.

Figure B3.1: GDP per capita and Exports of Goods and Services as % of GDP for Vietnam from 1986-2019

Source: Raw Data from World Bank

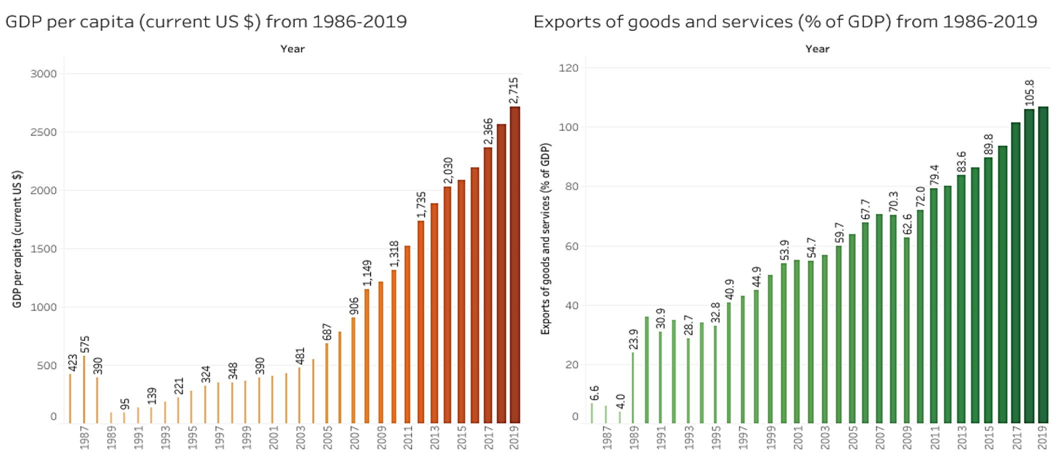
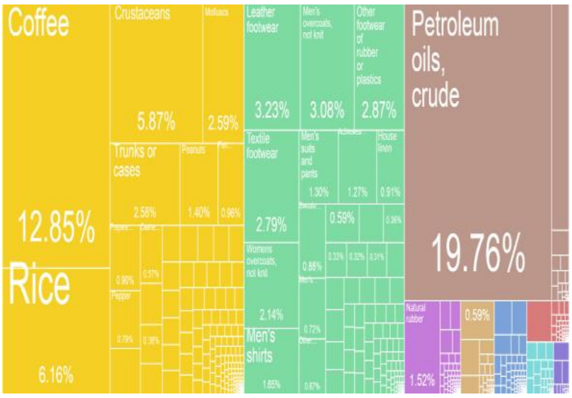


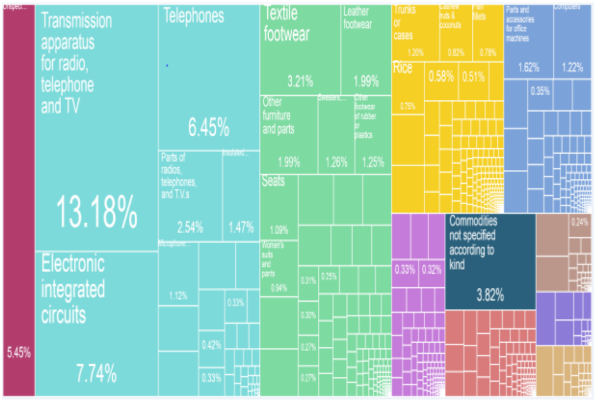
Figure B3.2: Vietnam's Export Basket composition in 2019 vis-a-vis 1995

Source: Atlas of Economic Complexity

1995



2019



Several factors have contributed to Vietnam's growth story. First, the country has favourable demographics, low labour costs and has enhanced human capital resources by investments in primary education and job creation. Second, the investment climate is vibrant owing to liberalisation, infrastructure (power, connectivity) and inclination towards global integration. Further, there has been relentless focus on increasing competitiveness, tax breaks, establishing minimum quality standards and promoting ease of doing business. In the WEF's Global Competitiveness Report, Vietnam rose from 77th place in 2006 to 55th in 2017. In the WB's Ease of Doing Business rankings, meanwhile, Vietnam rose from 104th place in 2007 to 68th place in 2017. Third, the political situation is stable and the country's geographic location is close to major supply chains of the world. Fourth, and most importantly, Vietnam has made significant headway in signing multiple bilateral and multilateral FTAs such as WTO, ASEAN, with US, Japan, EU, South Korea among others.

