Building Hope: Changing Global Health Innovation and Healthcare Systems According to Population Needs

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Abstract: Dividing the countries of the world into three major groups according to their scientific and technological development, this article analyzes its impact over the years on health indicators such as life expectancy at birth and Disability-Adjusted Life Year (DALY). It also brings the specific case of South Korea, a country that surely reached the group of the most scientifically and technologically advanced countries of the world in the recent years. The health macro-data used are from the Global Burden of Disease (GBD) available at the Institute for Health Metrics and Evaluation (IHME).

Key Word: Technology; Innovation; Global Health; Life Expectancy, DALY

Thematic areas: economic theory and applied economics and demography

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INTRODUCTION

The World is in a constant change considering socioeconomic, demographic and innovational framework. As an example, from the World Bank´s report, improvements in health standards influences countries economic growth by gains in productivity, reducing costs of health careand through the reduction of poverty (ALBUQUERQUE and CASSIOLATO, 2002). Transformations may cause direct and indirect impacts, since every action has a chain outcome. Global Institutes, such as World Bank, World Health Organization, United Nations are worried about the future of the nations, so they are upholding more projects with a multidimensional perspective.

Nowadays, in a globally connected environment, technological progress makes change easier, in a good way rather than in a bad way, depending on the situation. While optimist researchers in population studies argue the fact that technology will help humanity to ensure productivity and the power of replacing resources, pessimists believe that technology will not be able to slowdown the population deterioration because of the environmental changes (LIVI-ACCI, 2007, p.184).

According to a recent observation in The Lancet (BATSON et al, 2017), the world is living “interesting times” and innovation can help create new global health technologies to serve the emerging economies, especially for neglected diseases (Morel et al., 2005). On the other hand, OMS pointed out the insignificant participation rate (2.2%) of low-and-middle income countries in global funds premeditated for health researches (WHO,1996 *apud* ALBUQUERQUE *et al*, 2004)

Proposing an assertive framework for the global future Gardner *et al* (2007) argues that innovation system should be re-engineered so new ideas can be translated into products along with the increase of publications and patents. According to these authors, a development agenda may address the needs of developing populations by raising public and private investments. Considering the global scenario of socioeconomic inequality deep-seated among countries, this paper aims to set out the relationship of scientific and technological progress and the trajectory of health indicators at different levels of development. Nonetheless, unveil how social welfare systems suffer from the interference of innovation.

Innovation is a broad concept that can be interpreted in a systematic context in which it is inserted as in many fields of economy, specifically as a matter of concern of this paper, in the heath sector. As characteristics of this sector can be highlighted its strong base in scientific knowledge and the position it assumes between innovation system and welfare system (ALBUQUERQUE and CASSIOLATO, 2002).

In other words, there are complex linkages connecting innovation and health which enhance economic and well-being in one country and vice versa. To explore this relationship, Nelson and Rosenberg (1993) provide the concept of “national innovation system” referring to the process that involves the structure formed by public and private agents based on innovative capabilities that sustain national development of science, technology and economic growth.

To understand how scientific research and technological improvement occur in a national perspective within the health field is necessary to set out two points, namely, who are the institutions involved and how the flow of information connects them to generate innovative solutions. Albuquerque *et al* (2004) shows in detail the locus and the intertwining between these peers that are already funded in developed countries. The network is built by universities, industries, research and regulation agencies, hospitals, medical teams, and the public health system itself. Thus, a solid structure for the spread of scientific knowledge provides cooperation and effectiveness of innovations, as a sustain to country´s path on health quality gains.

However, if we focus on less developed countries with low per capita income and lagging behind in human development indicators, the dynamic surrounding the system of technological scientific innovations is incipient. As emphasized by Bernardes and Albuquerque (2003), there is a weak transfer of knowledge between these fields as a consequence of the lack of critical mass in the scientific infrastructure. It reflects the lower economic growth they can sustain. The authors point out that as countries cross a minimum threshold level of scientific production (mainly operating by universities and research institutions) it can impulse technological production (mainly operating by firms) which becomes more important as a determinant of growth.

