Pegem Journal of Education and Instruction, Vol. 16, No. 1, 2026 (pp. 3199-3215)

RESEARCH ARTICLE WWW.PEGEGOG.NET

Demographic Thought Transformations from Malthus to Artificial Intelligence: A Reading in Intellectual Shifts

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Received: 25/10/2025; Accepted: 13/04/2026; Published: 23/06/2026

Abstract:

Demographic thought has undergone profound transformations throughout the ages. Starting with classical theories that warned of the dangers of uncontrolled population growth, it has progressed towards modern concepts that use technology and big data to manage resources and improve quality of life. This article aims to trace these intellectual shifts, paying particular attention to the impact of the digital era and artificial intelligence on contemporary demographic thought.

Keywords: demographic theories, natural demographic theories, social demographic theories, economic demographic theories, artificial intelligence.

Introduction

Throughout history, population issues have been a central focus of intellectual and scientific debate. Perspectives on the relationship between population growth, economic resources and human progress have varied considerably. While Thomas Malthus warned of the dangers of uncontrolled population growth and resource scarcity in the eighteenth century, subsequent theories have challenged his ideas by emphasising the role of technological innovation and social organisation in overcoming the limits imposed by nature. Against this backdrop, the advent of artificial intelligence signifies a further qualitative shift in demographic thinking. Following the Industrial Revolution, AI proposes innovative solutions to demographic challenges by increasing productivity, managing resources more efficiently, improving healthcare services and planning sustainable cities. Consequently, material resources are no longer the sole decisive factor; the ability to use data and algorithms to govern societies efficiently and intelligently has also become significant. However, AI also raises new questions about the future of work, the fair distribution of wealth, and the social and ethical implications of technology for human life.

This study traces the intellectual evolution of approaches to the population question, from the classical Malthusian framework through modern economic and social perspectives to the age of artificial intelligence, which has redefined the concepts of productivity, planning and well-being. How, then, has the understanding of the relationship between population and resources changed? What impact will smart technology have on the future of demographic balance? This study will examine these questions through an analytical reading of these transformations.

A view of the study's key concepts

1.1 Demographic theory

Demographic theory can be defined as a set of interrelated propositions, based on observation and experimentation, that explain and predict demographic phenomena and relationships that can be observed and verified. (Daliah Milhassan Al-Estiatiyah, 2013, p. 128).

According to this definition, demographic or population theories constitute a scientific and intellectual framework that helps us to understand and interpret changes in populations, including factors such as population growth, geographic distribution, age, and social composition. These theories evolve over time to explain historical demographic patterns and anticipate their future effects on society, the economy and the environment. Accordingly, demographic theories play a central role in understanding demographic reality and guiding future policy.

1.2 Natural demographic theory is based on the shared belief that population growth is governed by human nature and the nature of the world in which people live. Human control over this growth, if it exists at all, is limited. This belief sheds light on how scholars of these theories attempted to identify a 'law' of population growth that would enable them to predict past and future occurrences. In most cases, these laws denied any meaningful role for human intervention, human values, or social orientations in population growth, treating it as a natural phenomenon beyond human control. Notable figures in this category include Thomas Malthus, Sadler, Davelday (Dublidai), Spencer, Quard and Gini. (Ali Abdel Razzaq, 2012, p. 91).

The natural theory of population growth is based on a deterministic view that attributes demographic changes to biological and environmental factors beyond human control. Proponents of this theory, such as Malthus, Sadler and Spencer, believed that population growth was governed by a fixed natural law, similar to the laws of physics. They therefore denied the role of human will or social values in altering its trajectory. Consequently, they predicted the inevitability of crises such as famines and diseases as 'natural' mechanisms for achieving demographic balance. However, this theory has been subjected to significant criticism, particularly for overlooking cultural factors, technological progress and social policies — elements that have proven capable of changing demographic patterns. The theory also failed to explain differences between societies or account for major transformations such as the Industrial Revolution and the demographic transition. Consequently, this theory provides a limited perspective from which to understand the true complexity of contemporary demographic dynamics.

1.3 Social demographic theory

Social demographic theory holds that population growth does not result from a fixed natural law, but rather from the social conditions surrounding members of society. These conditions include a variety of factors whose scope and nature vary according to the social structures present in society. Notable scholars associated with this type of demographic theory include Arsène Demont, Carson Darers (Carson–D...), Me..., and others.

