From the Flintstones to the Jetsons
Wonders of Technological Progress with Convergence*

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Summary

This article is based on a collection of essays. These describe how the convergence and acceleration of growth based on human capital and technological progress will put us in front of an economic singularity, where economics would cease to be the science of managing scarcity and become the science of the study of human action in an environment of radical abundance. Quantitatively, if the world converges in the 21st century, GDP per capita would grow at a rate of 4.18%, so it would multiply 59.1 times, exceeding the achievements of 20 centuries by 4.6 times. If you want to get an idea of what I'm talking about, compare our standard of living with that of the beginning of the Christian Era. Then consider what a person from that time would feel if I told you what is happening in our world today. Now, try to rationalize it and multiply those sensations by 4.6 times. ces. Welcome to the Singularity.

"Anyone who believes that exponential growth can continue indefinitely on a finite planet is either crazy or an economist"

Kenneth Boulding

1. Introduction

The apocalyptically pessimists, from Malthus, through Ricardo, Marx, Keynes, Harrod and Domar, to the Club of Rome, were always wrong. Analyzing history, believing that the best is yet to come, even when there is a crisis from time to time, is not excessive optimism.

I'm not asking you to believe me, but at least let me propose a game. Imagine that they give you a

*. This work is dedicated to my great source of inspiration, Conan Milei, who has pushed me to discover the limits of the possible by venturing to the "impossible" and beyond as well. In this sense, I believe that economic growth driven by technological progress is the bridge to the Singularity in economics, which will radically change our way of seeing the world.

Travel back in time to witness the birth of Jesus Christ. Overcome with joy at the magnitude of the event he witnessed, he decides to go for a walk through the city of Bethlehem and realizes that people live an average of 25 years (and I don't even tell you how they are dressed), so to give them a dose of optimism, he It is said that in the future that number will triple and that not only are there people who are over 100 years old, but also that the Nobel Prize winner in Economics Ronald Coase published a book at the age of 102. This prompts him to talk to them about Gutenberg's printing press and as he perceives that people are enthusiastic, he tells them that where you live there is drinking water, electric lights, refrigerators, air conditioning, microwaves, gas heating, cinema, television, DVDs, computers, iPads, landlines and mobile phones that allow you to see the other person while they talk, and skyscrapers, through which you move in elevators.

There is a crowd that cannot get over their astonishment and ask you about horses, donkeys and camels, to which you answer that although they exist today, we travel in cars, trains, buses, subways, huge ships and we even fly in planes. Naturally, explaining all these things takes a lot of time and it is getting dark, so if all this were not enough, he raises his hand and pointing to the dark sky tells them that we have also reached the Moon. When you finish describing our world, what do you think they will think of you? It is not necessary to read the

mind to guess that the locals will think you are completely crazy and that, given the customs of the time, it will not end well.

The counterpart of all these material achievements of 2,000 years has been a growth rate of the per-capita product of 0.13% annually, which implied that the level of income multiplied 12.9 times, at the same time that the population did so. in 26.9 times. However, doing the math at the tips hides a lot of information. Thus, separating the evolution of the Gross Domestic Product per inhabitant (GDP per capita) between the period from year 1 to 1,800 and the remaining 200 years, we can see that the growth rate went from 0.02% to 1, 1%, while the level of income, which during the first period had grown by 40.8% (concentrated in the 14th and 15th centuries), multiplied 9.18 times during the second period. This implies that during the last two centuries the per-capita growth was 817.7%, being 92.0% in the 19th century and 378.1% during the last one.

Moreover, the growth rate is accelerating. The number of years needed to double income went from 3,649 in the first period to 63. What's more, data from the last half of the 20th century show that the growth rate accelerated to 2.1% and the years to double the income fell to 33. In terms of countries, the United Kingdom was the first to double its GDP per capita and it took 58 years (1780-1838), followed by the United States with 47 (1839-1886), Japan with 34 (1885- 1919), Italy with 21 (1890-1911), Spain with 18 (1950-1968), South Korea with 9 (1978-1987) and China with 7 (1987-1994). At the same time, during the second half of the 20th century, not only has the growth rate accelerated, but it has also been maintained for long periods of time. For example, taking a growth floor of 7% per capita, Botswana multiplied its per capita product by 18 times in 45 years, China did it by 13 in 44 years, South Korea and Singapore did it by 12 in 41 and 33 years respectively, Japan and Taiwan multiplied their income 11 times in 33 and 37 years respectively, Hong Kong multiplied it by 10 in 37 years, Oman and Malta multiplied it 9 times in 39 and 31 years respectively, Malaysia by 6 in 30 years and Indonesia for 5 in 31 years.