In order to evaluate the interaction inside the national system of innovation for a large group of countries, Ribeiro *et al* (2006) presents a mechanism for delimiting a threshold considering the levels of economic development and the stages of scientific and technological production. They also intend to explore the evolution of each groups, following Bernardes and Albuquerque´s (2003) approach. The main goal of the former paper is underling the mechanism governing science, technology, and development over years and groups.

Ribeiro *et al* (2006) adopts a methodology for classifying the world countries' data in three different groups by number of patents and number of scientific papers from 1999 to 2003. The differential of the paper comes from adopting a physics' method on economic and innovational inter-country data. The technique applied is based on computer simulations that allows the data to distribute itself without any previous assumptions called Super-Paramagnetic Clustering Technique (SPCT).

In brief, each cluster of countries delimit a different pattern based on the correlation between economic development and scientific and technological production. Thus, the first group represents the countries considered less-developed where the connections inside national innovation system are too weak, so a correlation between science and growth cannot be found. The second is delimited by intermediary development and better connections between institutions which implies a medium level of patents converted in technological production. The third group includes the established countries in economic and welfare terms, so they represent the highest level of efficiency showing stronger correlation between scientific production and innovation.

The cluster technique delimited by Ribeiro et al (2006) are also applied over time to show how are the group´s trajectory and particularly some cases of catching-up, comparing to the threshold lines which changes over time. To conclude, countries must invest more in science and technology in order to maintain their position in economy and development area or make improvements in order to not stay behind peers. In light

of this review the next section explores the trajectories of two important heath indicators in each cluster delimited by Ribeiro et al (2006), which allows us to incorporate the dimension of science, technology, and development to the healthcare analyses, reflecting the multidimensional approach of this paper.

METHODS

In order to find an answer for the proposed aim, this paper used two sources of global data: (1) Innovation Data by country; (2) Health Data by country. The analysis was made considering three technological group divisions by countries between 1990 and 2016. Group one is classified as less developed economies, followed by group two as the intermediate and group three which represents the most developed economies.

Innovation Data

The data used was a merged made by Ribeiro *et al*. (2006) who collected data about patents and scientific papers. The merge was constructed considering the Super-Paramagnetic Clustering Technique (SPCT) which allowed the division of all countries of the world in different stages of economic development.

In order to investigate the possible relations between scientific and technologic production and health indicators (Life expectancy at birth and Disability-Adjusted Life Year - DALY), this paper includes four different analyzes, considering the division allowed by SPCT used by Ribeiro et al (2006). The first and the second analysis are extended from 1990 to 2016. Therefore, the covered countries are only those who have not changed their classification according to SPCT during this period. The aim of this point is to verify how these countries behave over time and to see if there is any pattern inside each group. The third assay follows a different logic from the previous ones, since it approaches only two periods of time (1998 and 2014); with a distinct aim that is to test if there is any relation between the variation of the country groups and the behavior of their health indicators. The fourth and last investigation tries to prove the same point of view of the previous ones, bringing a mixture of the used graphics.

South Korea is a different country case according to Ribeiro et al (2006) because it has crossed the development dynamic threshold between the groups. South Korea shows a successful catch-up of technological development, achieving impressive growth rates in articles and patents per million inhabitants. In 1974, South Korea was in group one and moved up over the next four dates until it reached group three in 1998. The graphic of South Korea's specific case compares DALY rates trajectory to that of countries from group two and three, which did not change the group between 1990 and 2016.

As explained above, for the first and second assessments, the covered countries are only those who have not changed their classification between 1990 and 2016. The countries of group one represents an exception, because they belong to the less developed group and consequently this group shows more variation. Hence the countries considered for it are the ones that appeared at some point in group one and never appeared in the others during the period. Group one is composed of Albania, Bangladesh, Belarus, Cameroon, Democratic Republic of the Congo, Dominican Republic, El Salvador, Ethiopia, Ghana, Guatemala, Haiti, Honduras, Indonesia, Iran,

Iraq, Kazakhstan, Liberia, Madagascar, Mali, Moldova, Nepal, Nicaragua, Nigeria, Pakistan, Paraguay, Peru, Syria, Tanzania, Tunisia, Turkmenistan, Uganda, Uzbekistan, Vietnam and Zimbabwe. Group two: Argentina, Armenia, Brazil, Bulgaria, Chile, Costa Rica, Croatia, Jordan, Kuwait, Lithuania, Mexico, Panama, Poland, Russia, South Africa, Ukraine and Uruguay. Group three: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Israel, Japan, Netherlands, New Zeland, Norway, Sweden, Switzerland, United Kingdom and United States.