Social theories in demography aim to provide a framework through which to understand how individuals and societies interact with demographic challenges and how these interactions affect

sustainable development and social well-being. Studying these theories provides important insights into achieving a balance between population growth and available resources and promoting social and economic justice amid the rapid demographic transformations currently taking place worldwide.

1.4 Economic Demographic Theory

Despite the fact that demographic and economic data relating to income, wealth, wages and unemployment, on the one hand, and demographic variables such as fertility, mortality and migration, on the other, were long considered insufficient on their own, they were nevertheless emphasised for extended periods and remained dominant elements in many demographic theories connecting population and the economy, developed by scholars on the eve of the nineteenth century (Firas Abbas Fadhil Al-Bayani, 2011, pp. 57–58). (Firas Abbas Fadhil Al-Bayani, 2011, pp. 57–58).

Economic demographic theories are therefore analytical frameworks that examine the interaction between demographic dynamics, such as growth, migration and age structure, and economic variables, such as productive resources and distribution. They aim to explain how each dimension affects the other and guide development policies. They are important because they can analyse challenges such as poverty and population ageing and propose solutions such as migration policies or pension systems. Furthermore, they facilitate the prediction of resource constraints and opportunities for economic growth in the context of demographic changes, making them a crucial instrument for comprehending the equilibrium between population and resources, and for ensuring economic sustainability.

1.5 Artificial intelligence

The challenges of the current industrial revolution have resulted in a parallel digital revolution spreading rapidly across countries. This has given rise to the digital economy, which has increasingly come to rely on new technological trends such as artificial intelligence, robots, cloud computing, financial technology (fintech), network technology, and the Internet of Things (IoT), including three-dimensional printing applications.

This process opens up broad horizons for continuous development while introducing unprecedented challenges aimed at enhancing human capabilities and technological potential in support of the foundations of sustainable development. The goal is to prepare people to handle, process, store, develop, expand and generalise the use of borderless internet networks in all countries by activating new digital platforms that connect billions of people to perform financial and accounting functions more efficiently and effectively. Recently, this has depended heavily on the intensive employment of developments in artificial intelligence technologies. (Mohamed Ahmed Al-Khouly, 2024, pp. 7–8).

Furthermore, the development of artificial intelligence has given rise to new sociological issues concerning the population. These include changes in the labour market resulting from automation, shifts in employment patterns and the increasing digital divide between social groups. It has also raised questions of justice regarding access to technology. Consequently, attention has shifted towards not only the size and growth rate of the population, but also the quality of human resources, their level of training, and their ability to adapt to the requirements of digital society.

Thus, artificial intelligence reflects a new stage in the development of demographic thought, in which the focus shifts from asking "How many people?" to asking "How can human capacities, knowledge, and technology be utilised to achieve sustainable development?"

2. Classical demographic thought: Malthus and the Warning Against Population Growth

Thomas Robert Malthus (1766–1834):

In his essay An Essay on the Principle of Population, Malthus critiqued Godwin's work on political justice (1793) and Condorcet's account of the development of the human spirit. Alongside these critiques, the essay formed the foundations of Malthus's demographic theory.

Godwin had advanced a set of views that gained wide circulation at the time. The most important of these was the argument that social problems, such as poverty, suffering and disease, stem from the social institutions and systems prevailing in society. These institutions and systems bear responsibility for the hardships experienced by the community. Accordingly, Godwin and Condorcet developed their own set of ideas characterised by optimism about the future progress of science, reason, technological knowledge and population. They believed that humanity would find ways to prevent population growth.

However, in his essay, Malthus responded by stating that human beings themselves, rather than institutions and systems, are the source of evil and problems. He argued that individuals should start by addressing the defects they exhibit in the form of rapid and continuous reproduction, which does not correspond to the amount of subsistence materials and food that can be obtained (Ali Abdel Razzak, 2012, p. 65). (Ali Abdel Razzak, 2012, p. 65).

Malthus's population theory, published in 1798, is based on several principles that define the general theory of population. The most important of these are as follows: (Munir Abdullah Kradsha, 2009, pp. 39–40).

Food is essential for human existence.

Human desire (sexual appetite) is an inevitable necessity for the continuation of humankind.