In fact, the very evolution of the term that describes "*to the remaining 85% of the planet*" that did not achieve the status of a developed country is in itself

same interesting. At some point these countries stopped being referred to as poor and were called underdeveloped. Later they were called less developed countries. They were then called developing countries, while recently they have been called emerging countries. This evolution in the language used to define the state of affairs of these countries reflects the awareness about the growth process that is being experienced and that naturally the present situation of poverty is not permanent. All of this would suggest that we are traveling the path of a transition, at the end of which lies a world with a high level of income and a substantially better quality of life.

In short, what the data are not showing is that the acceleration of growth is combined with the phenomenon of convergence. Therefore, if all countries reached the level of per capita product of the United States at the end of the 21st century, which grows at 2.5% annually, this would imply that the rest of the world would have to grow at 4.36%, therefore that world per-capita product would grow 4.18%. This rate, set at a level, implies that per capita income would multiply 59.1 times. That is, in one century we would have grown 4.6 times more than what was achieved in twenty. In short, we do not know what the future will be like, what we do know is that it will be much better and this puts us in front of *the economic singularity*.

In light of this, a set of small essays published in different media is presented (which, having been presented independently, at different moments in time leads to the repetition of the force data) in which the I manifest that not only is the world of the future a much better place, but economists will also have to rethink the way we do economics, since we could be facing a paradigm shift where *Economics would cease to be the science of scarcity management and become the field of study of human action.*. Based on this, in the first of the essays the three laws of economic well-being are established, drawing a parallel with Arthur C. Clarke's three laws of scientific knowledge. The scientific contribution of Adam Smith is analyzed below from the point of view of modern growth theory, which is complemented

with an article that summarizes the lessons of economic growth. Once this block is closed, we proceed to describe the convergence process, which shows us how it is possible to go from being a poor country to a rich one. On the other hand, given the role that knowledge has had in the generation of ideas that have allowed continuous and accelerating growth over time, two essays are presented, one on the role of human capital and others on the role of R&D. (research and development) in productivity growth. Finally, as a conclusion, the bases of the concept of singularity in economics are provided.

2. 21st Century: The Odyssey of Growth

Arthur C. Clarke, like Isaac Asimov (author of the three laws of robotics), from his science fiction writings imagined a set of laws that surpasses the boundaries of his own work. In this context, the three laws referring to the progress of scientific knowledge were born. The first of them points out that when a distinguished scientist asserts that something will be possible in the future, he is almost certainly right, while when he asserts that something will be impossible, he is surely wrong. The second maintains that the only way to discover the limits of the possible is to venture into the impossible. Finally, any technology that is sufficiently advanced is indistinguishable from magic.

The parallel to the three laws of scientific advance of the author of "2001: A Space Odyssey" in economics would come from the theory, and especially from the empirical evidence, of economic growth. Thus, the first law on the economic well-being of humanity would indicate that if a specialist in the history of growth assures that the future will be better than the present, he is probably right, while the champions of structural pessimism with their gloomy visions about the viability of the system They are surely wrong. Regarding the second law, it would maintain that one should go beyond the short-term vision that is shown to be full of costs, to launch ourselves into the long-term challenge (strongly embracing the statistical regularities on the matter). Finally, any vision of the long-term future is indistinguishable from a science fiction film.

In this sense, the first great optimist and visionary of the future was Adam Smith, who from the title of his monumental work of 1776, "Inquiry into the Nature and Causes of the Wealth of Nations" clearly perceived the foundations of economic growth. . The system of the Father of Economics was based on the following premises: (i) economic growth was linked to the division of labor, (ii) the promotion of free competition (which is not the same as the neoclassical model of perfect competition), (iii) the exaltation of savings in the process of capital accumulation (where the deferral of consumption over time is what finances investment), (iv) the linking of growth with innovation or what we also call progress technological, (v) a government that minimizes its intervention in the functioning of the economy and (vi) whose main function is the administration of justice, ensuring the safety of citizens and ensuring respect for property rights.

During the last 2,000 years, the growth rate of gross domestic product per capita has grown at a compound average rate of 0.13% annually, which implied that the level of wealth multiplied 12.9 times. However, this growth process was not uniform. Thus, separating the evolution of GDP per capita between the period from year 1 to 1,800 and the remaining 200 years, we can observe that the growth rate went from 0.02% to 1.1% (it multiplied 55 times). In turn, while the level of wealth grew by 40.8% during the first period (concentrated in the 14th and 15th centuries), during the second period it grew by 817.7%. Put in other terms, the per capita product multiplied 9.18 times (71.2% of the growth of the period), which in turn implies that during the last two centuries the growth was 817.7% (92 .0% for the XIX and 378.1% in the XX). What's more, during the second half of the 20th century the world economy expanded at a rate of 2.1% compounded annually, so per capita income multiplied by 2.8 times.

