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Industry 4.0: Some Conjectures on Employment and Technology Diffusion

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CONTENTS

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Satyaki Roy*

*[**Abstract:** Paradigm shift towards 'new technology' clubbed together as Industry 4.0 marks a significant departure in terms of human labour use and process of diffusion while maintaining continuity on account of emerging possibilities and challenges in terms of redistribution of employment similar to previous technological revolutions. Technologies are disruptive to established production functions, often following a non-linear path of development by mix and interactions of inventions and innovations and hardly pareto superior in their welfare effects. They drastically alter human labour use while at the aggregate level the net effect depends on the balance between human displacement in technology using sectors and jobs created in complementary labour using sectors. With the change in the composition of knowledge involved and the related learning curve, this paper argues that propertied knowledge traded through market may turn out to be restrictive in terms of realising the full potentials of new technology and its diffusion. Since continuous interaction between producers and consumers provides critical input in the development trajectory of new technology, it demands a more inclusive mix of institutional structure, and collaborative arrangement of production and distribution based more on reciprocity and cooperation.]*

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1. Introduction

Human civilisation is marked by phases of scientific and technological revolutions that augmented economic growth and development. The association largely manifests both geographical and temporal relationships between space and time of origin of such technologies and garnering of economic gains by related countries to begin with. Both within and between countries, the diffusion of technology is not actually determined by

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the science of technology; rather, it largely depends on access and receptivity of individuals and societies that encounter such changes. Technologies are socially embedded and the usage of new technology and its diffusion across societies relate to factors that do not depend on the novelty of the technology alone but its economics are weighed in comparison to existing arrangement and cost structures of production. Schumpeter (1961, pp. 132–136) made a distinction between invention and innovation where the former is the result of the pursuits of scientific knowledge while the latter is a more complex process located in the interface between invention, economy, and socioeconomic institutions.

The new technology largely referred to as Industry 4.0 includes a gamut of new scientific understanding and technological intervention including artificial intelligence (AI), internet of things (IOT), big data, block chain, 5G, 3D printing, robotics, drones, gene editing, nanotechnology, and solar photovoltaic. These technologies are in their various stages of applicability, adaptability, and refinements, depending on the readiness of technology infrastructure in various countries. In every phase we see the emergence of a cheap critical input with pervasive applicability across sectors; for instance, today it is semiconductor or microprocessor, in earlier phases it was oil and plastics, preceded by steel, coal, and water. Those sectors that are prime carriers of the new input become flag bearers of the new techno-paradigm and in the current phase these are computer software and mobile phones. In the previous technological changes, we find similar roles played by automobile and electrical appliances, before that steel made steam ships or iron made steam engines and initially textiles using water power.

The current phase seems to be disruptive enough with faster change in frontier technologies, destabilising existing work arrangements and advantages and will be displacing a large part of the workforce as more of those come into force. Fear and scepticism on something new is not surprising as average human behaviour is largely conditioned by inertia of existing habits that often create doubts on uncertain future. Nonetheless normal life as well as normal science face anomalies which they are not comfortable with and which gives rise to sparks not only in the mind of an innovator, but also its overbearing impact gradually destroys all potentials of gaining out of old production structures. This is the reason why technological progress has never been smooth and linear; rather, the new paradigm takes time to inaugurate an avalanche that eventually touches all walks of life. A series of punctuated equilibria as it may be characterised, technological progress also involves creating a dominant discourse, a different set of transactions, interdependence, preference, and even language. The articulation of the new order involves contestation between forces inclined to retain their gains from the older regime and potential losers in the new versus those who anticipate multilevel gains out of new technology. These contestations are rational responses of various groups and segments of the society, and the collective choice of technologies governed by various policies of state need to be sensitive to these contestations.

The full impact of Industry 4.0 is yet to materialise and for countries such as India, alike all other developing countries, the process of paradigmatic change would emerge with a lag in different aspects of its usage compared to advanced economies. This paper is primarily speculative in nature. While keeping an eye on the changes in advanced economies and learning from the past technological revolutions, this paper attempts to identify some broad contours of change as well as potential contestations that might arise in the world of work and the systemic infirmities in existing institutions that pose a fundamental challenge to existing modes of distributing gains emerging out of technological progress. Besides raising concerns about the potential changes in work and employment, it also highlights the need of a faster learning curve for necessary transformation in the context of a fast moving technology frontier.