- The population doubles every generation, or every 25 years, if not restrained by a strong obstacle. This can be seen from the significant growth in England's population, which increased from 5 million in 1700 to 9.3 million in 1801.

The earth's capacity to produce what is required for human survival, especially food, remains limited and is subject to the law of diminishing returns. Based on this, Malthus formulated the relationship between population and resources as follows: there is a direct proportional relationship between population numbers and food resources. However, world population growth generally follows a geometric progression (1, 2, 4, 8, 16, 32), while the growth of food resources follows an arithmetic progression (1, 2, 3, 4, 5).

In this context, Malthus identified two types of 'restraints' that could limit population growth:

First: Moral restraints

Moral restraints depend on human will, as well as on an individual's ability to afford the costs of family life before deciding to marry. If a person's financial situation allows them to get married, they can choose to delay the marriage for a certain period. If they cannot afford to marry, however, they must postpone it until they have sufficient economic resources to support a family. Alternatively, they may delay marriage indefinitely; marry with complete self-control (i.e. within the confines of marriage); practise restraint in sexual relations by neglecting, reducing or refraining from sexual activity entirely; or marry only after losing their ability to reproduce, so as to avoid having children they cannot support. In all cases, Malthus argues that individuals must avoid extravagance and moral corruption. He called on those unable to marry to remain celibate, guided by piety and self-restraint (Hussein Abdel Hamid Rushwan, 2001, p. 62). (Hussein Abdel Hamid Rushwan, 2001, p. 62).

Secondly, there are preventive or coercive (natural) restraints, which are restraints imposed by nature on human beings, such as diseases and epidemics, droughts and famines, and devastating wars. (Hussein Abdel Hamid Rushwan, 2001, p. 62).

Nevertheless, Malthus was subject to much criticism, including the following:

He overlooked developments in production technology that led to advances in food production and increased grain, fruit, vegetable and animal yields.

- He condemned actions associated with birth control and family planning, considering them to be "vices".

He ignored the role of social organisation, ideology and value systems in achieving a balance between population size and food production.

- He failed to explain (or correctly predict) world population growth according to the rates he assumed. In fact, some Western European countries experienced a decline in population numbers, and when the North American plains were exploited for agriculture and wealth increased, the population growth rate remained low (Hussein Abdel Hamid Rushwan, 2001, p. 63). (Hussein Abdel Hamid Rushwan, 2001, p. 63).

Malthus was also criticised by Michel Thomas Sadler in 1830 in his work The Law of Population. Sadler argues that Malthus did not invent this theory, but rather "stole" it from Townsend. Sadler notes that Townsend stated that, in places where conditions favour it, human sexual activity leads to an increase in population and that, if reproduction remains active, population will rise and this increase will be determined by the amount of food available. In Sadler's view, Malthus presented the same argument using almost identical words. However, Malthus added that there were more ways of linking population to food supply, while their nature remained the same.

As Sadler observed, Malthus's use of American population data was essentially the same theoretical approach as Townsend's. Townsend argued that the population of North America doubled every 25 years, and in some states every 15 years. Using the same method, Malthus restated this explanation in the same style. Therefore, Malthus did not adopt Townsend's theory as his own, but rather cited the same arguments as Townsend. (Joudaida Ammira, 2014, p. 73).

Based on the foregoing, we can conclude that Malthus's population theory is pessimistic and is based on two main assumptions: that population growth is geometric (i.e. accelerating) and food resource growth is arithmetic (i.e. limited). This inevitably leads to an imbalance between the two. Malthus attempted to explain this through moral and preventive checks, such as celibacy, delaying marriage, famines and epidemics. Although his theory was based on the reality of eighteenth-century European societies, where resources were scarce and technology was rudimentary, it was criticised for overlooking the role of technological progress, such as the agricultural and industrial revolutions, in increasing productivity. It was also criticised for neglecting social and cultural factors, such as women's education and family planning, that affect fertility. Furthermore, some critics faulted the theory for drawing on ideas proposed by earlier thinkers, such as Townsend, without making an explicit reference. Thus, despite its importance in highlighting the challenges of population growth, the theory failed to anticipate humanity's capacity to adapt through technological innovations and social transformations. This limits its usefulness as a theoretical framework for explaining the complex demographic dynamics of the modern era.