Based on this, to get an idea of   what convergence along with the acceleration of the economy's growth rate means, let's assume that it took place during the 21st century. The initial per capita product was USD 6,000 (in 1990 Geary-Khamis dollars), where said indicator for the US was USD

30,000, while for the rest of the planet it averaged USD 4,960. In turn, the United States economy during the last century has expanded at a rate of 3%, so if the same trend is maintained and along with a drop in population growth by half (from 1% to 0.5%) its per capita product would grow at 2.5% (which rises to 3.5% when the national accounts are corrected for technological progress). Thus, if convergence is achieved, the rest of the countries should grow by 4.36% compounded annually, which would imply that the world per capita product would grow by 4.18%.

However, despite everything that remains to grow for China, India, the Asian countries that have not yet achieved convergence, the countries of Eastern Europe and Latin America, added to the fact that Africa is just waking up, Suppose that in order not to fall into an optimism that could be taken as excessive, the world manages to maintain a per capita growth similar to that shown so far this century at around 3%. In terms of level of wealth, the inhabitants of the earth would multiply their income by 19.2 times, or in other words, a standard of living would be reached 3.5 times higher than that of the United States in the year 2000, while the income gap between groups would go from 6.1 to 3.3 times (with full convergence the gap would close).

That is, in one century we would have grown 49% more than what we did in the previous 20 centuries, which not only means something difficult to imagine (consider what the inhabitants of the year 0 would think if one told them what the world of 2000 is like) but that this would also imply the beginning of the path towards economic singularity (full convergence), where economics would cease to be the science dedicated to the administration of scarcity to become the science of the study of human action in the face of the existence of a radical abundance. Without a doubt, being able to imagine this world and turn it into a film production would not only be a box office success, but would also win the award for the best science fiction film in history. What's more, it may even win an Oscar for optimism.

3.Adam Smith and Economic Growth

The apocalyptically pessimists, from Malthus, through Ricardo, Marx, Keynes,

Harrod and Domar, even the Club of Rome, were always wrong. Thus, while during the period from year 1 to 1800 the per-capita product rose 40% (0.02% compounded annually), in the last two it grew by 818% (92% in the 19th and 378% in the XX -0.65% and 1.58% annually respectively). In turn, this acceleration of the growth rate has been pronounced since the end of the last century, which stood at 2.1% annually and so far now, it stands at 3%. On the population side, the number of inhabitants of the planet today exceeds 7,000 million, a figure 7 times higher than that recorded in 1810. Therefore, from this perspective of history, believing that the best is yet to come is not an excess of optimism.

In this sense, the first great optimist and visionary of the future was Adam Smith, who from the title of his monumental work of 1776, "Inquiry into the Nature and Causes of the Wealth of Nations" clearly perceived the foundations of economic growth. . The system of the Father of Economics was based on the following premises:

(i) the idea behind the hand metaphor invisible where the legitimate pursuit of self-interest leads to greater general well-being;

(ii) economic growth was linked side to the division of labor;

(iii) the promotion of free competition (which it is not the same as the perfect competition of the neoclassical world);

(iv) the exaltation of savings in the process capital accumulation (where the deferral of consumption over time is what finances investment);

(v) the linking of economic growth co with innovation, or what we also call technological progress;

(vi) a government that minimizes its intervention tion in the functioning of the economy; and

(vii) whose main function is to manage justice, care for the safety of citizens and ensure respect for property rights.

3.1. The invisible hand and general well-being

"But although man constantly has opportunities to greet his fellow men, it is useless for him to depend exclusively on the benevolence of others, so he will obtain it with

more security by interesting the self-love of others in his favor, showing them that it is in their own interest to do for him what he needs from them... You give me what I need and I will give you what you need . This is what lies behind every offering... It is not from the benevolence of the butcher, the brewer, or the baker that we expect our food, but from their consideration of what constitutes their own interest. We do not appeal to their benevolence, but to their self-love, and we never talk to them about our needs but about their advantages... Each person who employs capital and workers does not try to promote the public interest nor does he know how much he is promoting... He is guided by an invisible hand that does it and that is not part of his purpose... By following what his self-interest dictates he promotes that of society.”

3.2. Division of labor and productivity

“One man stretches the wire, another straightens it, a third cuts it, a fourth makes the tip, a fifth files the end to attach the head; To make the head you have to perform two or three different operations; Placing it is a special task, enamelling the pins is another; even putting them on paper is a craft in itself; The important work of making a pin is thus divided into about 18 different operations, which, in some factories, are all performed by different hands, although in others the same man sometimes performs two or three.” In this way Smith estimates that 5,000 pins can be produced per man per day, while at best an extremely skilled man could produce only 20 pins.

