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The climate emergency and the turning point of sustainable growth: a way forward for the economic discipline

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Introduction

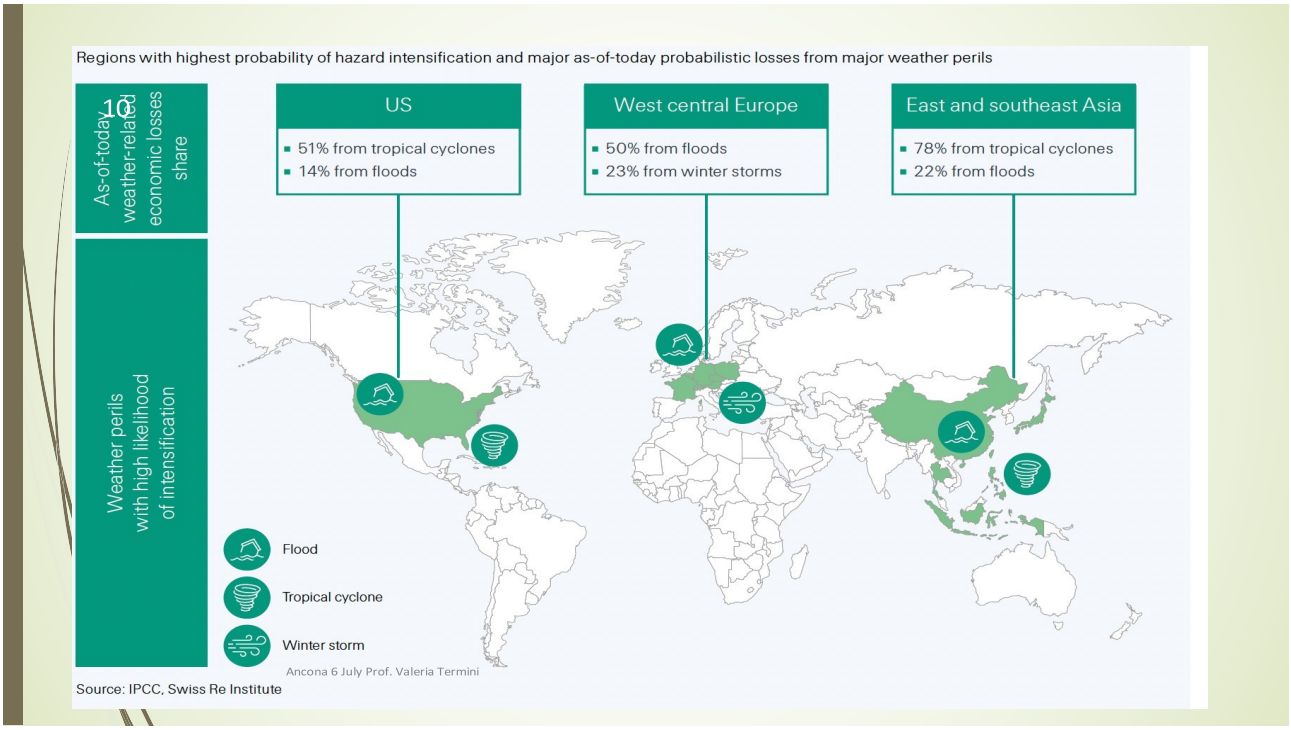
Today economists are called to understand and govern the dynamics of a system that in the last decades has changed radically, in natural, environmental and socio-economic terms. They have to deal with issues ranging from the economic consequences of the planet's energy imbalance to the vulnerability of the most defenceless places and social groups; from the analysis of the different radiative forcing on atmospheric warming to the costs of the ecological transition; from the preventive measures to reduce carbon dioxide emissions, to adaptation policies. And, above all, the costs of not doing anything.

The economist is also asked to analyse the consequences of the ecological transition on the world of labour and the opportunities for doing business that are opening up, and to apply the tools made available by scientific research - among others the possibility of conserving energy, once an oxymoron in physics, or the ability of quantum computers to process the countless possibilities of the future.

