Economics and Politics in the Robotic Age

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The Future of Human Society

By

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To my parents, Ma Yao and Li Pei-Lan, with gratitude.

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PREFACE

The rapid development of artificial intelligence (AI) and robotics is one of the most critical phenomena in the twenty-first century. For the pessimists, this will cause mass technological unemployment, and even humanity's future survival might be at stake if AI and robots are allowed to become more intelligent than humans. For the optimists, these new technologies will create more jobs than those they will destroy; as human history has repeatedly demonstrated, there is no need for scaremongering. Economists, AI researchers, business scholars, and popular science writers of both pessimist and optimist colors have published numerous books on the impacts of future AI and robots. Despite their opposing views on the impact of AI and robots on human employment, their policy recommendations are shockingly or understandably similar, that is, to improve education and re-training. The pessimists are particularly worried about the prospect that human workers have no jobs to do. Hence, their more detailed prescriptions usually contain how to let workers have jobs to avoid the three evils of boredom, vice, and poverty.

The plan to write a systemic analysis of human society's future direction arose from my experience of using robots in drug discovery and my view of human consumption from a physiological perspective. While measuring neuropeptides with radioimmunoassay during my Ph.D. in Neurophysiology/Neuroscience study, although radioactivity counters were automatic, manually handling test tubes and reactions allowed me to work with only one or two neuropeptides in dozens of test tubes. I could screen hundreds or even thousands of compounds a day with robots doing experiments. Looking back at the production history of humanity, we can find that it is a history of continually reducing human efforts or input in each output unit. Therefore, AI and robots taking over all human jobs should be the fulfillment of a dream long held by humanity. It should be celebrated rather than feared.

Viewed as such, the history of production began with the Manual Age, in which human muscles were the main power source, while tools were invented to enhance the efficiency of human muscle power. According to the materials used to make the tools, the early days of humanity were divided into the Stone Age, Bronze Age, and Iron Age. Labor productivity

increased more and more with better tools so that farmers could feed themselves and artisans, teachers, thinkers, administrators, and rulers. The further improvement of manual tools and a better understanding of natural forces brought humanity to the Machine Age with the Industrial Revolution. During the Machine Age, human physical strength is no longer essential in production as non-biological power sources drive machines. However, human workers still control production processes by contributing the intelligence needed by the production process. The further reduction of human input naturally is to replace human intelligence required for the production process with machine intelligence, which is the task of robots and AI. Intelligent machines will take control of most production processes in the coming Robotic Age. If robots and AI take all human jobs in production, the human input in each output unit will reduce to zero.

Orthodox economics thinks that humans desire infinite consumption with the axiom of non-satiation. As any medically qualified professional can testify, unlimited consumption is impossible because human physiology does not allow us to do so. As a neuroscientist, I understand that people consume materials to satisfy their senses and minds, which are constrained by their physiological capacity. Therefore, the quantity consumed sensibly by an individual is finite, which implies that everyone's non-vanity demands can be satisfied when productivity reaches a certain level. Inequality in outcomes has been the most significant driver of efficiency and productivity. However, civilization can promote equality at the expense of efficiency when AI and robots have dramatically increased productivity. There is no need to worry about what workers will do in the Robotic Age. Everyone could live like intellectuals on government stipends in ancient China or nobilities in feudal Europe with a much higher standard of living.

The prime objective of this book is to examine from a broad perspective how the economy will operate in the robotic age. As a fundamental economic change will inevitably affect politics, this book touches on political operations in the Robotic Age. The word robot used in this book means robots with artificial intelligence. It can also indicate AI systems (software) that do not have a physical existence, although I tend to refer to robots and AI systems in this book. While intelligent robots perform physical jobs, the AI systems that replace professionals for non-physical tasks can be viewed as virtual robots. The Robotic Age is an age of physical and virtual robots performing productive roles. Humans are still masters in the Robotic Age, just like they are masters in the Machine Age.