However, moving forward, there are certain constraints to Vietnam's growth trajectory. These are high dependence on foreign inputs, investment for production and small population size in comparison to China. This means that while the county has demonstrated its ability as a viable competitor to China in manufacturing, there still exists a large portion of the Global Demand pie that can be captured by other efficient producers in the race.

iii. China

China is an interesting example for this paper. Figures 12 and 13 show gently upward sloping REP(ex) line but a declining SI value from 2010-19. Not just SI, EXPY for the given time period has also shown moderate decline (Figure 14).

Why?

Figure 12 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:

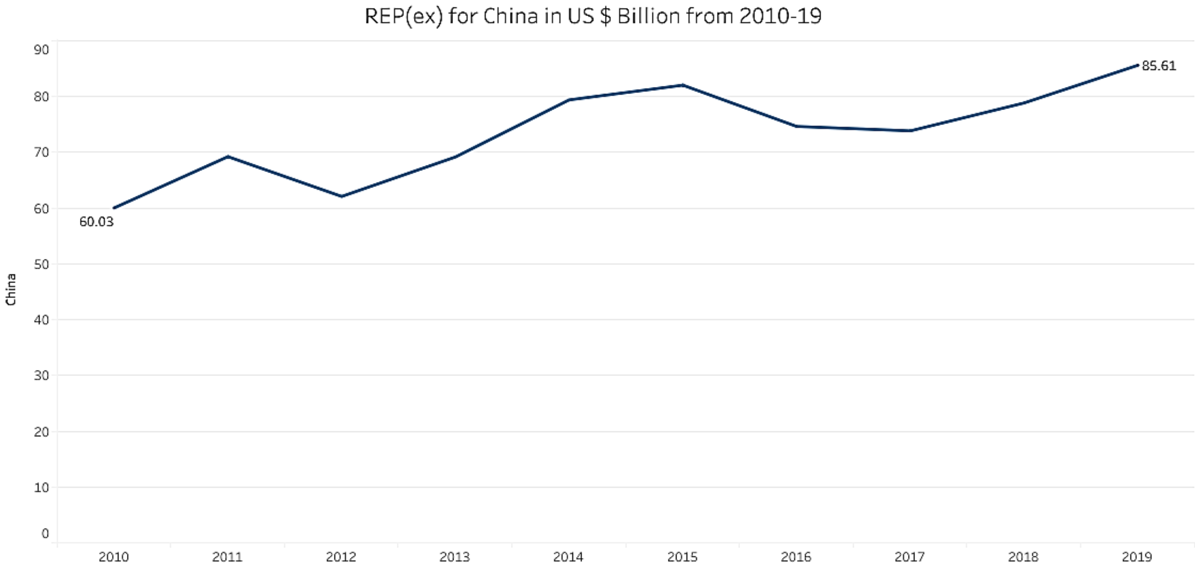


Figure 13 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:

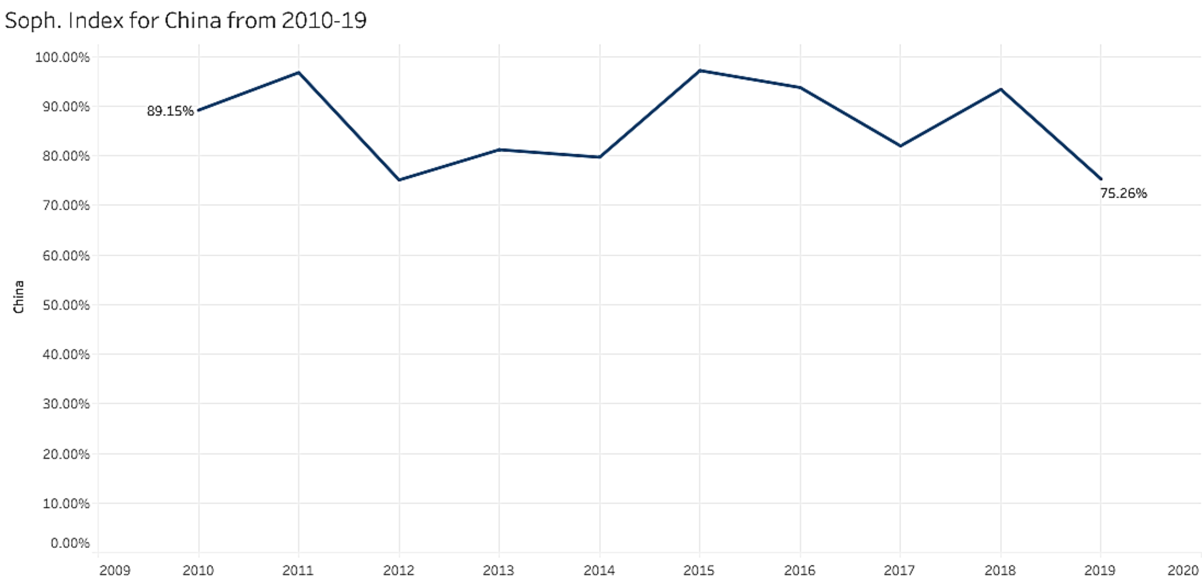
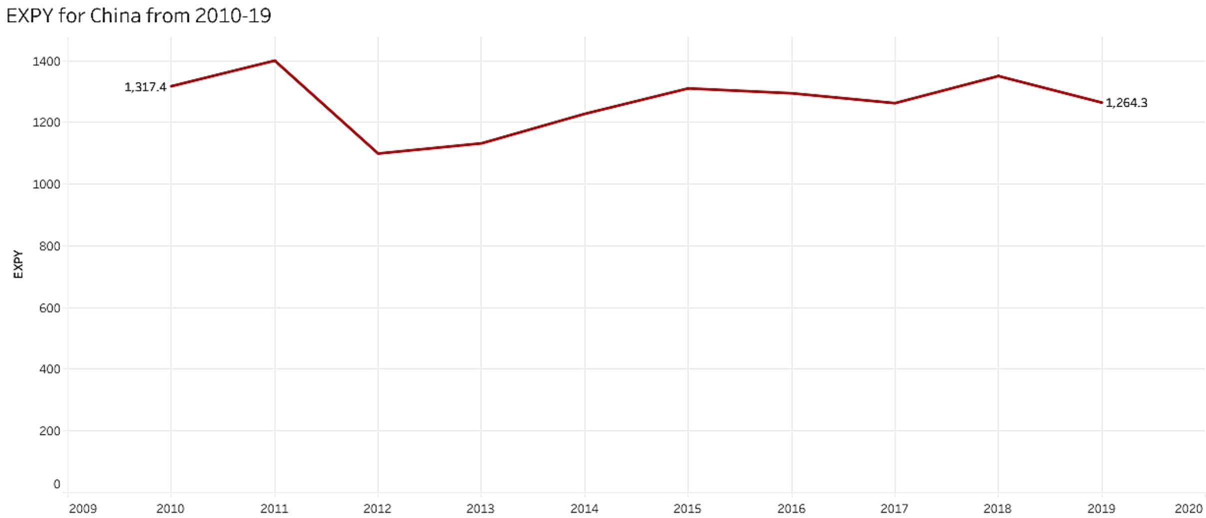


Figure 14 *(Source: Raw Data from WITS database (UN COMTRADE) and Author's own calculations)*:



Careful deliberation of the SI and EXPY formulas yields some plausible answers. EXPY is calculated as a summation of weighted $PRODY_k$ values. A fall in EXPY can arise from either/ both sources i.e. a fall in relative share of a given product in the total export basket of the nation or/ and fall in $PRODY_k$ values for the products.

The above can be explained by Table 3 below.

Table 3: Percentage Distribution of China's REP(ex) across Technical Complexity Categories from 2010-2019 *(Source: Author's own calculations)*

S.No.	Year	High	High-Medium	Medium	Medium-Low	Low
1	2010	1.63%	3.36%	75.86%	16.64%	2.50%
2	2011	1.54%	3.21%	75.21%	17.75%	2.29%
3	2012	1.94%	4.00%	68.65%	22.61%	2.80%
4	2013	2.01%	3.78%	64.58%	27.09%	2.54%
5	2014	1.97%	3.33%	60.33%	31.55%	2.82%
6	2015	2.15%	2.95%	59.04%	32.79%	3.08%
7	2016	2.17%	2.70%	56.69%	35.57%	2.87%
8	2017	2.09%	2.73%	58.47%	33.86%	2.86%
9	2018	1.78%	3.25%	59.73%	32.14%	3.10%
10	2019	1.62%	2.48%	62.83%	30.35%	2.72%

For China, there has been deterioration of the technical- content embodied in the REP(ex) from 2010-19. While the shares of High and Low technical Complexity Level Products (the extreme groups) has broadly remained stagnant, Medium-Low category has gained at the expense of High- Medium and Medium level products. Thus, despite the fact the REP(ex) have been growing during the period, the quality (measured here in terms of product sophistication) has taken a hit.