Health Data

The big Health Data used in this paper is from the Global Burden of Disease (GBD) available at the Institute for Health Metrics and Evaluation (IHME) updated recently in September 2017. For this paper the analysis of two health indicators was considered: (1) Life expectancy at birth; (2) Disability-Adjusted Life Year (DALY). Life expectancy at birth is the average years that a hypothetic cohort expects to live if the current mortality patterns remains the same. Besides, extended life expectancy does not necessarily mean a better life, because people can be living more, but with more morbidity. Therefore, this paper decided to also use the DALY indicator in order to consider health quality. According to WHO (2007), DALYs are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences.

The authors considered age-standardized data available by IHME to do year over year comparison by country. The standardization method used is presented on IHME's website.

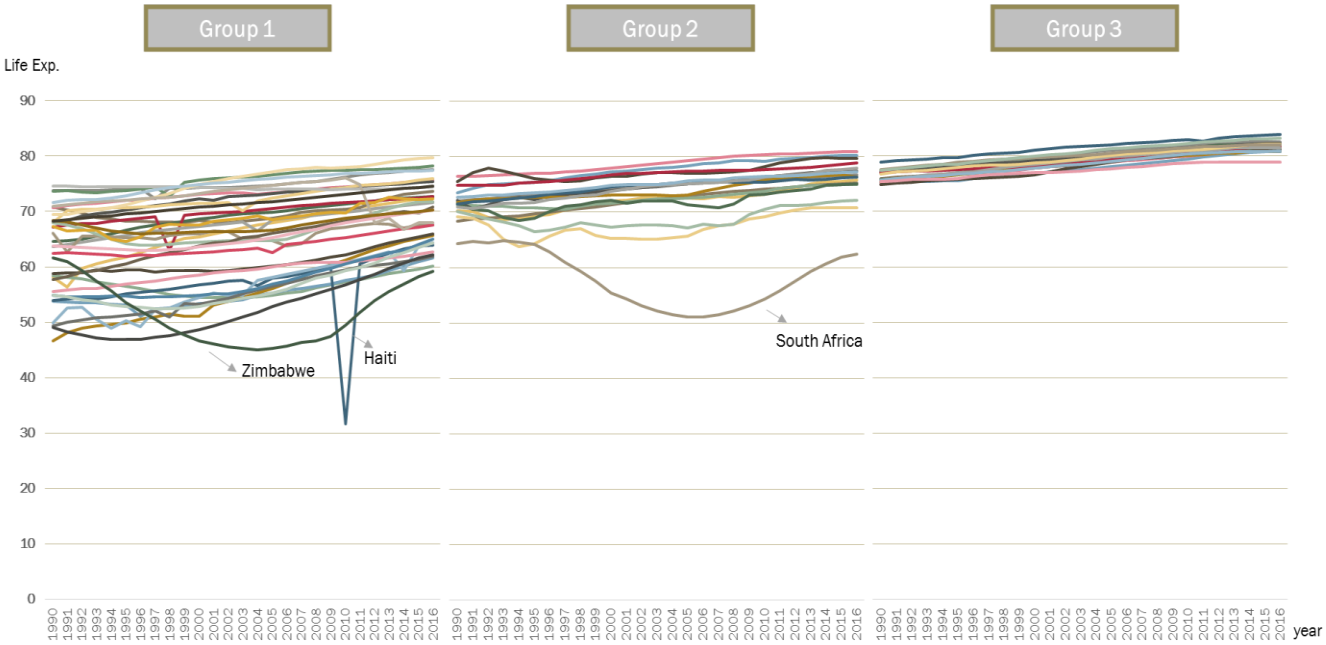
RESULTS & DISCUSSION

First, the results are shown in two frameworks. The first framework presents the evolution of life expectancy at birth over time, with the countries split by the three classifications of the SPCT. The second one follows the same configuration, although it addresses DALY rather than life expectancy. Thus, all the countries with any published scientific article and registered patent between 1998 and 2014 were considered divided in groups according to the SPCT and plotted on a graphic that brings DALY and life expectancy at birth at the same time.