A clear warning emerges from the scientific contributions. One cannot fail to act urgently, globally. Climate is therefore a potential element of global cohesion in objectives and necessary sharing of economic policy actions. Climate damage is already immense; calculable damage in 2023 alone amounted to USD 357bn, of which USD 110bn was covered by private insurance and only USD 13bn by public insurance institutions; 66% was unprotected damage. Among the regions most affected recently are China by floods, the Philippines, Taiwan and Mexico by hurricanes, India, Myanmar, Bangladesh, Oceania and New Zealand by cyclones; there were floods and droughts in South America, in Europe, Italy, Greece, Spain, and Libya; windstorms caused the most damage in France and Italy. The combination of heat and drought also hit Canada, and the US was damaged by hurricanes and cyclones, Florida by fires and Hawaii by drought, which greatly reduced agricultural harvests. For the whole of 2023, global warming growth exceeded +1.5° compared to pre-industrial revolution levels; it is considered an insurmountable limit without incurring the risk of irreversible damage (FIG 1).

• This paper was presented at the Accademia dei Lincei on June 11, 2024.

FIG.1 TEMPERATURE VARIATIONS IN DEGREES C°



Seemingly separate traumatic events - pandemics, biblical climatic migrations, wars, financial crises - highlight the West's loss of control and the difficulty of reconstructing multipolar balances from the decline of the United States' political and economic hegemony. At the same time, the application of radical scientific innovations revolutionises the organisation of life and work and builds the possibility of a *leap frog* in the more recently industrialised countries, as A. Ghosh has well explained in relation to India. The combination of these different pieces creates a fracture in the order built in the last century. The long-time faults in history are moving. Towards where?

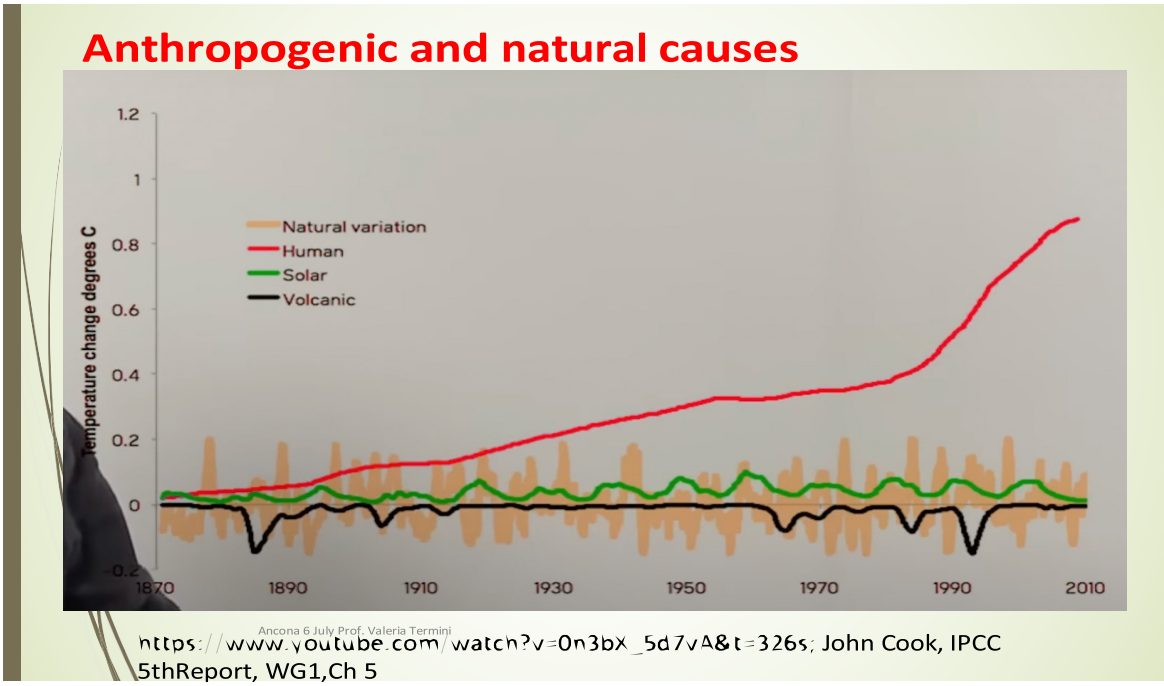
In a nutshell, the new millennium began facing three transitions: a 'hegemonic transition' (recalling Arrighi and Silver), an 'ecological transition', and an economic one, marked by the energy/digital revolution. As has always been the case in history, conflicts mark the difficulties of the hegemonic transition until new balances marked by global agreements are reached. We are witnessing a planetary disorder, which is appalled by the spread of conflicts made dramatic by the widespread availability of nuclear weapons. Historical analysis helps to understand these crises, while economic analysis and policy appear stuck in the theoretical foundations set at the beginning of the last century.