2. New Technology Paradigm

We are at the initial phase of a sixth technological revolution often marked by industry 4.0 as the deployment phase of the previous one led by ICT gradually comes to an end. Thomas S Kuhn's famous work, *The Structure of Scientific Revolutions*, discusses the phases of a non-linear trajectory of scientific revolutions (Kuhn, 1962). Indeed, Kuhn was primarily engrossed with theoretical research in science, undermining, to some extent, instrumental and experimental research and explained the trajectory of the emergence of new paradigm from the crisis of 'normal science.' Essentially, Kuhn was drawing the notion of 'paradigm' from Immanuel Kant who underlined two critical revolutions, namely mathematical techniques of deriving proofs from postulates was transferred from Babylon to the Greek, and the experimental method and use of laboratory starting from Galileo. According to Kuhn, paradigm indicates a new light to explain the emerging anomalies within existing practice of normal science and there arise some enduring group of adherents who inaugurate a new way of solving puzzles persisting for some time within the old framework. The rise of the new is not a simple negation or rejection of the old but actually pushing the frontier of knowledge away from inadequate conception rather than converging to a predetermined single truth. When it is about entities and concepts that cannot be physically pointed out, what indicates change is the choice of problems and change in the meaning of earlier concepts. New paradigm of scientific and technological change also involves a new way of interpreting things that gives rise to new sets of problems that the new paradigm chooses to answer and obviously some problems are pushed aside as lying beyond disciplinary boundaries or simply too problematic worth one's time.

In the field of technology, a paradigmatic change essentially indicates the process of innovation that initiates a critical input having the potential and promise of drastically reducing production costs in various sectors across the economy. Within a few years, production process in various sectors undergoes change with the use of that critical input and like an avalanche overwhelms all walks of life, essentially destroying possibilities of profit from older technology use. Something like this happened in 1971 when Intel's first microprocessor was launched as a precursor of a computer in a chip or in 1908 when Henry Ford launched the low cost model-T with its internal combustion engine powered by cheap gasoline. Similarly, Liverpool-Manchester rail line inaugurated the Age of Steam and Railroads or Bessemer steel mill in 1875 marked the big bang of the age of steel and heavy engineering (Perez, 2009). And now we are in the installation phase of new technology paradigm with AI, IOT, robots, and so on. Notable is the fact that technological paradigms mark a constellation of change that pervades backward and forward linkages of the key industries that emerge as carriers or motive force of new technological change. The invention of steam engine created opportunities for expansion in trade; this further grew with use of steel steamships and heavy engineering subsequently leading to expansion of intercontinental trade, new communication through telegraph, and hence demand for new infrastructure, new modes of transactions, and demand for new skills.

It is estimated that the market for Industry 4.0 technology at the moment would be 350 million US dollars and is expected to reach 3.2 trillion US dollars by 2025, the largest share being accounted at the moment by IOT (UNCTAD, 2021). Artificial intelligence conceived as an intelligent machine involves simulation of human intelligence that uses algorithm to process unstructured data. It understands the pattern of speech and image recognition used in iPhone and driverless cars respectively. Computers are taught to perform specific tasks without being programmed. Narrow AI is used in spotting cancer, responding to customers, booking hotels, and so on. Intelligent machines using deep learning through recursive neural networks undergoing successive stages of iteration are capable of performing complex tasks much faster than humans do. For instance, machines learn the skill of world-class players in mind games such as Dota 2 that gives millions of options in a week. Artificial intelligence enabled machines are able to write routine news reports, analyse stock market trends, process legal documents, and even provide customised education according to learning styles of students (Ramar, 2019). Internet of things on the other hand allows communication between closed internet networks and by this process collect huge amount of data, which in turn can be processed using AI to generate insights on patterns. Machines are now highly efficient in predicting equipment failures in oil refineries and power grids, enabling to save huge amount of money. A study suggests that one percent increase in weight precision saves five lakh dollars in a 14000-gallon batch of Twizzlers for Hershey (*ibid*., p. 33).