Life Expectancy at Birth

Figure 1 below shows the results for life expectancy at birth between 1990 and 2016 for both sexes and all ages for the three groups of countries.

Figure 1 – Graphs of Life expectancy at birth by technological group, 1990 to 2016



Source: Data from IHME and "Grupo de Pesquisa em Economia da da Ciência e Tecnologia Cedeplar/UFMG" aggregated by the authors.

Life expectancy at birth is generally increasing in all groups of countries. There is greater uniformity between countries moving from group one to group three. In addition, the graphics seem to indicate a mean life expectancy at birth by group higher in the same direction, from group one to group three. There is a trend towards a less sharp curve from the first group to third group, which shows a less accelerated growth rate of life expectancy at birth among more developed countries. With the exception of few countries, the trajectories followed by the groups seem to indicate a convergence of groups one and two into the framework observed in group three.

There is a marked difference between groups in the case of countries with lower life expectancies. However, when the countries with the highest values are found within each group, it is observed that these countries in the case of group one has similar life expectancies to most of the countries from group two. And in the case of the second group , countries with higher life expectancy at birth present values similar to those with the lowest values from the third group.

This better result observed in group three might be linked to the health transition described by Vallin and Meslé (2004), which started sooner in the more developed countries of the world. According to the authors, these countries are at a more advanced stage of the health transition, namely when infectious diseases have long been controlled and great progress has already been made in combating and preventing heart disease and man-made diseases such as cancer. The authors also identify another possible reason for this result found in the inequality produced by medical innovation cycle, because not all societies are equally prepared to innovate or drew the benefits of innovation from outside. Therefore, when medical technological advances are created in the pioneer countries it results first in a process of divergence followed by a process of convergence, when late-entering countries become able to catch up the pioneers (Vallin and Meslé, 2004).

It is remarkable the deviations in the trajectories of Zimbabwe, Haiti and South Africa. Zimbabwe has proclaimed its independence only in 1980 and its president Robert Mugabe was in the control of the country until late 2017. The country has been facing a lot of disturbances: land crisis, food shortage, sustained inflation, involvement in Democratic Republic of Congo's civil war and has been embroiled in an increasingly severe economic and political crisis since 1998 (BBC, 2017). At the same time, as the other Sub Saharan countries, Zimbabwe has been facing AIDS epidemic since 1980 (Vallin and Meslé, 2004). Haiti was hit hard by an earthquake with a magnitude of 7 on the Richter scale in 2010, which explains its downward curve from 2010 (WHO, 2010).

And finally, South Africa has been suffering from a concomitant HIV and tuberculosis epidemics since the end of the apartheid. In 2007, the country had just 0.7% of the world's population but 17% of the global burden of HIV infection (about 5.5 million people), in the same year and one of the world's worst tuberculosis epidemics, compounded by rising drug resistance and HIV co-infection. This was a result of social, economic, and environmental conditions created by apartheid (such as overcrowded squatter settlements, migrant labor, and deliberately underdeveloped health services for black people), which provided a favorable environment for efficient transmission of HIV and tuberculosis (Karim et al., 2009).

The life expectancy of the first group of countries was between 46.5 (Ethiopia) and 74.5 (Paraguay) in 1990, reaching a range between 59.2 (Zimbabwe) and 79.7 (Peru) in 2016. Only 8 of the 34 countries of group one presented values close to most of the countries of group two in 1990. By 2016, this difference has greatly diminished and in addition to these 8 countries 10 more have joined this group with values similar to most of the countries of the second group. This shows a great improvement in life expectancy at birth in group one compared to the group just above.

Putting South Africa apart because the country presents values out of order for the second group throughout the analyzed period (dropped from 64.3 to 62.4 between 1990 and 2016). The life expectancy of the countries in this group ranged between 68.4 (Brazil) and 76.5 (Costa Rica) in 1990, reaching a range between 70.8 (Russia) and 80.9 (Costa Rica) in 2016. Most of the countries in the second group (14 out of 17) had lower life expectancy at birth than Ireland, the country with the lowest life expectancy of the third group in 1990. In 2016 the United States had the lowest life expectancy values within the third group and the countries from the second group with smaller values which fell from 14 to 13.