The top 5 REP(ex) in China's basket (roughly 75% of total REP(ex) during 2010-19) are, Photovoltaic Cells (854140) [Medium-Low Technical Complexity Level], Electrical static converters (850440) [Medium Technical Complexity Level], Electric Lamps (940540)) [Medium-Low Technical Complexity Level], Electric motors and generators (850300) [Medium Technical Complexity Level], Electrical inductors (850450) [Medium-Low Technical Complexity Level], in descending order. From 2010-19, exports of PV cells have fallen, while electric motors, inductors have remained at similar levels, indicating stagnant performance. Only electric lamps have shown significant improvement in export numbers, with electrical static converters following a negligible growth path.

Under High-Medium Level, only 3 product categories have shown substantial positive growth in exports, while others have either fallen or followed a flat trajectory. In contrast, the Low Technical Complexity Level products have increased in absolute and relative terms, signifying worsening of technical sophistication in REP(ex) of China.

6. Way Forward

On one hand it was observed that benchmark cases, which had initially dominated the production and trade in REPs, have phased out of prominence over the past decade while on the other hand, manufacturing and technical advantage in these products has shifted to emerging producers. In comparison, the position of India has not been remarkable, with mixed growth across various sophistication categories.

Fortunato et al. [2014] [XV] stress the importance of focussing on expansion of high connectivity sectors (i.e. those which can '*easily jump to other potential exports*'). They argue that Newly- Industrialised Countries of Asia-Pacific region have used accumulated skills, knowledge and production techniques of these sectors to gradually transform the export structure towards products of higher efficiency and sophistication levels. For REPs of India, this serves as a valuable lesson going forward. Policy action may be directed to identify and enhance the performance of such connectivity sectors with wide-spread positive linkages.

Furthermore, India has performed poorly while mapping efficiency of REP(ex) basket against per-capita GDP. This suggests being mindful of not missing the wagon of raising per-capita GDP following a path of higher value added production. Growth and development in the coming years will depend strongly on the methodology and technology adopted today (path dependency).

Thus, there exists a huge potential (manufacturing and trade) for India to expand domestic competence in high-value REPs through knowledge-sharing, training, augmenting existing production structure and incentivising production in this sunrise sector. Comparative analysis has shown that countries which diversify in high-value added and competitive products i.e. position themselves at the sophisticated end of the spectrum, stand to gain more from the globalisation process. This is a definite avenue for addressing the dual concerns of lacklustre growth in secondary sector and unsustainability of non-renewable sources of energy. Moreover, from the understanding developed over previous sections, it was noted that Chinese REP exporters have witnessed lower earnings, and loss in market share of higher-end REP(ex) to close competitors. Since global demand in RE is marked for astronomical jump owing to international pressures and responsibility-sharing, the time is ripe for India to establish its manufacturing share in the world production network.

Reiterating that the more sophisticated (technical) a given product, the higher would be the value added in its exports, the rising share of Low Technical Complexity Level signifies missed opportunities and lower export earnings for India. Economic gains and adoption of efficient manufacturing processes can be realised by diversification to high value added and sophisticated products. However, improvements in productivity levels of REPs is a long process. Fortunato et al. [2014] [XV] have shown that for low and middle income countries, the risk of getting stuck in the middle of the technological spectrum is very high. Investment contributes to boosting production only for 'within the frontier production' [XV], while innovation and skill enhancement would enable a long-term shift to newer products and processes. This necessitates spending on R&D, training and inculcating a spirit of scientific curiosity.

To conclude, India's revised 5-fold commitments at the 26th Conference of Parties (CoP26) (Paris Agreement) i.e. the *Panchamrita* are laudable, but implementation is contingent on complementary legislations, political will, finances and ability to board the train of technological innovation on time.

7. Abbreviations

RE	Renewable Energy
REPs	Renewable Energy Products
REP(ex)	Exports of Renewable Energy Products

8. **Appendix**- Attached.