The urgency of addressing the climate crisis calls for a change of vision. Economics, too, must find a multidimensional perspective; the study of climate change demands a systemic theory in which knowledge from physics, chemistry, geography, volcanology, meteorology, history and

economics converge (FIG 2). Indeed, this opens up a fertile field of potential global sharing in objectives. But the ground of institutions – international, regional and national - is still not ready. And economic theory today does not seem to have adequate tools to understand and govern the unexpected dynamics of climate, nor to deal with the uncertain and overwhelming impact created by the new scientific and technological revolutions. The economist finds herself unprepared to interpret her role in the face of the environmental disaster that crumbles traditional growth models.

This leads me to share a reflection on the difficulties that economics faces in addressing the climate crisis with a cohesive set of relationships and concepts, and to look for a way forward *in order to grasp the fracture that is taking place in economic reality today*. It is ideas that shape the world, wrote Keynes in the 1930s. If reality changes, radically and with the increasing speed we are experiencing, economists' models must change. We can read this through the lens of the energy crises and climate risks.

FIG. 2. EXPECTED RISKS IN % GDP AND VULNERABILITY TO CLIMATE CATASTROPHES



Theoretical difficulties

The two pillars of the argument concern the method - the very foundations of economic theory - and the market ability to formulate appropriate economic policies. Regarding the world of energy, I realize that the prevailing economic vision is destroying the planet, its creatures and humanity itself. And it has almost succeeded. Firstly, this lack is rooted in the foundations of the economic discipline, which have remained anchored to the vision of the world built at the beginning of the last century, when political economy borrowed the method and analytical tools of classical physics. By building on those certainties, gradually adjusted over time in a progression of models, economic theory has been able to interpret and partly govern the

dynamics of the industrial and financial economy in the past century. But today, faced with the ongoing transformation of social, economic and environmental relations, its limits emerge. The natural sciences are entering by force the domain of the social sciences to counter the warming of the atmosphere, made irreversible by the carbon dioxide emissions produced by the forced industrialisation that followed the industrial revolution and today by the run-up of the emerging countries. I am an economist deeply convinced that history and the natural sciences are essential for improving economic life on the planet. It is time for the economist to confront the role of humanity as part of a complex universe.

The difficulty in economics comes from afar; it goes back to the fact that the discipline of economics was not affected by the change in the world vision and perspective brought about by the revolution in physics in the early 20th century. Quantum theory, as we know, brought about a complete revolution in the experimental determinism of Newton and Galileo, on which the (deterministic) foundations of economics of the last century, still dominant today, were built. "We are spectators and actors in the drama of life", Bohr explains, "and we have entrusted the task of ordering our perceptions to the principle of causality; which, however, does not intercept and explain the complex picture of the infinite possibilities of the future." Quantum theory, which has broken the mould of classical physics, has spread to the various fields of scientific knowledge, revolutionising their approach - from chemistry to biology and astronomy - without touching upon or changing the foundations of the discipline of economics, which has remained trapped in the determinism of classical physics, apart from a few attempts in the field of finance.

The results of frontier scientific research performed at the Accademia dei Lincei on energy sources and climate offered an extraordinary panorama of the potential that is opening up with the ecological and social transition, but also of the risks to be faced, which may affect the life of the planet in this century. The different angles give a sign of the multiplicity of the paths and solutions, of the choices to be made, of the unavoidable complementarity of solutions. We observe a horizon that is both scientific-technological and economic-social.

Economists' discomfort in dealing with the complexity of change is well known and widespread, as is the difficulty in making predictions. It emerges in the attempts, few in number, that overlap in the different areas of research: by Nobel laureates Kahneman and Tversky, for example, in the innovative study of complex individual behaviour; by Sabel, Silver, Kohane, among others, as well as by Nobel laureates Banerjee, Duflo and Ostram in the analysis of the collective decision-making processes required to deal with international economic developments and climate change. The necessary theoretical renovation concerns the representation of microeconomic phenomena, the behaviour of individuals, but it also invests the domain of macroeconomic dynamics, in which waves of possible overlapping paths must replace, *ex ante*, the numerical forecasts of traditional economic models. It seems, therefore, that determinism must be abandoned and linear certainties transformed in order to interpret social fragmentation on the one hand and, on the other, to govern the transcending of national boundaries, made cogent by climate objectives and the interdependence of global value chains.