3. The Development of Population Thought in the Twentieth Century: From Malthus to an emphasis on development and family planning. Following Malthus, population thought evolved through several theories.

3.1 Natural demographic theories:

Perhaps the most prominent of these theories are the following:

Sadler argues that people's tendency to increase will naturally decline as overcrowding intensifies. He claims that their numbers will stop growing at the point at which the greatest possible number of people enjoy the greatest possible happiness, provided that all other factors remain equal (Jamal Ismail At-Tahawi, n.d., p. 98). (Jamal Ismail At-Tahawi, n.d., p. 98). However, his theory has also been criticised for not being based on comprehensive knowledge of all the known facts regarding population growth. This is because, although the Chinese, Indians and Egyptians — among the largest populations in the world — are capable of producing many offspring, they simultaneously experience dangerously high population density. Furthermore, Sadler failed to distinguish between reproductive capacity and actual population growth. (Khalil Abd Al-Hadi Al-Badu, 2009, p. 27).

Sadler's theory is based on an optimistic premise that differs fundamentally from Malthusian pessimism. It posits that high population density naturally leads to a decline in fertility rates, thereby achieving demographic balance and ensuring 'the greatest happiness for the greatest number'. However, the theory has clear methodological shortcomings. It assumes the existence of an automatic population regulation mechanism without providing sufficient evidence, and it overlooks the cultural and economic factors that influence fertility. This becomes evident when the theory is applied to countries such as China and India, where high population density did not automatically result in reduced population growth. This reveals a confusion between 'biological capacity to reproduce' and 'actual population growth', the latter of which is governed by complex factors beyond mere population density, such as social traditions, government policies and levels of development.

Dublin Day (Duvlmay/Dubleday) believes that population increase is inversely related to food resources: the better the food supply, the slower population growth will be. (Hussein Abd Al-Hamid Rushwan, 2001, p. 67). Dublin Day's theory was also criticised. It was argued that those with the greatest reproductive capacity are often the most miserable and that the power of reproduction always declines as a result of abundant food. This claim remains controversial and is not supported by solid facts. (Khalil Abd Al-Hadi Al-Badu, 2009, p. 28).

Dublin Day's theory offers a different perspective on the relationship between population and resources. It argues that improvements in the food supply lead to a slowdown in population growth, which is contrary to Malthus's view. However, this theory is inadequate for explaining the complex demographic reality as it has been criticised for presuming an automatic inverse relationship between welfare and fertility without sufficient evidence. The assertion that 'the most miserable are the most prolific' ignores the influence of cultural, educational and political factors on fertility rates. Furthermore, empirical evidence suggests that poorer communities often exhibit higher fertility rates due to the absence of social protection systems and the prevalence of child labour. In contrast, more affluent societies tend to have lower fertility rates as a result of rising childcare costs and increased female participation in the labour force. Consequently, Dublin Day's theory remains an inadequate theoretical framework for understanding the complex interaction between development and demography.

Spencer's ideas are distinguished from those of Sadler and Dublin Day in that they constitute a more fully developed theoretical work. Moreover, he entered the field of population studies after Malthus and based his explanation of population growth and balance in society on social evolutionary factors. If his ideas were to fulfil the image of a deductive system, consisting of a set of propositions, some of which are treated as premises, then this would include his assumptions about the effect of food on reproductive capacity, the conflict between reproduction and self-development/maturity, and his progression towards the general conclusion that the more effort an individual devotes to their own development, the lower their reproductive capacity becomes. Finally, Spencer predicted that the population problem would be resolved in the future. (Ali Abd Al-Razzak, 2012, p. 97).

Spencer's population theory was a significant development in demographic thought. Attempting to explain population growth through social and biological evolution, it posits that there is a conflict between reproduction and individual maturation. It also suggests that increased investment in self-development (intellectually and socially) inevitably leads to a decline in fertility. While this theory is distinguished by its logically coherent structure linking biological and social premises, such as the effect of food on reproduction and the effect of education on fertility respectively, it remains an abstract/deductive framework with limited practical applicability. It overlooks differences in values and social structures between societies, and overgeneralises the inverse relationship between individual development and fertility without accounting for diverse cultural contexts. Nevertheless, Spencer's ideas constitute an important contribution to the shift from deterministic theories, such as the Malthusian perspective, towards more comprehensive theories that connect social development with demographic dynamics.