3.3 Promotion of free competition and commercial openness

Regarding free competition, Adam Smith, like the other classical authors, free competition means the same as economic freedom. Although for the Scotsman, like the classical authors, the fundamental criterion was the power of each company and economic agent over the price of the good, they considered that the measure of that power is the ability to obtain profits above normal. The classic version of the competitive model comes from a real fact that is important in itself: the tendency towards leveling of the rate of profit in the different

sectors of production when capital can move freely between them.

A direct consequence of this vision was the position in favor of free trade, which is reflected in the following passage: “The maxim of any prudent head of family is never to try to make at home what would cost more to make than to buy. "If another country can supply us with a commodity cheaper than we can make it, it will be better to buy it from them with a part of the product of our own industry, employed in a way in which we have some advantage."

3.4. The role of savings in growth

“Everything that a person saves from his income he accumulates in his capital and uses it to maintain a greater number of productive hands, or makes it easier for another person to do so, lending it to him in exchange for interest or, which amounts to the himself, of a share of the profit. Just as the capital of an individual can only increase with what society saves from its annual income or profits, in the same way the capital of society, which coincides with that of its individuals, cannot increase except in the same way. ... Increase in fortune is the means by which most human beings aspire to improve... their condition. It is the most common and most obvious means, and the easiest way to increase one's fortune is to save and accumulate part of what one acquires... Every spendthrift is a public enemy and every saver is a public benefactor.”

3.5. Technological progress

“A large part of the machines used in these manufactures, in which work is highly subdivided, were at first the invention of workers, since each one of them was occupied in a simple operation, all their imagination was concentrated in the search for faster and easier methods to execute it.”

3.6. Minimization of State intervention in the economy

“It is the greatest impertinence and presumption, therefore, in kings and ministers, to try to monitor the private economy of the people and restrict their spending, both through sumptuary laws and

prohibiting the importation of foreign luxuries. They are themselves, without exception, the most squanderers of society. It is better that they watch their own spending and can safely trust the private people who decide theirs. If their own extravagance does not ruin the state, it will not be for lack of desire... Great nations are never impoverished by the private sector, even if they sometimes act badly, with public prodigality. All, or almost all, of public income in most countries is used to maintain unproductive hands. This class of people, who make up a splendid and numerous court... contribute nothing and have nothing that can compensate for the expense of maintaining them... All these people, who produce nothing for themselves, are maintained thanks to the work of other men. ."

3.7. The essential function of the State

"Little more is needed to take a State from the worst of barbarism to the maximum degree of opulence except peace, low taxes and a tolerable administration of justice, the rest will come with the natural course of things."

Therefore, Adam Smith was not only an optimist who clearly understood how the world was changing for the better, but he was also more than 200 years ahead in laying the fundamental foundations of growth theory and its empirical foundation as it is today. we know. In short, as Alfred Marshall maintained: "it's all in Adam Smith."

4. The Lesson of Growth

During the last 2,000 years, the growth rate of gross domestic product per capita has grown at a compound average rate of 0.13% annually, which implied that the level of wealth multiplied 12.9 times. However, this growth process was not uniform. Thus, separating the evolution of GDP per capita between the period from year 1 to 1,800 and the remaining 200 years, we can see that the growth rate went from 0.02% to 1.1%. In turn, while the level of wealth grew by 40.8% during the first period, during the second period it grew by 817.7%. Put in other terms, the per-capita product of the second period multiplied 9.18 times.

As for the 20th century itself, the growth rate of per capita income was 1.57%, which implied an improvement of 378.1% compared to what was achieved during the previous nineteen centuries. That is, despite the two world wars, the great contraction of '29, the oil shock of '73, the unhealthy inflation of the '70s and the stabilization of the '80s, in the last century, the world grew by 77% more than what was done in the rest of the period under analysis. In fact, during the second half of the century, the world economy expanded at a rate of 2.1% annually, so per-capita product multiplied by 2.8 times (64% more than the first half).

At the same time, during the second half of the century XX, not only has the growth rate accelerated, but it has also been maintained for long periods of time. For example, taking a growth floor of 7% per capita, Botswana multiplied its per-capita product by 18 times in 45 years, China did it by 13 in 44 years, South Korea and Singapore did it by 12 in 41 and 33. years respectively, Japan and Taiwan multiplied their income 11 times in 33 and 37 years, Hong Kong multiplied it by 10 in 37 years, Oman and Malta multiplied it 9 times in 39 and 31 years, Malaysia by 6 in 30 years and Indonesia by 5 in 31 years.

Therefore, based on the successes mentioned and those that have not been able to get on track in the process, one should ask: What are the elements that separate the successful cases from the disappointing cases? In an attempt to offer a very synthetic answer to this question, a series of stylized facts about growth are described below.