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APPENDIX

Table A1: Classification of REPs based on HS 6 level of disaggregation of HS 2007 standard
(Source: WITS database: Trade Statistics by Product (HS 6-digit))

Broad Category	HS Code	Description
Nuclear Products[1]	840110	Nuclear Reactors
	840120	Machinery and apparatus; for isotopic separation, and parts thereof
	840130	Fuel elements (cartridges); non-irradiated
	840140	Nuclear reactors; parts thereof
	840211	Boilers; watertube boilers with a steam production exceeding 45t per hour
	840212	Boilers; watertube boilers with a steam production not exceeding 45t per hour
	840219	Boilers; vapour generating boilers, including hybrid boilers n.e.s. in heading no. 8402
	840220	Boilers; super-heated water boilers
	840410	Boilers; auxiliary plant, for use with boilers of heading no. 8402 or 8403 (eg economisers, super-heaters, soot removers, gas recoverers)
	840420	Boilers; condensers, for steam or other vapour power units
	840490	Boilers; parts of auxiliary plant, for use with boilers of heading no. 8402 and 8403 and parts of condensers for steam or other vapour power units
	840681	Steam turbines & other vapour turbines (excl. for marine propulsion), of an output >40MWclear
	840682	Steam turbines & other vapour turbines (excl. for marine propulsion), of an output not >40MWclear
	840690	Parts of the steam turbines & other vapour turbines of 8406.10-8406.82
	841950	Heat exchange units; not used for domestic purposes
Wind Products[2]	841480	Pumps and compressors; for air, vacuum or gas, n.e.s. in heading no. 8414
	850239	Electric generating sets; n.e.s. in heading no. 8502
	850300	Electric motors and generators; parts suitable for use solely or principally with the machines of heading no. 8501 or 8502
	903289	Regulating or controlling instruments and apparatus; automatic, other than hydraulic or pneumatic
	392099	Plastics; plates, sheets, film, foil and strip, of plastics n.e.s. in heading no. 3920, non-cellular and not reinforced, laminated, supported or similarly combined with other materials

[1] 840310, 840390 have been excluded because they pertain to central heating boilers and parts, which are mainly used for household indoor heating purposes. 8410, 8411 have not been included since they mainly pertain to hydraulic turbines, turbo jets which primarily uses hydropower.

[2] Other products under 8414 have not been included since they mainly pertain to general-use pumps, compressors irrespective of source energy. 903290 not included because it refers to regulating instruments of all uses.

Broad Category	HS Code	Description
Solar Products[3]	841919	Heaters; instantaneous or storage water heaters, non-electric, other than gas
	850440	Electrical static converters
	850450	Electrical inductors; n.e.s. in heading no. 8504
	850490	Electrical transformers, static converters and inductors; parts thereof
	850710	Electric accumulators; lead-acid, of a kind used for starting piston engines, including separators, whether or not rectangular (including square)
	850720	Electric accumulators; lead-acid, (other than for starting piston engines), including separators, whether or not rectangular (including square)
	854140	Electrical apparatus; photosensitive, including photovoltaic cells, whether or not assembled in modules or made up into panels, light emitting diodes
	854150	Electrical apparatus; photosensitive semiconductor devices n.e.s. in heading no. 8541, including photovoltaic cells, whether or not assembled in modules or made up into panels
	870990	Vehicles; parts of the vehicles of heading no. 8709
	870911	Vehicles; electrical, self-propelled, (not fitted with lifting or handling equipment), of the type used for short distance transport of goods in factories, warehouses, dock areas or airports
	910211	Wrist-watches; battery or accumulator powered, whether or not incorporating a stop-watch facility, with mechanical display only, other than those of heading no. 9101
	910212	Wrist-watches; battery or accumulator powered, whether or not incorporating a stop-watch facility, with opto-electronic display only, other than those of heading no. 9101
	910119	Wrist-watches; battery or accumulator powered, whether or not incorporating a stop-watch facility, with other than mechanical or opto-electronic display, excluding those of heading no. 9101
	280461	Silicon; containing by weight not less than 99.99% of silicon
	940540	Lamps and light fittings; electric, n.e.s. in heading no. 9405
	700719	Glass; safety glass, toughened (tempered), (not of a size and shape suitable for incorporation in vehicles, aircraft, spacecraft or vessels)
Biomass Products[4]	841620	Furnaces; furnace burners, for pulverized solid fuel or gas, including combination burners
	840790	Engines; rotary internal combustion piston engines, for other than aircraft or marine propulsion
	840510	Generators; producer gas, water gas, acetylene gas and similar water process gas generators, with or without their purifiers

[3] Electric capacitors, resistors and apparatus under 8532, 8533, and 8536 have not been included since it may be used for non-RE use.