The necessary theoretical breakthrough requires an all-embracing reflection. The energy and digital revolution, which go as far as the first applications of artificial intelligence, guide this path; they impose the vision and analysis of the world as an open system. After many years of research, the dissemination efforts of the physicists who spanned the 20th century, from Bohr to Feyneman, from Schroedinger to Heisenberg, Pauli, Parisi, have provided the key I was

looking for, as an economist, to understand and improve economic life on the planet. Humanity is part of nature, as Spinoza well understood and explained, and before him Lucretius, among the greats, and after him Einstein and even Goethe. The quantum physics revolution then changed the way of seeing the world and reading the path of humanity in it.

In the foundations of quantum theory, I have found a wonderful analytical solution to unlock rigidities in the method of the economic discipline. The potentialities of the future thus contain an infinity of possible overlapping outcomes, indeterminate *ex ante*, among which one will become real (the reference to Schroedinger's cat is quite obvious). A simplified example is offered by the diverse potentialities contained in a block of marble, from which can emerge the steps of a staircase, the stone of a sepulchre, or the statue of Moses with which Michelangelo's creativity made one of marble's many potentialities real.

Heisenberg's "uncertainty principle" corresponds to the intuition of the uncertainty of processes. The number of matrices occurs in history, but intermediate processes disappear from view, between one state of unstable equilibrium and the next. I will try to illustrate the theoretical concept with an example, which I refer to as the 'Heisenberg lampposts'.

It is evening. Through the window I observe a passer-by walking on the sidewalk in front of me. A lamppost illuminates him: I can see him distinctly, he is walking in a winter coat to protect himself from the cold. Then his image fades and disappears from sight; I can no longer distinguish his step or his figure, absorbed in the darkness. Then the next streetlight, will illuminate him again. But it will be a new state. Between the two lampposts, in the darkness, a process takes place that takes the man from one state to the next, a new one. I cannot know or perceive what happens in the dynamics of the journey. I do not see, I do not know.

It is not just perception (the epistemology of the phenomenon). The possible reality of the path I observe varies. The passer-by may have stopped to tie his shoes, he may have slowed his pace to answer a message on his phone, he may have been stopped by a dog, an exogenous event, or he may have continued his walk at a brisk pace; he may even have decided to change course because of a sudden recollection. The outcome of the dynamics occurring is different in the different cases. The second street lamp will illuminate a new, also temporary, state of the passer-by.

Ex ante, I do not know the duration, the state, the intensity, the direction of the process. I do not know the gradients of the vector of his movement, nor the internal dynamics, nor the possible external events that have occurred and the passer-by's relationship with them. I know nothing of what happens or may happen in the process of transition from one state to another. With this awareness I can no longer assume the invariance of the translation of axes in time, as classical mechanics suggests.

Chance enters powerfully into the depiction of the new state, which might not even arise if the passer-by has changed direction. Physicist G. Chaitin, from the Quantum Centre in Singapore, along with Eckert defines chance as 'statistical incompressibility' and in a theorem explains that the existence or non-existence of chance could not be proven.

Intermediate processes disappear in perception between one (unstable) equilibrium condition and the next. The uncertainty represented by quantum theory is of this nature. The time taken,

whether the passer-by will arrive at the new state, is only a scalar result that can be statistically verified ex-post.

The outcome of the process is not a function of time, but of the subject's relationships with other variables whose probability I can imagine intervening in its path. Selecting some of the infinite number of possible variables and relationships (the telephone message that slows the pace, the cold of the evening that accelerates his pace, the occurrence of a thought that causes a change in direction) is the task of the scholar, of the economist. I can attribute different probabilities to these events, to the reaction in the behaviour of the passer-by who is affected by them, and different haphazard hypotheses. The economist's task is to define the dominant variables and establish the probability of possible events and reactions extrapolated from the statistics of past history.