First of all, we must highlight the importance of free markets and incentives. Growth requires the use of markets that generate price signals, thus providing the correct incentive system to guide the allocation of resources. At the same time, stimulating the competition process generates very powerful dynamic incentives to reduce costs and improve product quality. Naturally, this process of competition and change, where companies enter and leave while the economic structure changes, given that adjustments in the labor market can take a long time (which will be longer the less

be the level of education and the flexibility of the labor market), it is necessary to protect agents during the transition. That is, it is key to generate minimum income levels for agents to have access to basic services that allow them to achieve a minimum standard of living and thus avoid permanent damage, which in turn will provide social sustainability to the process of change.

Third, high levels of savings and investment have played a predominant role in all cases of strong growth. Saving involves deferring present consumption into the future and its importance lies in providing financing for investment. As for investment, it is the mechanism that makes the productivity gains derived from the transfer of knowledge and technological innovation a reality. Naturally, the legal counterpart to the process is a legal framework that respects property rights. Otherwise, the savings will be lost and the investment will not be made, thus generating problems with the level of activity and stagnation in the long-term per-capita product.

Fourthly, there is a role for the sector in the provision of public goods such as investment in certain types of infrastructure and the financing of education. The experiences of countries that have grown at high rates for several years show levels of public investment in infrastructure of around 5% to 7% of GDP, especially in those sectors where there are strong economies of scale (size of investment relative to to the depth of the capital market). On the other hand, education plays a prominent role in the growth process, where it not only improves the living conditions of those who have been educated, but also generates positive externalities on the rest of the economy. However, in the latter case, given the imperfections in the capital market (impossibility of expropriation of collateral), the government should ensure the financing of the agents, while providing a framework of free competition between study houses (generating thus a high quality product).

Finally, the design of economic policy, although it deals with short-term management, is extremely important. Thus, economies with low inflation grow 3 percentage points more

than inflationary ones. Parallel markets cost 2 points to the growth rate. The fiscal deficit implies a burden of 1.5 points, while its closure to international trade detracts another 1.5 points (in fact, the economies that have always been open show a per-capita product 9 times higher than the which have always been closed).

Therefore, the empirical evidence is clear and compelling. A much better future is possible. However, getting on board with convergence requires putting aside the ideological blinders that cling economic policy makers to the short-term manual, to adopt a set of consistent policies that not only provide a framework of short-term stability but also enhance growth. long term.

5. Growth and Convergence: Wonderful World Movie

Examining the history of humanity up to the 19th century and comparing it to the 20th century, believing that the best is yet to come (even if there are crises from time to time) is not excessive optimism. You may not believe me, for which I propose an exercise. I will describe some characteristics of a country and you will tell me which country I am describing. In this country, life expectancy at birth is less than 50 years and 1 in 10 children die before reaching one year of age. More than 90% of homes lack electricity, refrigerators, telephones or cars. Less than 10% of young adults have a high school education. Is it Kenya, Bangladesh or perhaps North Korea?

All of these answers could be good, but in reality that country is the United States, not today but at the end of the 19th century. Today, in that country, almost all homes have electricity, refrigerators, heating, telephones and even several cars. Most young adults have a high school education and many go to college. Think of the large number of goods that were unimaginable a hundred years ago: television, air conditioning, satellites, airplanes, skyscrapers, DVDs, computers, cell phones, the Internet, portable music players and many others. goods that are within easy reach. Here is the power of growth for

achieve development and for those who have not been able to achieve this standard of living there is the challenge of convergence.

By the end of the 18th century, it had become apparent that the systematic use of science and engineering on productive technology would revolutionize the productivity of labor, making possible a process of wealth creation never before imagined. In this sense, William Godwin developed the idea of the perfect society, where the technological revolution would solve humanity's problems by reducing poverty and disease. Thus, separating the evolution of GDP per capita between the period from year 1 to 1,800 and the remaining 200 years, we can observe that the growth rate went from 0.02% to 1.1%, while the level of wealth that during the first period had grown by 41%, during the second period it multiplied 9.18 times. The number of years necessary to double income went from 3,649 in the first period to 63. What's more, if the data from the last half of the 20th century are taken, it can be seen that the growth rate accelerated to 2.1% and The number of years for an individual to double their grandparents' quality of life has fallen to 33.

In terms of population, despite Malthus, the numbers are no less impressive. During the last two millennia, the growth rate was 0.16%, which implied multiplying by 26.95 the number of inhabitants in year 1. On the other hand, separating the same preceding periods, the rate went from 0.08%. to 0.9%, so while in the first period the population multiplied by 4.2 times, in the second it multiplied by 6.4. On the other hand, improvements in health care have led to life expectancy at birth from 26 years to 64 and it is expected that by 2100 the world population will stabilize at around 10 billion inhabitants.