The life expectancy of the countries within the third group ranged between 74.8 (Ireland) and 78.9 (Japan) in 1990, reaching a range between 78.8 (United States) and 83.9 (Japan) in 2016. The life expectancy of the United States has suffered slight declines since 2013. According to Bob Anderson, chief of the mortality statistics branch at the National Center for Health Statistics, it is still early to define it as a trend but one of the causes for this may be found in a substantial slowdown in the rate of decline for cardiovascular mortality, since about 2010 added to an increase in the drug overdose deaths. It is also important to highlight the increase in death rates for unintentional injuries, Alzheimer's disease and suicide since 2014 (CNN, 2017).

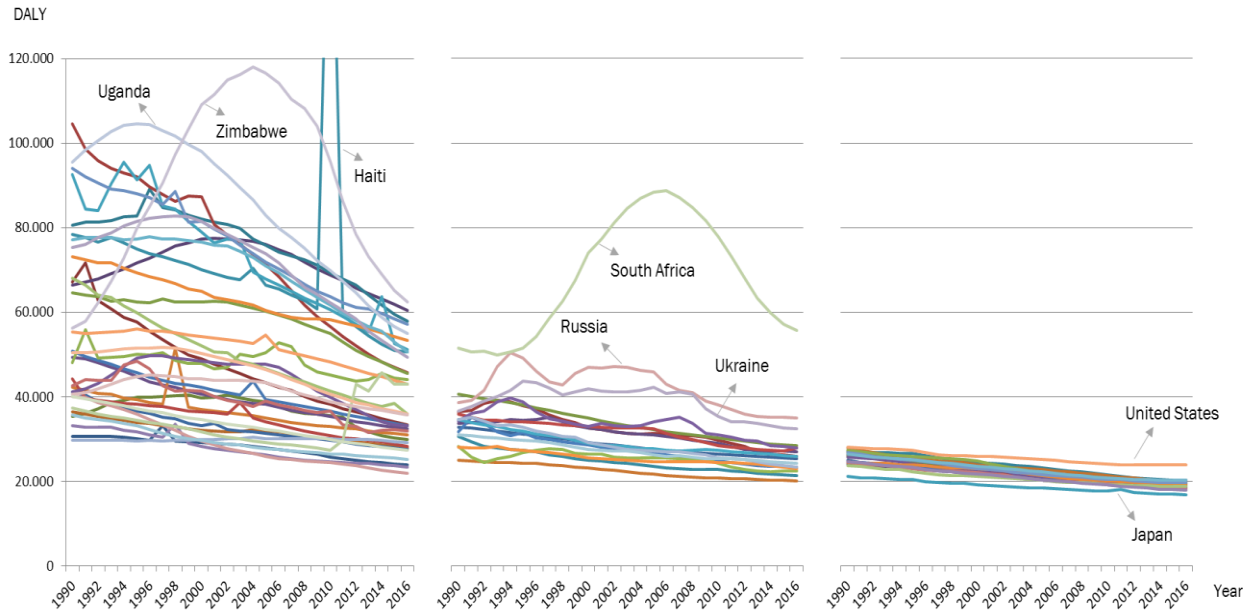
Overall, there seems to be closeness between most countries inside each group, with clear exceptions for countries with the lowers life expectancies of groups one and two,

which pulls down the average of their respective groups. The differences are higher among the minimum life expectancy values of each group and smaller among the maximum values. The differences between countries of the same group are getting even smaller, from the less developed to the more developed group. Lastly, it is important to highlight the relative improvement in the minimum life expectancy of the first group, which increased almost 13 years.

Disability-adjusted life years (DALYs)

Figure 2 shows the rates (per 100.000) of disability-adjusted life years (DALYs) for all causes identified by the Global Burden of Diseases, for both sexes and standardized by age from 1990 to 2016 for the three groups of countries.

Figure 2 - Graphs of DALYs by technological group, 1990 to 2016



Source: Data from IHME and "Grupo de Pesquisa em Economia da da Ciência e Tecnologia - Cedeplar/UFMG" aggregated by the authors.