[4] Under HS code number 850220, goods run on fuels other than petrol/gasoline, such as auto gas (LPG), methanol, ethanol, bioethanol, compressed natural gas (CNG), hydrogen, and (in drag racing) nitromethane.)

Broad Category	HS Code	Description
	840590	Generators; parts of producer gas, water gas, acetylene gas and similar water process gas generators, with or without their purifiers
	847930	Machinery and mechanical appliances; presses for the manufacture of particle or fibre building board of wood or other ligneous materials and other machinery for treating wood or cork
	4401	Wood; sawdust, waste and scrap, whether or not agglomerated in logs, briquettes, pellets or similar forms
	850220	Electric generating sets; with spark-ignition internal combustion piston engines

Table A2: Average Value of REP(ex) for top 30 nations from 2010-2019 (*Source: WITS Database and author's own calculations*)

Rank	Country/ Region	Average Value of REP (ex) in $ Billions (2010-2019)
1	China	73.486
2	Germany	30.633
3	United States	21.757
4	Japan	19.101
5	Korea, Rep.	11.731
6	Italy	8.584
7	France	6.621
8	Netherlands	6.503
9	Mexico	6.456
10	Malaysia	5.673
11	Switzerland	5.643
12	Hong Kong, China	5.531
13	Singapore	5.357
14	United Kingdom	4.921
15	Spain	4.115
16	Hungary	3.955
17	Thailand	3.815
18	Austria	3.722
19	Vietnam	3.704
20	Sweden	3.471
21	Poland	3.444
22	Czech Republic	3.285
23	India	2.695
24	Canada	2.554
25	Russian Federation	2.536
26	Finland	2.251
27	Belgium	2.134
28	Denmark	1.957
29	Romania	1.802
30	Slovak Republic	1.357

Illustration of UNCTAD's STATA do-file for $PRODY_k$ calculations (A Practical Guide to Trade Policy Analysis)

The formula employed for calculation of $PRODY_k$ values is as follows:

```
*Prody balanced GDPpc PPP adjusted current USD
*****************************************************************
*****
     use  baci_export_to_world.dta, replace
     keep  exporter year hs6   gImport
     duplicates drop
     rename exporter ccode
     sort ccode year
     merge ccode  year using GDPpc_PPP.dta
     tab _merge
     keep if _m==3
     rename gImport x_i_k
     by ccode hs6,sort: gen Ncount=_N
     by hs6,sort: egen Nmax=max(Ncount)
     keep if Nmax==Ncount
     drop Nmax Ncount _m
     by ccode year,sort: egen X_i=sum(x_i_k)
     gen share_i_k=x_i_k/X_i
     by hs6 year,sort: egen share_k=sum(share_i_k)
     gen RCA_i_k=share_i_k/share_k


* Construct  Prody index
     gen temp1=RCA_i_k*GDPpc
     by hs6 year,sort: egen Prody_k=sum(temp1)
     gen temp2=share_i_k*Prody_k
     by ccode year,sort: egen EXPY_i=sum(temp2)
     save prody_b_current,replace
```

The code breaks down the calculation first, into estimation of RCA and second, using RCA as weights to obtain $PRODY_k$ values. The issue arises in case of computation of RCA, wherein, as can be seen from above, '*share_k*' is the summation of '*share_i_k*' values only, and does not allow to create a separate variable denoting the total exports of a nation. Consequently, '*share_k*' is used in generation of '*RCA_i_k*' which is then used to construct the '*PRODY Index*'.