Although this growth has not been uniform in different areas of the world, giving rise to a clear separation between developed and non-developed, in the last 100 years it is possible to see a reversal in this trend. Prior to the Industrial Revolution, the developed world owned 26% of world income, a number that after the productive milestone began to grow until reaching a maximum of 60% at the beginning of the 1950s. However, that number today has dropped to

45%, while the Gini coefficient (which measures income concentration) fell from 0.7 to 0.6. That is, the data confirm the hypothesis of alpha convergence (in the long term all countries would have the same per-capita product). Therefore, a better world is possible and to achieve it we only have to carry out a set of policies in accordance with the stylized facts of growth.

6. Human Capital and Economic Growth

Why are some countries rich and others poor? Economists have asked this question since the time of Adam Smith (1776). Regarding the main ideas about the effects of the accumulation of physical capital on the long-term expansion of income, these are due to Robert Solow and Trevor Swan, who developed the neoclassical growth model. However, when the model was tested for the non-agricultural private sector of the United States, the total factor productivity -TFP- (part not explained by the accumulation of factors, that is, the residual of the equation) represented almost 80 % of production growth rate.

The recognition that the accumulation of physical capital (at least as traditionally measured) explained only a modest part of the income growth of many countries led to the search for more adequate explanations. In this context, Theodore Schultz noted the importance of human capital and its contribution to economic growth, which was formalized and tested by Gary Becker and reflected in a bisectoral growth model (where both physical capital and human capital are accumulated) by of Hirofumi Usawa, who made time dedicated to education the main determinant of the growth rate of technological progress (TFP).

Human capital is the amount of knowledge and skills that individuals accumulate and that make them more productive. Obvious examples of human capital are health expenditures and university education. However, human capital is also accumulated when elementary school students learn to read, when construction workers learn to operate a crane, and when doctors learn to read.

doctors master a new surgical technique that improves the quality of life of individuals. In this sense, the difference in TFP between countries can be attributed, in part, to the fact that the quantity and quality of workers' human capital varies from one country to another.

Regarding human capital linked to health, Robert Fogel quantified the contribution of improved nutrition to economic growth in the United Kingdom between the years 1780 and 1980. Fogel calculated that in 1780 the poorest 20% of adults were as poorly fed that he did not have the energy necessary even to perform an hour of daily manual work. By 1980 this type of malnutrition had disappeared and this change alone multiplied production per adult by 1.25. On the other hand, the increase in calorie intake allowed the amount of work to increase by 56%. Thus, nutritional improvement multiplied production by 1.95 (1.25 x 1.56), which in a period of 200 years means an increase of 0.33% per year. Given that the per capita income growth rate for the period was 1.15%, improved nutrition explains almost a third of the improvement.

Regarding human capital linked to education, the table shows the impact on salaries for developing and advanced countries. Thus, finishing primary school implies a salary improvement of 143% compared to someone who has no education of any kind. On the other hand, the difference stretches to 216% for those who finish high school, while for those who finish university the improvement is 311%. Furthermore, inequality in income distribution is, in general, positively correlated with inequality in education and other forms of learning. At the same time, there is a close, usually negative, relationship between education and unemployment. That is, education improves the profile of the income and risk relationship over time in a notable way. Finally, the table shows that while the proportion of individuals without education in advanced countries is 2.5%, in developing countries this number rises to 20.8%. In turn, while in the first group 63.9% have completed secondary school (where 16.6 points are university students), in the second this figure reaches 31.4% (with only 5.3 in the highest ranking).

In light of empirical evidence and in line with Paul Romer's developments on endogenous growth, Robert Lucas returned to the fray with the idea of growth driven by human capital. In parallel, Gregory Mankiw, David Romer and David Weil, using a mixed sample of 98 countries, assuming that a fixed proportion of income is spent on investment in human capital and using the proportion of the working-age population enrolled in schools secondary education as an approximate indicator of the proportion of income invested in human capital, the estimated equation not only substantially reduces the residual (TFP) but explains 80% of the difference in per capita income between countries. At the same time, the weight of physical capital within income (31%) is very close to the participation calculated directly.