In automobiles, electronics, metals, and chemicals as well as in warehouses and assembly, general purpose robots are increasingly in use. The costs of robots are declining and, importantly, the electricity required to use robots is much cheaper compared to the wages of workers that they are supposed to replace. In other words, cheap labour advantage of developing countries is not going to remain forever and already there are signs of reshoring of production to home countries in the West relying on robots. However, the process is not as uniform as it appears to be, particularly in sectors where the choice of location in developing world was primarily driven by closeness to large markets as in the case of garments or automobiles where the possibilities of reshoring would be less. In the context of the current pandemic, we see that AI has been used extensively for disease screening and identifying places of high concentration. Internet of things is also used to monitor ground water quality and drones are being widely used in delivering food, medicine, and other necessities to remote communities during crisis. It is amply clear now that jobs and tasks that are repetitive in nature or intelligible through identifying patterns from behavioural data are likely to be performed more efficiently by machines, and human proficiency would be required in tasks of grey areas where judgments need to be made without much analyses of available information or in cases where there is not enough information to derive a pattern. In fact, many studies suggest that precision of machines if matched with human judgments would produce optimal results.

3. Productivity and Employment

John Maynard Keynes in his famous article 'Economic Possibilities for our Grandchildren' (1930) predicted that the society would be afflicted by a new disease of 'technological unemployment' emerging out of rapid technological progress (Keynes, 1932). A similar fear was expressed by David Ricardo in the chapter on 'Machinery,' written in the context of a national debate on the machinery question in the wake of industrial revolution in Britain in the nineteenth century (Ricardo, 1817). It was argued that labour saving technology is going to reduce the demand for undifferentiated labour and eventually reduce wages. In fact, the Luddites held the same view that the machines are taking away jobs from humans. Two decades after Keynes, Leontief (1952) was explicit in predicting that the way technologies in the beginning of twentieth century replaced horses, the demand for human labour is going to reduce because of the use of new technology and hardly there are chances of absorbing the released labour force. But these predictions fortunately did not come true. Humans did not become redundant like horses because they are amenable to multiple tasks and human labour is much more creative and adaptable to new tasks that emerged out of new technology use. More importantly, the replacement effect and consequent unemployment during the industrial revolution did not turn out to be as huge as predicted by Ricardo and Luddites, and similarly the unemployment caused by mechanisation of agriculture in Asia in the 1970s was also much lower than predicted (Mokyr, 1997).

Studies on automation almost definitively suggest that technology use in a particular sector reduces employment, cause decline in wages as well as decline in the share of wages in value added. It is quite obvious because as the relative supply of labour increases in the specific sector, it would result in downward pressure in wages. But notable is the fact that the share of wages in value added remained more or less stable in the past two centuries despite technological progress. This indicates to the fact that wage share continued to remain same in the aggregate not because productivity increased uniformly in all sectors because of new technology but because of creation of new jobs in non-automated sectors that favoured human labour use. In other words, as Acemoglu and Restrepo (2019a) argue, new technology not only causes 'displacement effect,' but also 'reinstatement effect' and the net effect is the result of these two as well as what they call 'composition effect.' If the growth of the complementary sector is labour using in nature, then the growth of the economy would cause a change in the composition of labour force in favour of more labour use.

The use of new technology entails productivity growth and that had been the purpose of technological progress in the course of human civilisation. General equilibrium models would therefore suggest that higher productivity in different sectors reduce cost of production, hence prices fall and real income of consumers would rise as a result, which in turn gives rise to increased demand for goods and services and thus generate employment. However, this has not been the case whatsoever clear cut this stylised argument may appear to be. And precisely because the net effect on employment due to the rise in productivity depends on several factors, of which the two important dimensions are quantum of productivity growth and diffusion of technology across sectors particularly mediated through the rise in real wages. It is also important to note that despite the fact that the aggregate effects on employment in different industrial revolutions had been moderate, in particular sectors there had been gross displacement. In fact, pains were actually non-negotiable at the micro levels. Productivity gains are higher if the use of technology is focussed on sectors that employ skilled labour, where there is scarcity of labour and the wages are relatively high. On the contrary, if technologies are meant for sectors that employ unskilled labour that are abundantly available, productivity gains would be less (Acemoglu and Restrepo, 2019a).