Quantum mechanics thus introduces uncertainty into the theory, an understanding of the potentially limitless processes that separate one equilibrium state from another, in the cosmic wave and in the natural world. These are processes that disappear when one focuses on the comparison between two provisional equilibrium states. The continuous movement in the dynamics of processes and the relations between subjects (with immense potentialities of a probabilistic, ex ante nature) produce new realities, whereby the sum of relations, as we shall see, is different from the new context. Also in this area the revolution in thinking must permeate the theoretical framework of economics. An economic example can be taken from the world of finance where the future value of a sum invested today depends on the tangle of micro-macroeconomics, political, social and environmental relations, which combine to construct the process and dynamics of the portfolio value tomorrow.

Climate is an example of the need to develop an analysis of pathways and processes whose possibilities overlap and it is not known in advance which one will prevail. The IPCC, for example, shows in science the probability curve of the impact of positive radiative forcings (CO2 emissions) and negative radiative forcings (eruptions of volcanoes) on global warming. Energy flows and the laws interpreting their movements respond to beautiful, simple and general criteria; they also affect the micro and macro-economic sphere.

Waves of higher magnitude are complementary with the behaviour of micro-entities (atoms, individuals). Like the drops of water in the sea, the micro-magnitudes flow into the waves; they seemingly disappear, but their individual existence remains, giving shape to the wave. It is the complementarity of micro and macro worlds.

The third principle captured by quantum theory, in fact, is the definition of the corpuscular particle, the individual, 'the elementary quantum of action in the discrete world' that explains specific behaviour within its orbit. The social fragmentation that struggles to find political representation in traditional categories concerns the orbit of the individual. And nothing prohibits the 'quantum leap' between different orbits in economic relations as well. The passer-by, the individual in economics, is a discrete element in Bohr's particle granularity, whose behaviour contributes to the course of the macro wave.

This micro and macro complementarity is also rooted in quantum theory. The duality principle recognises the necessary simultaneous existence of the micro particle (the individual in the economic sciences, the drop of water in the sea) and the macro wave (the dynamics of the social

sphere, the wave breaking on the beach), into which the discrete particles converge; the micro granularity is lost in the macro wave, where the individual (the individual/discrete particle) disappears; but the particle continues to exist, according to the principle of complementarity between particles and waves.

This is therefore the key that allows economics, among the social sciences, to break out of the trap of determinism in order to grasp, among other things, the relationships of the energy transition. Quantum physics, as was initially the case with the revolution in classical physics, now offers tools to change the perception of the world even in the discipline of economics, as I will discuss in the following pages. The tools are always essential to the change: as was the telescope for Galileo, the quantum computer today is capable of processing an infinity of data very quickly. "The search for the simple leads to the complex," explains Edgar Morin in his study of complexity (cf. Morin 2012, p.45; like the physicist Chaitin). The mathematical tools for analysing possible processes are the matrices of quantum mechanics (Heisenberg 1925) or the probability waves of Schroedinger's wave mechanics (1926). The quantum computer, a technological application of this theory, supports a turnaround of the analysis. It can process an immense number of probabilistic paths in a minimum of time.

In technical application, quantum mechanics gives birth to semiconductors, laser beams, and microchips, enabling the industrial transformation of this millennium. In theory, quantum mechanics changes the vision of the world, including for the discipline of economics.

In the uncertainty of processes, a probability wave, initially conceived by Niels Bohr (1925), indicates a tendency towards something. In fact, it offers a quantic version of the concept of power (Heisenberg p.48); in a multi-dimensional space it describes the superimposed potentialities, the infinite possibility of events in the uncertainty of their actual occurrence, until a possibility of the wave function 'collapses' and becomes real, thus verifiable ex post.

At the basis of the new vision is the superposition principle introduced by Dirac: he conceives the possibility of different event alternatives superimposing themselves (economists would say 'ex ante') also due to the intervention of chance. According to the particle superposition principle, several events are possible outcomes at the same time (as with Schroedinger's cat, which in the box with the vial of poison is both alive and dead), i.e. not A or B, but A and B are possible together, until only one event (ex post) becomes reality. I will return to this in the following pages.

It is important to underline, however, that the 'quantum entanglement' probability (Schroedinger, 1935) is different from classical probability. In classical probability the variables are independent (like the faces of a dice) and the probability is therefore additive. In quanta, the superposition principle requires that the probability amplitudes be added together, producing a cross term (for Heisenberg $(a+b)^2 = a^2+b^2+2ab$). The probability amplitude is calculated with complex numbers ($i= \sqrt{-1}$) to express the phase relationships of the waves and interpret interference phenomena, i.e. whether the waves are in phase or out of phase. But probability is an integer number, the sum of which is 1.