With some well-defined exceptions, overall, DALYs appear to be declining markedly in all groups. Some exceptions deserve to be mentioned such as the sub-Saharan countries, Haiti and the countries that belonged to the former Soviet Union. There are well-defined differences between groups, with countries in the first group showing the highest rates of DALYs by far, followed by the second group of countries, and finally developed countries belonging to the third group exhibit the lowest rates. Group three shows a more uniform downward trend with smaller variations between countries and within countries.

Following the trajectories of the countries within each group over the period, a conversion seems to be taking place towards the pattern existing in developed countries. There is greater uniformity among countries as we move from the less developed group towards the more developed one. Group three shows a steadier downward trend, with smaller variations between countries and within countries. The group also contains lower values for DALY rates than the others.

The sub-Saharan countries have a higher DALY rate, not only because of poverty and its problematic health system, but mainly because of the combination of this conjecture with the AIDS epidemic since 1980s, which hindered the affected groups to draw substantial benefit from the very costly treatments developed in western countries (Vallin and Meslé, 2004).

As mentioned before, Haiti was hit hardly by an earthquake with the magnitude of 7 degrees on Richter scale in 2010, which has increased the DALY rates not only because of the numerous wounds, injuries and mental disorders due to the initial impact of the earthquake and subsequent rescue and clean-up activities. But because it has generated a health and nutrition crisis with damage in: health infrastructure, sewerage system, plantations and food and water distribution, which also propitiated the spread of infectious diseases (WHO, 2010).

Ultimately, the former Soviet Union countries are a more complex case that can be explained by different reasons. One of them is the high rates of non-communicable diseases that stands out in these countries among the first group (Kazakhstan, Turkmenistan, Uzbekistan, Moldova, Belarus) and the second group (Russia, Ukraine, Lithuania, Armenia).

According to Field (1995), health conditions began to deteriorate in the late sixties, and were exacerbated by the collapse of the Soviet Empire in late 1991. The author highlights the importance of non-communicable diseases for the health crises in the former Soviet Union according to him almost half the increases in deaths between 1992 and 1993 can be attributed to a rise in cardiovascular mortality. The proportion of people engaging in physical activities was very low at that time, estimated by 21% of men and 12% of women.

However, the other half of death causes for Field (1995) can be attributed to social causes. The burdens of economic difficulties faced in the first years after the downfall of the Soviet Union caused an increase in a series of pathologies including anxiety, hypertension, nervous diseases, depression and also a rapid escalation in suicide rates. The incidence of acute alcoholic-psychoses and alcohol poisonings also rose. It is possible that alcohol contributed heavily to the increasing mortality rate whether through violence, occupational and traffic accidents, and crimes. For example, in Russia, murders were up by about half from 1992 to 1993, and deaths attributed to alcoholism increased by 100% in that time period. The author also points to the continued decline in investments in Soviet health sector since the 1960s, being neglected in favor of industrialization (around 2 to 4% in Gorbachev’s regime and even smaller with the end of the Soviet Union), leading to a shortage of all kinds of medicines, instruments, vaccines, and dilapidated, under and poorly maintained facilities.

The main highlight for this graphic of DALY rates is South Africa, which despite having number of patents and scientific articles similar to the group two, was affected similarly to the other Sub-Saharan countries by AIDS and therefore, shows a similar pattern of rates. Considering this, as it was done for life expectancy, it will be also analyzed apart here.

The DALY rates for the countries of the first group are between 104,616 (Ethiopia) and 29,747 (Paraguay) in 1990, reaching a range between 62,456 (Zimbabwe) and 21,947 (Peru) in 2016. The majority (24 out of 34) of the countries in group one had worse values than Brazil (second worst result in group 2, ahead only of South Africa) in 1990. By 2016, group one became a little similar to group two. Russia had the second worst result of the second group and 18 out of 34 countries of the first group had worse rates than it.

Zimbabwe stands out with a high DALY rate among countries of the first group for the same reasons explained before for life expectancy. Uganda is also a negative highlight in the graphic, mainly because of non-communicable diseases (second worst DALY rate for infectious diseases among all countries analyzed).