Also notable is the fact that technologies may replace humans but if productivity gains turn out to be marginal then these technologies would contribute to negative net effect on employment. In case of goods and services that show low income elasticity such as food, clothing, or basic goods, the fall in prices caused by rise in productivity may not lead to higher demand. As productivity increases, per unit of output involves less labour. Hence, the demand for labour increases as a result of rise in productivity only when the demand for goods rises by a larger proportion to the declining price as a response. This happens in cases of goods and services showing higher income elasticities such as health services, the consumption share of which increases with the rise in real incomes. Besides income elasticity, price elasticity also matters in determining the impact of productivity on employment. As prices fall and commodity reaches a wider span of satiation, i.e. unmet demand is relatively less, then higher productivity is not likely to generate higher employment. Therefore, segments where unmet demand is high, if prices fall, the demand increases much higher compared to the fall in prices. However, if the vast segment of the population possesses a very low income, the advantages of rising productivity together with higher price elasticity due to unmet demand do not materialise and hence productivity increases, ultimately cause a decline in employment (Roy, 2020).

The consumption basket also changes over time. Productivity increase and consequent fall in prices result in higher discretionary incomes and consumers do not stick to the goods and services that constituted their consumption basket in the past. For instance, to achieve a level of consumption of 1915 in 2015, an average American needs to work seventeen weeks in a year; however, as consumption basket expands, productivity rise may not cause a shrinkage in demand for labour in the long run (Autor, 2015). Solow (1987) pointed to the surprising fact that rapid technological progress in industrialised countries has been accompanied with disappointingly slow growth in measured productivity. A number of sectors that introduced computers and IT enabled machines did not show any increase in residual measure of total factor productivity indexes (David, 1990). One explanation is that any new technology use may generate gains that are not always captured in quantities.. David (1990) discusses a similar slowdown in productivity growth during the period 1890–1913 in Britain and the US even after the invention of electric dynamo during the industrial revolution. It took about a few decades for the diffusion of electricity use in the factories replacing water and steam power. It was only when older technologies faced obsolescence and macro policies favoured fixed capital formation in the 1920s did electric dynamo emerge as a general purpose technology which enhanced productivity across sectors. Therefore, the slow growth of productivity despite the advent of Industry 4.0 indicates that for AI or IOT to emerge as general purpose technology it may require a few more decades in making visible changes in productivity across the economy. Hence, the pace of diffusion of technology and the distribution of productivity gains are important aspects of realising growth out of new technology use.

The worrying fact, however, is the rising inequality within countries and polarisation in the job market in terms of skills and adaptability to new technology. True that inequality between countries has shown a declining trend due to high growth in countries such as China, India, Indonesia, and Vietnam while advanced capitalist countries are experiencing a protracted slowdown, but developing countries are also showing high inequality within their economy, particularly India and China (UNCTAD, 2021). One of the reasons could be the fast pace of development of frontier technologies. Developing countries earlier adhered to a trajectory of transferring people from agriculture to light manufacturing and then gradually moving to high value adding manufacturing and services. With the advent of new technology and with the rising use of robots, AI and IOT that essentially replace a large segment of low and medium skilled workers in different sectors, the conventional transition process of developing countries becomes difficult. It demands faster adjustment in learning process of labour force as most of these jobs are knowledge intensive and require certain skills that cannot be easily acquired. New technology revolutions always pose a challenge of adjustment, both in terms of capital use and workforce. In case of investment that takes a particular shape of machine or infrastructure, it becomes obsolete with the increasing use of new machines embedded with new technology. Rent on new technology increases over time and prices of old machines decline due to obsolescence. Eventually capital shifts from the old to the new compensate the losses from old machines by increasing investment on new technology (Mokyr, 1997). The problem arises when due to slow growth of complementary jobs, or because of delayed adjustment in skills, the displacement caused by new technology is not being adequately compensated, leading to a net contraction of employment.