Finally, everything is connected in space and time; entanglement (connection) rejects the principle of separability between sciences and the separation of elements from their environment. This leads to systemic theory, which shows that a whole is more than the sum of

its parts, creating an eco-system that requires interdisciplinary knowledge of geography, volcanology, meteorology and seismology in the study of climate change. "Space-time is the world of separation, but if there is a state of inseparable interconnection between particles" this would not be describable by the concepts of space and time as the absolute, separating reality described by Einstein. Bohr and t h e Copenhagen School knowledge cannot be separated. Hence Heisenberg's uncertainty principle, the leap of flocks, the absence of time.

Pauli's interaction principle allows one to go further: one can show that interference is creative. From the meeting of two particles (events), a new reality arises. For example, from the merger of oxygen (O) and hydrogen (H) particles, water (H2O) is generated, i.e. the whole is more than its parts.

Towards a new vision

A different worldview follows. The quantum system replaces collision (e.g. competitive confrontation) with the tendency to overlap and combine in a creative encounter. Interaction enriches. This is the message concerning the potential offered by the cross contamination of cultures between East and West that is worth reflecting on.[1]

In social terms, the concept of the free market that does not create community but competition is replaced by community dynamics with participation taking over from the individualism of the market. This approach generates the vision of Durkheim's 'social identity'. Defence against migrants is replaced by the concept of demographic complementarity that enriches the parties.

From this also follows the second critical pillar in the organisation of economic thought, namely the need to overcome the centrality of the market in the relations of the new millennium. The market - the core of the discipline - no longer helps to understand current interactions. The 'virtuous' rules and mechanisms, according to which collective welfare is achieved through confrontation in the market, the 'war of all against all', as Hobbes defined the market, do not seem to apply today. We will see that collision in the market can only be replaced by principles of sharing.

Let us make an elementary simplification to recall some well-known passages that will allow us to quickly reach the theoretical questions related to the challenge of tackling climate change.

In economic discipline, it is well known that the market is the central element in the relations between subjects. Prices are attributed the function of balancing the supply and demand conditions on the market. The form of the market - competition, oligopoly, monopoly, to name the main ones - attributes greater or lesser rebalancing effectiveness to prices. The function of prices weakens as one moves away from competition toward monopoly, in which the price only guarantees the producer's extra-profit. Around the market and the production of goods for the market, social categories have been defined as classes, which include workers, industrial capitalists, rentiers, agricultural and financial capitalists.

[1] Schroedinger studies Sanskrit to interact with the Indian Vedas.

After years of prevalence of the liberal paradigm to 'free the market' and let its laws operate, and after a belated return, marked by recurring crises, to the responsibilities of public policy towards a socially and environmentally sustainable economy, the dominant economic paradigm has entered a crisis. Two central problems arise. The first is the contraction of the market's role with the expansion of common, collective and public goods. The second is social fragmentation, on the one hand, and the overcoming of national borders, on the other, of which climate is an example, but certainly not the only one.

In a nutshell, the theory based on the centrality of the market implodes with the spread of public, collective and common goods, and the awareness of their importance in the economy of the planet's life as the demand for common goods (so-called because they are not traded on the market) grows. The climate is the paradigmatic example of a global common good in which market interaction through market prices loses its function in the planet's economy. But also at a local level it proposes, for example, the reality of Renewable Energy Communities, in which the comparison through prices on the market loses any balancing role, since they are composed of subjects that self-produce the energy they consume. Therefore, what is relevant is the participation and behaviour of citizens.

In recent decades, the economy of the Western world has been transformed into an economy dominated by services (which have reached 70 per cent in their share of GDP), while the production of market trade commodities has shrunk to 20 per cent. At the same time, the pressure of radical innovations has strengthened the oligopolistic power of a few large global innovator entrepreneurs protected by rules on property rights that limit the upstream diffusion of innovations, escape market relations and transcend the powers of the state (examples can be found in the energy, telecommunication and A.I. sectors).

These conditions affect the possibility of using market-based instruments to implement economic policies useful for contrasting climate change and promoting sustainable economic growth. Pricing tools - from carbon prices to tariffs in international trade - are proving ineffective. There is a growing need, and for the climate the urgency, to devise a system for sharing objectives and above all to allow for the cross contamination of different cultures, to replace the collision of subjects in the global marketplace.