Separating South Africa which presents values out of order to the second group throughout the period (raised from 51,443 to 55,756 between 1990 and 2016). The total DALY rates of the countries in this group ranged between 40,703 (Brazil) and 24,953 (Costa Rica) in 1990, reaching a range between 34,981 (Russia) and 20,039 (Costa Rica) in 2016. Most of the countries of the group (15 out of 17) had worse rates than United States, the country with the highest DALY rate (and therefore, worst result) of the third group in 1990. In 2016, group two presented a better relative result, the United States still had the highest values within the third group but this time 11 out of 17 countries of the second group had worse rates than it.

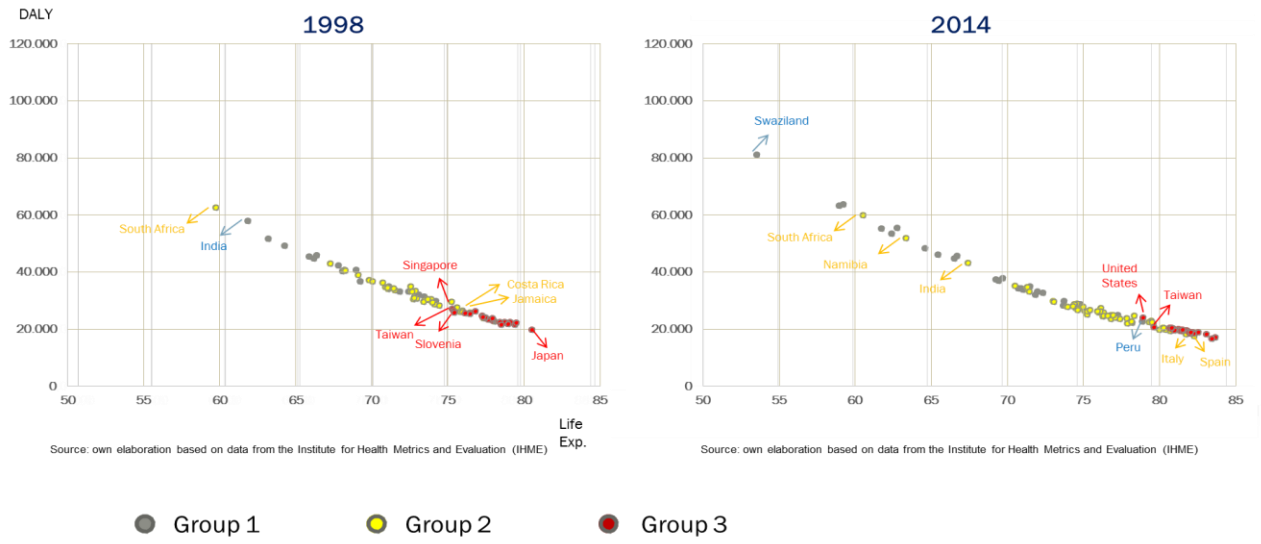
The total DALY rates of the third group of countries ranged between 28,162 (United States) and 21,119 (Japan) in 1990, reaching a range between 23,975 (United States) and 16,853 (Japan) in 2016. Japan is a positive highlight within group three, presenting rates much lower than the other countries over the whole period. On the other side, the United States distinguishes itself negatively from the rest of the group, due to a slowdown in the fall of its DALY rate, which has even begun to demonstrate a growth after 2013.

Overall, the results for DALY rates indicate differences between the minimum values much smaller than between the maximum values. Countries with better health indicators are showing close results regardless the group they belong to. Among countries with high DALY rates and worse results, the differences are more pronounced. The differences between the groups seems to be reducing within the period and the less developed groups seems to be approaching in the future to the pattern existing nowadays in the most developed countries. In this way, there is a greater reduction of the rates in the less developed groups and a greater variability among the countries of these groups. Among the most developed countries within group, progress is less pronounced and there is greater uniformity among countries' rates.

Final results - DALY versus Life Expectancy

Figure 3 plots all the countries from groups one, two and three, regardless if they have changed the group or not contrasting their total DALY rates versus their life expectancy at birth in 1998 and 2014.