Mokyr (1997) argues that technology can never be *pareto* superior as it cannot bring good to all; rather, there would always be losers and gainers. More so because market votes for those who can buy and hence favours gainers while the losers have to seek other means to raise their voice. This is precisely the reason why innovation and technology diffusion has never been smooth and without any contestation. In fact, every complex system that undergoes evolutionary processes does face inertia from the past and conservatism can be the result of rational choice when people apprehend losses from introduction of new technology. Mokyr (1997) argues that like all evolutionary biological systems there has to be a balance between tendencies of the past and that of the future, otherwise conservatives would lead to a stasis and too much receptibility leads to chaos. History of previous technological revolutions suggest that technologies do not grow in isolation, instead there have to be appropriate institutions in place that create a regulatory regime that tries to balance and diffuse conflicting interests. Technologies work in systems with the development of interrelated components, appropriate mechanism of facilitating skill acquisition, political processes and institutional modes of balancing contesting rational choices, and also mending inequality by transferring a share of gains to losers that hardly happens. A cultural milieu that is intransigent to any sort of change creates roadblocks in accepting new technology. In fact, the question of access to new technology and the distribution of gains need more attention as the space of the choice of technology through national policies has drastically shrunk in a globalised world.

4. Market and Diffusion of New Technology

Diffusion of technology in capitalism embarks upon a spontaneous process driven by competition that reduces the gap between frontier technology and the average technology prevailing in the industry at a particular point in time. New technology allows reducing costs below the prevailing average costs in the industry. Firms introducing new technology will be able to garner a premium over and above an average profit realised as technology rent. Over time, as more and more firms adopt the same technology to earn higher profits, gradually the new technology becomes predominant in the industry; however, the average cost in that process declines, thereby transferring producer's gain to consumer's surplus. But, garnering technology rent requires establishing property rights on new technology so that it can prevent competitors from free access to the new technology. Scarcities created by assigning property rights through various modes of protecting intellectual property is *sine qua non* for articulating diffusion through market.

Diffusion of technology through market presupposes codification of knowledge, i.e. knowledge being separated from the creator and reduced to conveyable messages. The codification process involves acceptable models of generality and language within a community such that knowledge can be exchanged as an economic good. Such a process significantly changes the storage and use of knowledge. Its storage is no longer limited to the capacity of human memory; rather, externalised codified knowledge can be stored in various devices, books, and artefacts that can be accessed multiple times and also simultaneously be used by multiple users. It can be easily retrieved independent of its creator and can be reused. Codification enables commodification of knowledge by making knowledge transferable but all forms of knowledge are not codifiable.[1] There is knowledge that is non-codified at a particular time but is tractable and intelligible and can be interpreted through impersonal codes at a later time. But there is knowledge that is not at all codifiable. The whole gamut of knowledge that is being used in productive activities and also otherwise is a mix of these three categories of knowledge and their dynamics determine the private appropriability of knowledge. Hence, knowledge that involves intuitive capacity and sensory judgments flowing from subconscious motor skills is not amenable to codification and therefore cannot be exchanged. This part of knowledge is considered infra-marginal or tacit knowledge that cannot be tractable through codes or represented through language. They are extremely relevant in solving problems by practitioners through trial and error and may not flow from a generalised understanding or a theory of the process so to say. Hence converting knowledge into an exchangeable economic good largely depends on the evolving nature of knowledge through innovation and inventions. Inventions are more about individual genius of breaking constraints of understanding things and processes and augments the aggregate set of knowledge, pushing the frontiers farther. Innovation depends on social milieu, structures of competition, institutions, and market. The complementarity between invention and innovation and of reducing the gap between average knowledge and the frontier defines the interface of science, technology, and its economics.

Arrow (1962) addresses the issue of allocation of resources for invention or knowledge creation. Here knowledge is theorised as an addition to information and assumes public good characteristics namely non-rival or non-exclusive. Non-rival property implies that the expansion of production or use of such goods does not reduce the utility of those goods. Non-exclusion criteria suggest that it is very difficult to exclude someone from using a public good. Because of these properties public goods often have high positive externalities; as a result, it is very difficult to appropriate all the benefits of creation by the innovator. In this context Arrow (1962) argues that there would actually be very little incentive for private agents to invest in knowledge creation, and markets would only end up to suboptimal results. Assuming knowledge to be a public good and also adhering to a solitary perspective of knowledge creation and its private appropriation being the sole incentive for knowledge production is highly contested (Dosi, 1988; and Pavitt, 1984). Cohendet and Meyer-Krahmer (2001) argue that knowledge is not only information, it is both input and output. This is even more true in the case of today’s technology when