The climate crisis forces the economist to reduce the role of the law of the market, which is omnipresent in the economic discipline. It requires sharing instead of collision, interaction between cultures where there was Western hegemonic thinking and the analysis of possible overlapping paths where there was determinism of solutions.

Conclusion

The world is an open system. With the revolution and vision introduced by the quantum theory at the beginning of the last century, physics once again marks the path of theoretical change for all sciences, with one caveat: in the discipline of economics, these foundations must be accompanied by history and the theory of evolution which explains the survival of the fittest. Breaking with the pre-existing determinism inherited from the classical physics of Newton and Galileo, quantum theory conceives the world 'as the flow of an open system'. A few key words guide this vision.

The first is in the method: the concepts of "potential" and the uncertainty that prevails in the *ex ante* superposition of irreversible processes are contained in the first keyword.

The second is the market: with the prevalence of public goods, especially global ones, the market cannot remain at the centre of the dynamics analysed by the economic discipline. Climate risks bring humanity back to nature, although without returning to the transcendent conception that attributed to divinity the role of dispenser of rewards or punishments for human behaviour. Economists, among the social scientists, are faced with the responsibility of understanding and identifying new forms of economic growth in a direction that preserves the planet's natural foundations, protects the most vulnerable populations, and defends places made fragile by the climate change that has begun.

Finally, a necessary consequence of this path is the cross contamination of cultures. Closed in a self-referential West, the economists of the 20th century followed hegemonic Anglo-Saxon thought (centred on market exchanges) and did not perceive the great potential of hybridisation with Eastern thought, which other social scientists, from Asia, use today. Among them are Keshore Mahubani, a political scientist and economist from Singapore, like Edward Saw, or Lee Kuan Yew, a great innovator who was able to transform the Singapore economy in a single generation.

The planet in the cosmos demands consideration. We know at least two scientific ways of relating to nature: one, developed with the industrial revolution, conceives humanity's control over nature, which becomes an object, an instrument to be used, to be bent to progress; the other, an opposite one, finds its foundations in the Eastern vision of harmony, which defines the responsibility of the individual towards the community and of humanity towards the cosmos. In it, humanity must respect the harmony of the cosmos, whose rules maintain the balance between the parts and cannot be violated.

The cross contamination of these two cultures is a harbinger of the richness of thought; it affects and modifies the economic dimension of the dominant paradigm.

These key words show that the path to overcoming the difficulties of the discipline of economics is theoretical and can find a way in the revolution in physics that pointed the way in quantum theory; it seems possible today, and necessary, to make a belated break with the determinism of classical physics from which the discipline of economics borrowed its foundations in the last century.

Everything has changed compared to the economy of the last century. The new frame of reference must deal with the fragmentation of the organisation of work and therefore of social figures, with the need to return to public intervention that the state is unable to guarantee. The prevalence of a small number of innovative entrepreneurs (a narrow oligopoly) destroys the very concept of competition in the different regions of the planet. Social fragmentation, the prevalence of the service economy, and huge climate migrations call for a new economic vision; added to this is the overcoming of national borders by the few subjects who, being great innovators, escape the rules of the nation state.

Uncertainty marks our political and economic future. The economy must deal with a new

condition in which services prevail over the production of goods and demography plays a dominant role. Climate change, a global common good, cannot be dealt with naturally by individual nation states, while the ground for global agreements is not yet ready.

The climate crisis forces the economist to downgrade the role of the law of the market, omnipresent in the economic discipline. It demands sharing instead of collision, the cross contamination of cultures where it was Western hegemonic thinking, the analysis of possible overlapping paths where it was determinism of solutions. The cross contamination of different realities - between East, West and the so-called 'Global South' - can only replace antagonistic conditions.