To understand how the economy will operate in the Robotic Age, it is helpful first to trace the production evolution in human history and try to find clues from the development in the Manual Age and the Machine Age as well as the progress in the current germination stage of the Robotic Age. Examining historical and present evidence forms the first part of this book. Chapter 1 examines the Manual Age, Chapter 2 the Machine Age, and Chapter 3 the development of automation, information and communications technology (ICT), AI, and robots. I call the present time the dawn of the Robotic Age.

Part 2 investigates the economy in the Robotic Age, which will focus on consumption and production. The widespread application of robots will fundamentally change the production process and consequently affect consumption as well as utilization of resources. Chapter 4 provides a framework for consumption theory, which includes the physiological, time, and space constraints for consumer choice in addition to the monetary budget constraint. Chapter 5 examines how the economy operates in the Robotic Age. Chapter 6 looks into how resources, especially human resources, are utilized.

Part 3 examines wealth distribution and political operations in the Robotic Age and discusses how individuals, firms, governments, and the international community should prepare for the coming Robotic Age. Chapter 7 focuses on income and wealth distribution. Chapter 8 investigates social organization in the Robotic Age, looking at how individuals, local communities, governments, organizations, countries, and international communities behave differently from in the Machine Age. Chapter 9 discusses how individuals, universities, firms, professional organizations, and governments should prepare for the Robotic Age.

I hope this more detailed and broader-based approach can shed more light on the future of human society, which is currently at the dawn of the Robotic Age. I also hope readers will find this book helpful in understanding the impact of AI and robotics on the economy and society. I want to thank my family, friends, and colleagues for their support and help.

Qing-Ping Ma

PART I

A BRIEF HISTORY OF PRODUCTION REVOLUTIONS

CHAPTER 1

THE MANUAL AGE: FROM THE EMERGENCE OF HOMININS TO THE BRITISH AGRICULTURAL REVOLUTION

To understand the future of human society, a useful starting point is to look back at how humanity has arrived at where we are now. The primate ancestor of modern humans (*Homo sapiens*) can be traced to the primitive catarrhines, the common ancestors of old-world monkeys and apes. From catarrhines arose the hominoids (apes, members of the superfamily Hominoidea) over 20 to 23 million years ago (Kumar and Hedges 1998; Hedges and Kumar 2003; Pilbeam and Young 2004). Around 16.8 million years ago, the lesser apes, such as the gibbons, separated from the great apes (orangutans, gorillas, chimpanzees, and humans, members of the family Hominidae) (Carbone et al. 2014). The hominines (gorillas, chimpanzees, and humans, members of the subfamily Homininae) parted with orangutans around 12 to 14 million years ago.

The gorillas diverged from the hominins (the chimpanzees and humans, members of the tribe Hominini) around eight million years ago, and the chimpanzees split off from the hominians (humans) and *Australopithecus* around 6.3 million years ago (Hill and Ward 1988; Pilbeam and Young 2004; Cote 2004; Fuss et al. 2017; Böhme et al. 2017). The hominians, the modern humans, and their close relatives are members of the subtribe Hominina. The *Australopithecus* evolved in eastern Africa around four million years ago. The genus *Homo* was thought to be derived from *Australopithecus* about three million years ago, and its earliest known member, *Homo habilis,* appeared 2.8 million years ago (DiMaggio et al. 2015; Villmoare et al. 2015). Human society or, more appropriately, human communities emerged with the genus Homo. In this chapter, we will examine socio-economic development in the long period from the emergence of humanity to the Industrial Revolution, which we call the Manual Age because production depended mainly on people's manual power.

1. Basic Economic Entity and Periodization of Economic History

An individual ancestry primate such as a catarrhine has already demonstrated some essential elements of an entity in a modern economy. A monkey is both a producer and a consumer. Its four limbs provide tools for production and mobility; its nervous system provides the process control, communication, and motivation; its muscles are the power source for the production process; its digestive and circulatory systems transport the materials and energy to where they are needed; its skin and fur provide some essential protection against adverse factors in the environment (Fig.1). The consumption (eating) happens almost simultaneously with the production (picking up fruits and other foods). They also play to have fun, want companions and might enjoy congenial environments that comfort their senses. These activities and conditions bring them satisfaction or utility similar to humans. The later economic progress of human society is just externalizations, expansions, divisions, scale-ups, specializations, separations, and alienations of these processes, as well as additions and scale-ups of raw materials and products.