[1] For a detailed discussion see Polanyi (1958), and Witt, Broekel and Brenner (2012).

knowledge creation is heavily reliant on feedback loops and iterations through engagement with users. Codification does not necessarily ensure diffusion as codes need to be absorbed by its users and both creation and understanding of codes demand identifying generalities and specifying languages that are acceptable and readable to communities of practitioners. Hence, knowledge production and diffusion increasingly invoke a process of collective construction where there are two way flows between producers and consumers of knowledge. Perspectives essentially looking at knowledge as solitary creation of innovators and driven by the sole objective of deriving monopoly rents through private appropriation cannot help much in explaining the dynamics of emerging technology. In fact, the complex process of codification also alters the share of non-codified and tacit part of knowledge; hence, the dynamics of incentives relating to knowledge creation is much more complex than just ensuring returns through ascertaining property rights to creators. Different forms of knowledge cannot simply be categorised as pure public goods or as something amenable to private appropriation; rather, a wide range of knowledge inputs fall in the range between the two extremes (Romer, 1993). The incentives can be the willingness of the firm to be at the technology frontier, or build reputation, networks, and competencies, and may not be singularly determined by cost-benefit analyses in the marginal sense. Economists hardly tend to explain technology production as it is considered to be like a black box and the exercise is essentially focused on finding equilibrium with the given set of conditions. But creation of technology as Mokyr (1990) argues is an act of breaking the constraints; it is essentially disruptive and hardly amenable to equilibrium analysis.

In many cases, the marginal cost of sharing information is zero, which facilitates a burgeoning pool of knowledge that is freely available on the internet and equally accessible by all. In fact, huge data and information flow is naturally generated through various modes of human interaction. Such free flow has to be restricted in the form of propertied capital and then only market is able to generate signals sensitive to profit motive. Hence, diffusing technology gains through markets presuppose proprietary rights on the entire process of knowledge creation, its networks, and feedback loops. This requires huge concentration of market power and control for which the global tech giants are competing with each other. Market as an institution of distribution, a mechanism of impersonal choice that responds to profit motive and functions in a milieu of scarcity has not proved itself to be an adequately appropriate mechanism of diffusion for the new technologies. In the context of use of AI, Acemoglu and Restrepo (2019b) argue that markets do not allocate resources for the right kind of AI, often favour immediate profit motives, and cannot capture externalities. Markets often create inertia that makes changing from one technical paradigm to a superior one difficult. In fact, pulling back to alternative choices is discouraged by market (Acemoglu and Restrepo, 2019b). It is also important that once immediate profitability and particularly maximising shareholder returns becomes the overriding concern for the corporates, expenditure on R&D for long term developments recede back in priority. In most countries, governments are more on a privatisation spree and making expenditure cuts in view of fiscal prudence that essentially chokes funds for long-term research for innovation and excludes many from the learning process necessary to acquire fast changing skills.

Diffusion of technology happens through converting productivity increase into rise in real income and hence discretionary incomes that creates demand for existing and new commodities. In other words, in an economy of exchange, factors contributing to production receive returns which create demand for the goods and services produced. The rationale of the fundamental circular flow of income essentially suggests that if direct human labour is increasingly becoming redundant in the process of production, meaning the net effect turns out to be negative, it would not receive any factor incomes and will not possess any purchasing power to buy goods and services produced. In fact, employment is the only mode of transaction that converts productivity gains into real income. Therefore, the more the technology makes direct labour redundant in the process of production, the more important it becomes what could be the rationale and mechanism of distribution of income since unemployed people have no claim on the output produced in the economy. And this question begs a fundamental change in the process of distribution where income becomes increasingly delinked from contribution in productive activity. The proposals on universal basic income or negative income tax where the government is supposed to pass on purchasing power to households independent of work done is an attempt to address this question. It appears that the new technology and its progress demands a more collaborative structure of production that would release the potentials of knowledge sharing rather than restricting critical inputs in the hands of a few tech giants. At the same time, distributing gains of new technology favours a societal culture of reciprocity based on cooperation and empathy rather than excluding those who are superfluous in the changed structure of production.

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