Therefore, the most important empirical conclusion is that people with higher levels of education almost always have better incomes, which is true both in developed countries

Disaggregation of the Population by Educational Levels and Salaries

Nivel de estudios más alto	Número de años de estudios	Salario en relación con la ausencia de estudios	Porcentaje de la población	
			Países en vías de desarrollo	Países avanzados
Sin estudios	0	1,00	20,8	2,5
Algunos estudios primarios	4	1,65	10,4	3,4
Estudios primarios terminados	8	2,43	18,0	12,3
Algunos estudios secundarios	10	2,77	19,3	17,8
Estudios secundarios terminados	12	3,16	23,2	37,4
Algunos estudios superiores	14	3,61	2,9	9,9
Estudios superiores terminados	16	4,11	5,3	16,6

Source: David Weil (2010)

as in underdeveloped. On the other hand, no country has achieved sustained economic growth without having invested significant sums in human capital. In short, as Alfred Marshall stated in his "Principles of Economics" (1890): "the most valuable capital of all is that which has been invested in human beings... Thus, while nature shows a tendency towards diminishing returns, Man shows a tendency towards increasing returns (which allows permanent endogenous growth). Knowledge is our most powerful production machine; "It allows us to subdue nature and satisfy our desires."

7. Growth and Productivity: The Economy of Ideas

During the last two centuries, especially during the 20th century, humanity's progress in terms of well-being has been enormous. Thus, while in the centuries from the 1st to the 18th the per capita product grew by 40.8% (which is concentrated in the 14th and 15th centuries), during the last two the growth was 817.7%. %, which breaks down into a rate of 92.0% in the 19th century and 378.1% during the last century. At the same time, the data show an acceleration process, which can be seen in the number of years it took to double GDP per capita. Chronologically, the first to achieve this was the United Kingdom, which took 58 years (1780-1838), then followed by the United States with 47 (1839-1886), Japan with 34 (1885-1919), and Italy with 21 (1890-1911). , Spain with 18 (1950-1968), South Korea with 9 (1978-1987) and China with 7 (1987-1994).

The fact is that the growth rate of the world economy has accelerated over time and this trend cannot be attributed solely to the forces of the accumulation of productive factors (capital and labor), which, although they can explain the convergence , the presence of diminishing marginal returns (each new unit of production requires a greater amount of inputs) leaves them aside in the explanation of permanent growth. To reconcile this acceleration of growth with the process of accumulation, technological change has to increase over time at a rate fast enough to counteract production constraints.

In 1990, Paul Romer, dissatisfied with his original 1986 work that gave rise to the theory of endogenous growth (based on the presence of knowledge externalities, this generated increasing returns, which allowed growth with perfect markets), developed a model of Schumpeterian style for the purposes of studying the evolution of productivity based on the generation of ideas.

In this new framework, companies invest resources in R&D in order to develop new products, which are protected by patents. In this way, innovators gain monopoly power that they can use to obtain more profits and the additional profits give incentives to invest in R&D. At the same time, given that knowledge is not a rival good and is only partially excludable, this allows other innovators to benefit from new ideas at lower costs, amplifying the social benefits of R&D. In these circumstances, the stock of knowledge that innovators can access is a function of previous efforts dedicated to R&D, so the more R&D that has been carried out, the greater the stock of knowledge, which will make the new R&D more cheap and with it the incentives to continue creating new ideas grow.

Under this new scheme, institutions become fundamental. The private performance of R&D depends, among other things, on the life of patents, trademark protection, the effectiveness of the legal system in protecting intellectual property rights, and the nature of the economic environment in which companies operate. companies. In turn, savings play a determining role, where the higher the level of said variable, not only the per-capita product is higher, but also the permanent growth rate is higher.

Based on this, if the world managed to create enough ideas to sustain a growth rate of around 4% (something feasible in light of convergence) during the 21st century, the GDP per capita at the beginning of the The next century would be 50.5 times greater than that of 2000. That is, the economic growth rate would have accelerated to 4950.5%, leading us to an economic singularity, so the expansion factor would not only be 10.6 times greater than that of the 20th century, but it would also be 3.9 times greater than what was achieved during the last 20 centuries.

Therefore, one might wonder how many potential ideas there are before the dreaded steady state is reached. To answer this, suppose we only consider instructions that can be written in a paragraph of 100 words or less (a typical summary of a scientific article). In turn, the English language (dominant language in publications) contains about 20,000 words. Based on this, the number of paragraphs with different ideas that we can create is given by 20,000 to the power of 100, which is greater than 10 to the power of 430 (that is, a 1 followed by 430 zeros). Although most of these combinations will not make sense, others would describe the fundamental theorem of calculus, Darwin's theory of evolution, Pasteur's germ theory of disease, the chemical formula of penicillin, the structure of DNA, and perhaps a motor. to propel spacecraft in the future.

Let us further assume that only 1 in 10 to the power of 100 of these paragraphs contain a coherent idea. In this way, the possible paragraphs would amount to 10 to the 330th power, a figure zillions of times greater than the number of particles in the Universe. In short, as the father of the theory of endogenous growth stated: "All generations have noticed the limits that finite resources would impose on growth if new ideas were not discovered. And all generations have underestimated the possibilities of finding new ideas. "We systematically make the same mistake of not realizing how many ideas remain to be discovered."