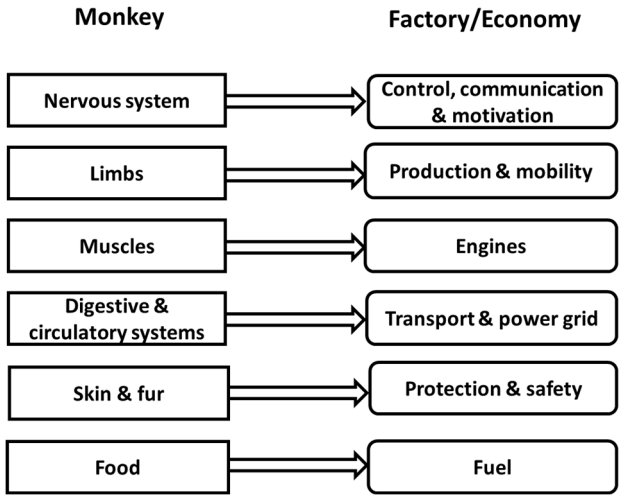

Fig.1 An economy as the externalization of a monkey's "production" mechanism.

Externalization is the partial or whole replacement of an internal or proximal process by an external or distant process. For example, compared with a monkey's hand-to-mouth production-consumption mode, the goods

we consume are generally produced far away without our participation. Expansion is an increase in the range or variety. The division is to split a process into subsegments that can be performed by different people or at other times. Scale-up is to conduct the same process on a large scale. Specialization narrows what a person has to do in a complex process down to a specific task. Separation transfers some rights from their owners to somebody else. Alienation is the disconnection of products and processes from their creators, which enables them to acquire a life of their own. We will find numerous incidents of these activities when we examine the history of humanity.

The first sign of progress was using and making tools as extensions of human hands and limbs. When primitive humans began to make stone tools, they entered the Stone Age. The development of civilization is usually divided into three stages according to the materials used to make tools: The Stone Age (2.6 million to 6,500–4,000 years before present, BP), the Bronze Age (3300 BCE to 1200 BCE in the Near East), and the Iron Age (starting at around 1200 BCE), with some transitional periods between two adjacent ages. Bronze and iron enabled humanity to make better tools and massively increased labor productivity compared with the Stone Age.

The Stone Age can be further divided into the Paleolithic Age, the Mesolithic Age, and the Neolithic Age. The Paleolithic Age was pre-agricultural. The beginning of agriculture coincided with that of the Neolithic Age. Agriculture provided the foundation for more complex social structures than hunter-gatherer communities. The Mesolithic Age was the transition period between the Paleolithic and Neolithic Ages (Bellwood 2004; Ammerman and Cavalli-Sforza 1971). The technological progress in the Stone Age was extremely slow, and the same technology was often invented at multiple sites because of the lack of effective communication and transportation means. We will look into these periods in the following sections.

Although iron and steel continue to be the primary material for making tools up to modern times, the Iron Age was thought to end with the beginning of recorded history because the three-age division is used to describe the prehistory and history of humanity. Since the production process was largely dependent on human physical strength until the First Industrial Revolution in the eighteenth century, the long period from the emergence of humankind to the Industrial Revolution was a Manual Age. The Industrial Revolution brought humanity to the current Machine Age, where production no longer depends on human manual power.

After the replacement of human manual power by machines, the next epoch will be the Robotic Age, in which intelligent robots replace both human manual and mental abilities. The digital revolution or information revolution that began during the period between 1950 and 1970 is a transitional period between the Machine Age and the coming Robotic Age. In the Robotic Age, human mental power is substituted by artificial intelligence (AI) in the production process, so labor will no longer be a critical factor for economic growth. We propose that economic history be periodized according to how human contributions to the production process are supplemented and substituted by tools and machines (Table 1). We divide economic development into the Manual, Machine, and Robotic Ages.