Figure 3 - Graphs of DALYs *versus* Life Expectancy at Birth by technological group, 1998 to 2014



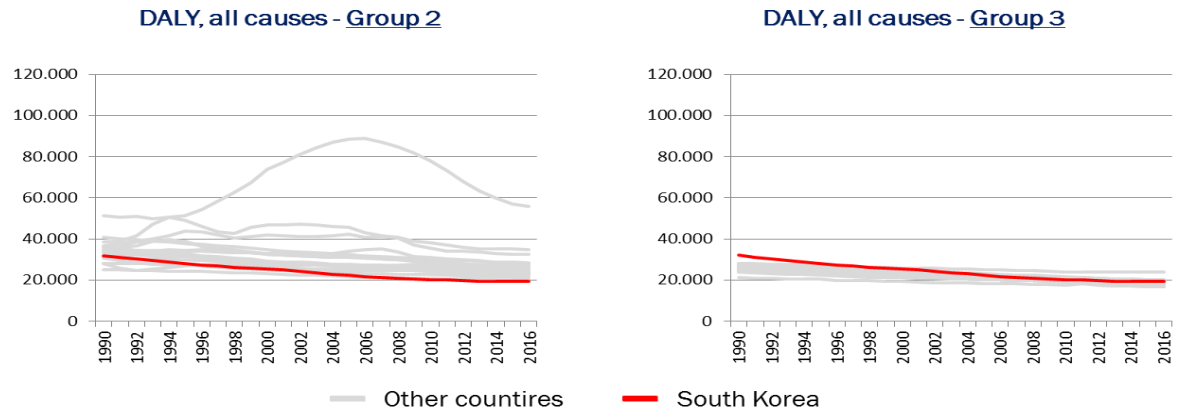
Source: Data from IHME and "Grupo de Pesquisa em Economia da da Ciência e Tecnologia - Cedeplar/UFMG" aggregated by the authors.

A movement in all groups diagonally to the right and downwards is observed indicating that life expectancy is increasing and DALY rates are decreasing. With some exceptions, countries seem to be moving in blocks divided by the groups to which they belong. The countries in the third group generally have the best numbers, followed by the countries in the second group and finally the countries in the first group.

South Korea, a case of ascending country at groups hierarchy

Closing this result section, Figure 4 presents a different perspective in the effort to expose the similarity among countries of the same group. It is described the specific case of South Korea due to its impressive technological development trajectory described in Ribeiro et al (2016). The graphic compares South Korea's total DALY rates trajectory to both second and third group, from 1990 to 2016, considering only the countries that have not changed the group in this period.

Figure 4 - Graphs of DALYs by technological group changing, South Korea *versus* Others countries, 1990 to 2016



Source: Data from IHME and "Grupo de Pesquisa em Economia da da Ciência e Tecnologia - Cedeplar/UFMG" aggregated by the authors.

Between 1990 and 2014 South Korea experienced a nearly 40% drop in its DALY rate. In 1990, South Korea presented a rate very close to the average of the countries of the second group. As early as 2016, it had the lowest rate among the group. In 1990, South Korea had the worst results within the third group. However, by 2016, it was already in the average of the group, outperforming countries like Canada, Finland, Ireland, New Zealand, Germany, Belgium, Denmark, United Kingdom and United States. This perform seems to be in accordance with the change of group that South Korea suffered in 1998, rising from the second to the third group.

CONCLUSION

Most of the analyzed countries have similar health indicators within the same group and appear to follow a similar trend. The exceptions seem to be able to be explained by economic, political and social conjunctures or therefore, added to externalities, as in Haiti.

The similarity among countries of the same group is even more evident among the more developed countries of the third group. Technological development and the consequent change of group appear to lead to improvements in health indicators as well as could be observed in South Korea's case.

There seems to be a convergence towards the scenario observed in the more developed countries, mainly from group one towards the health framework observed in group two. It seems to be more difficult for the countries of the second group to reach the third group. The explanations for these differences may be associated with several factors, such as the relative weight of communicable and non-communicable diseases, behavioral factors, technological development, among others that go beyond the scope of this article.

The future agenda of these researchers intends to answer questions such as this one, examine the relative importance of technological advance to struggle communicable and non-communicable diseases and research the particular cases of countries that even without much technological advance presented great health indicators.

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