8. Final Thoughts:
Towards the Singularity in Economics

As humans, we first become aware of the world as it currently is. The first instance is like taking a snapshot, and then incorporating movement into it. Initially we assume that the snapshot is permanent and not just a moment of a trip whose landscape changes continuously. Perhaps this is because changes are or seem to us to take place slowly. And perhaps also because changes are difficult to anticipate or it is difficult to think about them forward. Plus, it's always much simpler to look back.

During the last 2,000 years, the growth rate of gross domestic product per capita has grown at a compound average rate of 0.13% annually, which implied that the level of wealth multiplied 12.9 times. According to these two millennia, it would take 542 years to double the standard of living of a group of agents at a given moment. However, this comparison between tips hides a lot of information.

However, by the end of the 18th century, it had become apparent that the systematic use of science and engineering on productive technology would revolutionize the productivity of labor, making possible a process of wealth creation never before imagined. In this sense, William Godwin developed the idea of the perfect society, where the technological revolution would solve humanity's problems by reducing poverty and disease. Thus, separating the evolution of GDP per capita between the period from year 1 to 1,800 and the remaining 200 years, we can observe that the growth rate went from 0.02% to 1.1%, while the level of wealth that during the first period had grown by 40.8% (which is concentrated in the 14th and 15th centuries), during the second period it multiplied 9.18 times, which implies that during the last two the growth was of 817.7%, which breaks down into a rate of 92.0% in the 19th century and 378.1% during the last century. Therefore, the number of years necessary to double income went from 3,649 in the first period to 63. What's more, if the data from the last half of the 20th century are taken, it can be seen that the growth rate accelerated to 2, 1% and the number of years for an individual to double the quality of life of their grandparents has fallen to 33. That is, the data show an acceleration process, which can be seen in the number of years it took to double GDP per capita. Chronologically, the first to achieve this was the United Kingdom, which took 58 years (1780-1838), then followed by the United States with 47 (1839-1886), Japan with 34 (1885-1919), Italy with 21 (1890-1911). , Spain with 18 (1950-1968), South Korea with 9 (1978-1987) and China with 7 (1987-1994).

In short, the fact is that the growth rate of the world economy has accelerated over time and this trend cannot be attributed solely to the forces of the accumulation of productive factors (capital and labor), the

which, although they can explain convergence, the presence of diminishing marginal returns (each new unit of production requires a greater amount of inputs) leaves them aside in the explanation of permanent growth. To reconcile this acceleration of growth with the process of accumulation, technological change has to increase over time at a rate fast enough to counteract production constraints.

On the other hand, although this growth has not been uniform in different areas of the world, giving rise to a clear separation between developed and non-developed, in the last 100 years it is possible to see a reversal in this trend. Prior to the Industrial Revolution, the developed world owned 26% of world income, a number that after the productive milestone began to grow until reaching a maximum of 60% at the beginning of the 1950s. However, today that number has dropped to 45%, while the Gini coefficient (which measures income concentration) fell from 0.7 to 0.6. That is, the data confirm the hypothesis of alpha convergence (in the long term all countries would have the same per-capita product).

To get an idea of   what the convergence and acceleration of the economy's growth rate means, let's assume that it took place during the 21st century. The initial per-capita product was USD 6,000 (1990 KY dollar), where said indicator for the US was USD 30,000, while the rest of the plant averaged USD 4,960. At the same time, the American economy during the last century has expanded at a rate of 3%, so if the same trend is maintained and together with a drop in population growth by half (from 1% to 0.5%), its product per inhabitant would grow at 2.5% . Thus, if convergence is achieved, the rest of the countries should grow by 4.36% compounded annually, which would imply that the world per capita product would grow by 4.18%. Put in other terms, the level of wealth of the earth's inhabitants would multiply by 59.1 times, or in other words, a standard of living 11.8 times higher than that shown by the United States in the year 2000. This is , in one century we will have grown 4.6 times more than what we did in 20 centuries, which not only means something impossible to imagine (if you do not consider what the inhabitants of the year would think

0 if one were to tell the world of 2000) but it would imply entering a singularity in economics, where economics would cease to be the science of managing scarcity and become the science of the study of human action in a context of abundance. radical.

Therefore, a much better world is possible. To achieve this goal and to accelerate the transition process, it is necessary to stimulate the formation of human capital (health and education), keep inflation low, preserve fiscal balance, promote foreign trade and competition, make the labor market more flexible (for new entrants), stimulate savings via a stable macro and protect property rights so that investment not only provides the capital stock to produce more but also so that it brings with it technical progress that allows a leap in productivity, in real wages and consumption. In short, as Robert Lucas Jr. (1988) pointed out, "the consequences that these types of issues entail for human well-being are simply shocking and once one begins to think about them it is difficult to think about anything else."

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