Table 1 Periodization of Economic History

	Period	Subperiod	Time
Manual Age	Paleolithic Age	Lower Paleolithic	2.6 -0.3 MY BP
		Middle Paleolithic	300-50 KY BP
		Upper Paleolithic	50,000-12,000 BP
	Mesolithic Age		
	Neolithic Age		10,200-3,300 BCE
	Chalcolithic Age	Copper Age	4,500-3,200 BCE
	Bronze Age	Early Bronze Age	3,300-2,100 BCE
		Middle Bronze Age	2,100-1,550 BCE
		Late Bronze Age	1,550-1,200 BCE
	Iron Age		1,200-550 BCE*
	Classical Antiquity	Archaic Period	8th–6th centuries BCE
		Classical Greece to Roman Empire	5th century BCE–5th century CE
		Late Antiquity	250–750 CE
	Post-classical Era	Middle Ages	500–1500 CE
	Modern Era	Early Modern Period	1500–1800 CE
Machine Age		Late Modern Period	1800–1945 CE
	Contemporary History		1945–Present
Robotic Age			

* In the Neareast. BP: before present. KY: thousand years. MY: million years.

2. The Hunter-Gatherers in the Paleolithic Age

The typical Paleolithic society was a hunter-gatherer economy (Stavrianos 1991). The oldest stone tools found before 2015 were those from the excavation sites in Gona, Ethiopia, which could be firmly dated to 2.6 million years ago. The Paleolithic Age is considered to have started 2.6 million years ago. It could be further divided into Lower (2.6 million–300,000 BP), Middle (300,000–50,000 BP), and Upper (50,000–10,000 BP) Paleolithic ages. Recently, more primitive stone tools dated over 3.3 million years ago have been excavated in the Lomekwi 3 site in Kenya (Harmand et al. 2015), and they are called Pre-Mode 1 tools. These stone tools are thought to have been produced by Australopithecus.

2.1. The Lower Paleolithic Age

In the Lower Paleolithic Age, the most basic human need was the physiological need for food and water to survive. The primitive Mode I and II stone tools were produced and used in this period. Early humans were omnivorous, so the early stone tools, such as choppers, scrapers, and pounders, represented a new category of products that met human needs for acquiring and processing foods more efficiently and extending the function of their hands. They used natural caves as a shelter against adverse environmental conditions.

2.1.1. Oldowan Stone Tools

The Mode I tools were characterized by their simple construction (Stavrianos 1991; Klein 2009). They came from the earliest Paleolithic stone tool-making technology, the Oldowan industry, named after its type site found in Olduvai Gorge, Tanzania. The Oldowan industry was a percussion technology that predominantly used core forms. It used river pebbles or similar rocks to produce cores and struck them with a spherical hammerstone to cause conchoidal fractures to remove flakes from one surface. The removal of flakes created an edge and often a sharp tip at the distal end of the core, and the proximal end remained blunt. The hominin grasped the blunt proximal surface, bringing the distal surface down hard on an object they wished to detach or shatter. The flakes could be used as light-duty tools. Oldowan tools included choppers, scrapers, pounders, burins (with points for engraving), and awls (with points for boring). Fig. 1-2 illustrates an Oldowan chopper. These stone tools could help users prepare food for better consumption or make tools from other materials.

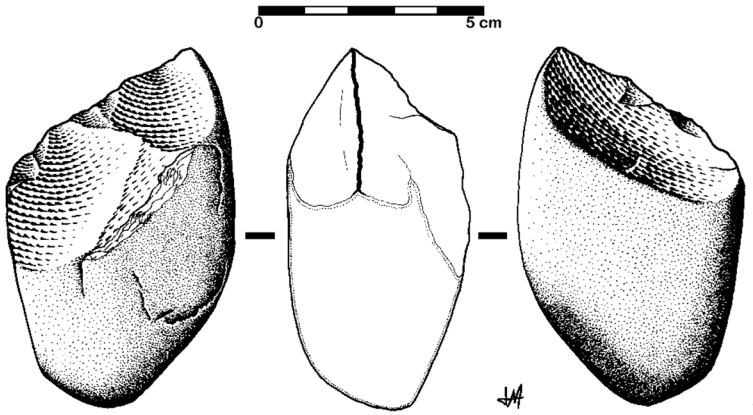

Fig.1-2 A typical Oldowan simple chopping tool from the Duero Valley, Valladolid, Spain (by José-Manuel Benito Álvarez, CC-BY SA2.5, https://commons.wikimedia.org/w/index.php?curid=548566). The three images are views from three different directions.