Meanwhile, the consequences of climate events contribute to the biblical migrations of populations fleeing from environmental disasters, and the awareness and urgency of human intervention to reverse the trend of air pollution is beginning to spread. This reality revolutionised by radical innovations requires a new vision of the world, not the one inherited from the 20th century. Quantum theory offers this vision, the content and the tools to interpret its dynamics.[2]

Art intuits, mathematics describes new phenomena. But to understand a new reality, it is indispensable to have a cohesive set of concepts that provide the interpretative key. New phenomena to be observed, interpreted and governed require concepts suited to them. They bring with them the need for a transformation of economic theory and its way of facing the future. From quantum physics I have tried to select the theoretical foundations that are functional today to introduce a radical change in the worldview of the economic discipline. Quantum physics expresses them in a cogent and rigorous manner; it participates in shaping them by building a set of coherent principles. The synthesis and conceptualisation of the examples given in the text point the way to overturning the paradigm still dominant in economic theory. I will try to recall them:

a) the world is an open system; b) the uncertainty of processes prevails: it is formalised in Heisenberg's uncertainty principle; c) the superposition principle interprets in Bohr's probabilistic wave a path of overlapping possibilities, i.e. it offers a quantitative version of the concept of power; d) but the probabilities of Bohr's waves, unlike in classical physics, are not independent of each other; everything is connected in space and time: entanglement interprets this connection; e) the principle of duality explains that particles (micro-variables) and waves (macro-variables) necessarily coexist and are complementary; f) the principle of interaction shows that interference is creative (Pauli): from the union of two particles/events a new reality is born, different from the sum of its parts; g) the principle of entropy interprets the irreversible consequences of radical innovations and the inexorable growth of disorder that accompanies every transformation.

We are confronted with a general scientific innovation and technological applications that

[2] Concepts that have proved useful in ordering things easily acquire such authority over that we forget their human origin and accept them as invariable. They become 'necessities of thought', 'a priori data'. The path of scientific progress then remains barred for a long time....There is therefore no point in analysing current notions and highlighting the conditions on which their justification and usefulness depend(...) Thus their authority is shattered. And they (...) are replaced with others if we can develop a new system that for good reasons is preferable", in Bohr, p.XIII - the example is the centrality of the market.

imply a radical economic change, as was the case with the steam engine and electricity. Once again, the discipline of economics can perhaps rely on the theoretical tools of physics; in the last century they were the ones offered by the classical physics of Newton and Galileo, today they are the ones prepared to deal with the uncertainty of processes and change from quantum physics. It has always been useful to introduce the methods of physics into economic science, for example, to observe the dynamic processes in the space-time curvature of relativity; but to analyse the probability of events today one must rely on quantum theory.

In other words, it can be stated that a logical dynamic (of a-temporal relations) describes theoretical processes out of time. Economic policy is determined by the logical relations interpreted in the observation of the statistical regularities of history, but its consequences are not rendered reversible by symmetrical policies of an opposite sign, unlike what is established by economic theory. They produce cumulative and irreversible effects even in the short term in the interaction between subjects in different unstable equilibrium conditions.

Entropy is a measure of how far a system moves away from the equilibrium state; in statistical terms, it measures the number of possibilities/states describing a system. Entropy increases (in thermodynamic processes) up to an equilibrium condition.[3] Higher entropy, it is known, corresponds to less information, less order. Entropy never decreases; state transformations occur at increasing entropy.

Transformation increases entropy, i.e. it determines an imbalance between the elements of the system in a process that is irreversible: burnt coal does not return to wood, ash does not return to a tree, the industrial economy does not return to an agricultural economy, nor does the service economy return to its previous state. Entropy measures disorder: the tree is more ordered than the ash. The Heisenberg matrices foundation of quantum mechanics are in fact non-commutative [AB =/=BA].

In light of this different perspective, the foundations of the economic discipline can be re-read. These principles offer the essential theoretical framework for constructing a cohesive vision of today's economic reality, since the economic discipline is (no longer) able to interpret them, let alone govern them with the theoretical tools at its disposal. "Our collective ways of thinking, feeling, acting," as Emile Durkheim defines them, are "the feeling of time."

[3] Entropy, a scalar quantity in physics, originated with thermodynamics (Clausius 1865-94); the variety of entropy measures in physics the intrinsic capacity of a system to transform itself, by changing the elements that determine the state -P (pressure), T (temperature), V (volume occupied by the system)-, through intermediate states. In thermodynamic transformations, state values are changed through exchanges of energy (heat and work) between the system itself and other physical systems or the environment. Disorder increases,

According to the 2nd pr. of thermodynamics, heat exchange only occurs from warmer to colder bodies. The change in entropy is measured in Joules, unit o f energy, / Kelvin K (unit o f absolute temperature); delta S= deltaQ/T, i.e. q. of energy exchanged (delta Q) at temperature T. See Inherited.

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