Table A3: Average Value of $PRODY_k$ for REPs from 2010-2019 (*Source: WITS Database and author's own calculations*)

S.No.	**Product HS Code (k)**	**Average $PRODY_k$ for 2010-2019**
1	840110	36926.83
2	840120	48546.04
3	840130	46280.26
4	840140	38952.75
5	840211	32058.92
6	840212	33197.81
7	840219	40729.71
8	840220	42065.18
9	840410	38830.54
10	840420	33914.19

11	840490	39839.51
12	840681	38951.69
13	840682	36692.28
14	840690	39313.27
15	841950	41062.17
16	841480	35818.81
17	850239	40962.60
18	850300	39102.46
19	903289	36133.03
20	392099	40527.00
21	841919	38055.32
22	850440	40021.59
23	850450	36853.81
24	850490	38904.08
25	850710	34325.87
26	850720	30399.94
27	854140	34933.62
28	854150	46955.80
29	870990	43207.09
30	870911	45697.37
31	910211	54932.39
32	910212	41651.47
33	910119	53515.87
34	280461	41316.98
35	940540	36538.36
36	700719	35054.41
37	841620	44057.49
38	840790	36935.09
39	840510	41715.78
40	840590	46548.48
41	847930	43125.28
42	4401	26111.56
43	850220	44271.56

Table A4: Categorisation of REPs based on the technical sophistication (*Source: author's own calculations)*

S.No.	Product HS Code (k)	Average PRODY$_k$ for 2010-2019 ↑(t_i)	Technical Classification Category
1	4401	26111.56	**Low**
2	850720	30399.94	
3	840211	32058.92	**Medium-Low**
4	840212	33197.81	
5	840420	33914.19	
6	850710	34325.87	
7	854140	34933.62	
8	700719	35054.41	

S.No.	Product HS Code (k)	Average $PRODY_k$ for 2010-2019 ↑(t_i)	Technical Classification Category
9	841480	35818.81	
10	903289	36133.03	
11	940540	36538.36	
12	840682	36692.28	
13	850450	36853.81	
14	840110	36926.83	
15	840790	36935.09	
16	841919	38055.32	**Medium**
17	840410	38830.54	
18	850490	38904.08	
19	840681	38951.69	
20	840140	38952.75	
21	850300	39102.46	
22	840690	39313.27	
23	840490	39839.51	
24	850440	40021.59	
25	392099	40527.00	
26	840219	40729.71	
27	850239	40962.60	
28	841950	41062.17	
29	280461	41316.98	
30	910212	41651.47	
31	840510	41715.78	
32	840220	42065.18	
33	847930	43125.28	**High-Medium**
34	870990	43207.09	
35	841620	44057.49	
36	850220	44271.56	
37	870911	45697.37	
38	840130	46280.26	
39	840590	46548.48	
40	854150	46955.80	
41	840120	48546.04	
42	910119	53515.87	**High**
43	910211	54932.39	

Table A5: Average EXPYi in REPs for world (*Source: author's own calculations)*

S.No.	Country/ Region	Average EXPY$_i$ for 2010-2019
1	Austria	892.37
2	Belgium	262.53
3	Canada	226.33
4	China	1265.92
5	Czech Republic	731.22
6	Denmark	726.25
7	Finland	1297.56
8	France	468.90
9	Germany	821.10
10	Hong Kong, China	520.68
11	Hungary	1363.94
12	India	335.37
13	Italy	679.04
14	Japan	996.40
15	Korea, Rep.	809.20
16	Malaysia	923.87
17	Mexico	609.36
18	Netherlands	455.53
19	Poland	602.34
20	Romania	986.59
21	Russian Federation	248.47
22	Singapore	541.31
23	Slovak Republic	623.81
24	Spain	545.07
25	Sweden	885.83
26	Switzerland	936.86
27	Thailand	626.77
28	United Kingdom	397.13
29	United States	630.38
30	Vietnam	659.23

Table A6: Average SIi for world (*Source: author's own calculations)*

S.No.	Country/ Region	Average Soph. Index$_j$ for 2010-2019
1	Austria	57.37%
2	Belgium	8.73%
3	Canada	6.01%
4	China	86.33%
5	Czech Republic	44.59%
6	Denmark	44.39%
7	Finland	88.82%
8	France	24.63%

9	Germany	51.65%
10	Hong Kong, China	29.87%
11	Hungary	93.52%
12	India	14.52%
13	Italy	40.95%
14	Japan	65.31%
15	Korea, Rep.	51.02%
16	Malaysia	60.34%
17	Mexico	35.63%
18	Netherlands	23.62%
19	Poland	35.31%
20	Romania	64.96%
21	Russian Federation	7.86%
22	Singapore	30.43%
23	Slovak Republic	36.87%
24	Spain	30.31%
25	Sweden	56.89%
26	Switzerland	60.26%
27	Thailand	37.22%
28	United Kingdom	19.19%
29	United States	37.06%
30	Vietnam	39.87%