The Oldowan industry flourished with early species of *Homo,* such as *Homo habilis* and *Homo ergaster,* in southern and eastern Africa between 2.6 and 1.7 million years ago. It could have been invented by the species *Australopithecus garhi* or *Homo habilis* (De Heinzelin et al. 1999; Toth and Schick 2009). *Homo habilis* was the hominin that used most Oldowan tools in Africa; about 1.9–1.8 million years ago, *Homo erectus* and *Homo ergaster* inherited them (Semaw 2000). *Homo ergaster* (meaning "working man"), living in eastern and southern Africa between 1.9 million and 1.4 million years ago, is also called African *Homo erectus* (Gabunia et al. 2000; Antón 2003; Rightmire, Lordkipanidze, and Vekua 2006). It is often thought to be the same species as *Homo erectus* (meaning "upright man") living in Asia between 1.9 million years ago and 143,000 years ago, such as "Java Man" and "Peking Man" (Antón 2003; Indriati et al. 2011; Swisher III, Curtis, and Lewin 2001).

The Oldowan tools are found across much of Africa, the Middle East, South and East Asia, and Europe. The lithic technology was thought to have spread out of Africa and into Eurasia by traveling bands of *Homo erectus*. The consumption of hunter-gatherers depended totally on the natural endowment of their region, so they needed to migrate from time to time, and their legs were their transport "tools." They reached Riwat in Punjab in northern Pakistan by 1.9 million years ago (Dennell, Rendell, and Hailwood 1988), Caucasus by 1.8 million years ago (Gabunia et al. 2000; Garcia et al. 2010),

Java by 1.8 million years ago (Swisher et al. 1994) and Northern China by 1.66 million years ago (Zhu et al. 2004). Oldowan tools were used at Lézignan-la-Cèbe in southern France 1.57 million years ago (Crochet et al. 2009) and at Monte Poggiolo in Italy 0.85 million years ago (Muttoni et al. 2011). The slow pace for the technology to spread reflected the lack of fast transport and communication tools.

2.1.2. Acheulean Stone Tools

Homo erectus started the more complex Acheulean (Mode II) stone tool industry around 1.8 or 1.65 million years ago in the West Turkana region of Kenya (Roche et al. 2003; Lepre et al. 2011). Acheulean tools, characterized by their bifacial, oval, and pear-shaped "hand axes," are found across Africa, Asia, and Europe. The Acheulean tools of the Madrasian culture in South India included flake tools, microliths (small stone tools), and other chopping tools, besides the characteristic bifacial handaxes and cleavers (Armand 1985; Avari 2016). The oldest tools date to 1.5 million years ago (Pappu et al. 2011). Fig.1-3 illustrates a typical Acheulean handaxe.

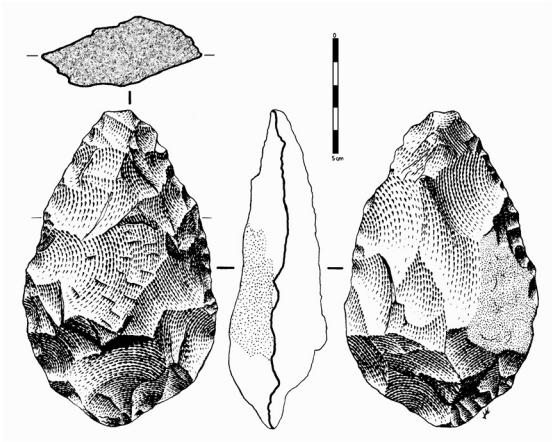

Fig.1-3 A typical Acheulean handaxe from the Duero Valley, Valladolid, Spain (by José-Manuel Benito–own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=548596). The four images are views from four different directions. The small flakes on the edge were from reworking.

Stone tools excavated at the Gongwangling site in Lantian, in the Shaanxi province of China, appear to be Acheulean (Wang, Lu, and Xing 2014). These include cores, flakes, choppers, hand axes, spheroids, and scrapers.

The remnants of Lantian Man, *Homo erectus lantianensis*, found there were dated to 1.63 million years ago (Zhu et al. 2015). Acheulean tools were used in the Bose Basin in Guangxi, China by 800,000 years ago (Xu et al. 2012; Hou et al. 2000). Acheulean flint tools dating around 500,000 years ago were found at the Boxgrove site in West Sussex, UK (Pitts and Roberts 1997). About 250,000 years ago, Acheulean stone tools almost completely replaced Oldowan tools.

2.1.3. Fire

The use of fire was an essential milestone in the history of human technology. A controlled fire could be used for cooking and keeping away large predators. It is generally accepted that the control of fire by *Homo erectus* had begun some 400,000 years ago (James et al. 1989), but a fire might have been used by the Lower Paleolithic hominin *Homo erectus* 1.5 million years ago (McClellan III and Dorn 2015). Burned animal bones found at the Xihoudu site in Yunan and dated to 1.8 million years ago are one of the earliest pieces of evidence of using fire by humans. In Shaanxi, blackened mammal bones and ash from campfires were found at the sites of Yuanmou Man and dated to 1.7 million years ago (James et al. 1989; Qian et al. 1991).

2.2. The Middle Paleolithic Age

The Middle Paleolithic Age saw the emergence of anatomically modern humans, *Homo sapiens*. The fossils of *Homo sapiens* excavated in the Omo Kibish area, Ethiopia, were dated to 200,000 years ago (McDougall, Brown, and Fleagle 2005). The fossils unearthed at the Jebel Irhoud site in Morocco that were thought to be *Homo sapiens* were dated 300,000 years ago (Hublin et al. 2017). New tools, such as the Mousterian tools, replaced the Acheulean tools.

2.2.1. Stone Tools

The Mode III or Mousterian (160,000–30,000 BP) industry, named after Le Moustier in the Dordogne region of France, adopted the Levallois or other prepared-core techniques to produce handaxes, racloirs, points, and other smaller and sharper knife-like tools (Haviland et al. 2012). The new approach allowed the invention of stone-tipped spears by hafting sharp, pointy stone flakes onto wooden shafts. Fig.1-4 shows a typical Mousterian point. These new tools represented a category of new goods, the attacking weapons for hunting. In Europe, the Mousterian industry was developed and

used primarily by the Neanderthals (Semaw et al. 2003). In contrast, in North Africa and the Near East, it was used by anatomically modern humans.

Fig.1-4 A typical Mousterian point from the Darai Rockshelter in the Sirwan Valley of Haweaman, Zagros, Iran (by ICAR, Iran–own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=107930591). The four images are views from four different directions. The small flakes on the edge were from reworking.

In China, Mousterian stone tools have been excavated from the fourth and fifth layers of the Sanlongdong cave site in Chifeng of Inner Mongolia and dated to 50,000 years ago (Shan et al. 2017). Paleoanthropologists also found Mousterian stone tools in the Dahe Paleolithic cave site in Fuyuan of Yunnan, which included choppers, scrapers, carvers, and prepared cores with charcoal, burned animal bones, and burned clay. Its lower layer was dated by the uranium isotope method 40,000 years ago (Ji et al. 2006).

2.2.2. Cooking, Rafts, and Non-Lithic Tools

The use of fire became common in the Middle Paleolithic Age (McClellan III and Dorn 2015; Toth and Schick 2007). The early humans began to cook their food at the latest in the early Middle Paleolithic (250,000 BP). Cooking may have improved their health because cooked foods are more digestible, tastier, and less likely to contain pathogenic bacteria (Wrangham and Conklin-Brittain 2003; Marlowe 2005). Heating may have degraded toxins contained in plants. This early cooking was the origin of the modern catering and food industry. Cooking can be viewed as an extension and externalization of the human digestive system.