Coardugini (Gouardojini/Coardojini): Gini (after whom the approach is named) studied the impact of demographic changes on societal and general human development. He likened the stages of population growth to the human life cycle: birth, childhood, adolescence, youth, adulthood and old age, followed by death. He stated that the population of a given country grows rapidly in the first stage, followed by a period of stability and then ultimate decline/extermination. (Mounir Abdullah Kradsha, 2009, p. 46).

Similar to the human life cycle, Coardugini's theory provides a dynamic view of population growth, where societies pass through successive stages of rapid growth, stability and ultimately decline. This reflects a more flexible understanding of demographic transitions than earlier deterministic theories. However, the theory remains largely general in that it cannot specify the time span of each stage or the factors that determine a society's transition from one phase to another. Furthermore, it overlooks the possibility of renewed population growth through migration or socio-economic transformations. While this idea may fit some historical societies that experienced demographic collapse, it fails to explain why many contemporary societies are able to restore demographic balance through targeted policies or technological developments. Consequently, the theory is closer to a descriptive model than a comprehensive explanatory framework.

3.2 Social and Economic Population Theories:

The most important of these are as follows:

Karl Marx (1818–1883):

Marx was a German social thinker. Together with his associate Friedrich Engels, he is renowned for laying the foundations of scientific socialism. Marx did not write a book specifically about population; rather, he addressed the issue through his studies of economic, political and philosophical matters. These "insights" collectively formed a specific and clear concept of population, developed through his interpretation of historical materialism as presented in his work Capital, published in 1928. The most important of these views are:

Marx states that poverty and misery do not arise from a natural human tendency to have many children. Rather, he argues that poverty results from social and economic arrangements that prevent people from finding work and supporting their offspring. This is in contrast to Malthus, who argued that poverty reflects an inability to support a rapidly increasing population.

- Marx agrees with Malthus that poverty and unemployment are economic manifestations associated with population increase. However, Marx's explanation of population increase differs from Malthus's. For Marx, population growth is simply an excess supply of labour relative to available employment opportunities.

According to Marx, population increase is one of the necessities of the capitalist economy and an inherent characteristic of it. This is because the growth of capitalism creates an excess of labour power, which increases the supply of workers and, consequently, lowers wages — wages being a basic condition for the expansion of capitalist industries.

- Marx argues that population growth does not stem from an eternal and immutable natural law, nor from a lack of food resources as Malthus claimed. Instead, he argues that it results from the unequal distribution of resources within the particular economic and social system of private property under capitalism.

Marx emphasises that the demographic 'explosion' was not universal in terms of time or place. Rather, it was capitalism that created the illusion of a growing population. He attributes the decline in average individual income to poverty, rather than to population increase arising from contradictions within the capitalist system. This system is unstable and therefore liable to 'burst' at any moment. (Joudaida Ammira, 2014, pp. 99–100).

Based on these facts, Marx predicts that under a socialist system of production, there will be no surplus population because of full and balanced employment between capital and labour. In other words, balance is achieved between the growth of constant and variable capital, such that no surplus population emerges and poverty and misery diminish.

Marx concludes from his analysis that there is no fixed general law governing population. Instead, each stage of a society's development and mode of production has its own specific population 'law', applicable only to that stage. The only case in which a single population law exists is among plants and animals, provided that human beings do not interfere in their reproduction.

The problem of population growth diminishes as society develops and reaches the stage of socialist production. This means that, insofar as they are linked to population increase, poverty and misery do not stem from a biological factor that raises or lowers human reproductive capacity or any other natural variable. Rather, they arise from the economic system's inability to employ all members of society (Ali Abd Al-Razzak 2012, p. 108). (Ali Abd Al-Razzaq, 2012, p. 108).

Nevertheless, this theory has been criticised.

It has been conclusively proven, both theoretically and empirically, that this theory has failed. Evidence of this can be seen in the fact that most socialist countries still suffer from a demographic 'explosion'. Furthermore, the inaccuracy of this claim is revealed by the fact that these same countries also experience social and economic backwardness alongside their population problems.

While Marx leans towards the view that Malthus and his followers were biased against workers and favoured the ruling class, he too is open to criticism for allegedly being biased in his own way. Critics argue that this bias shaped his research trajectory and affected its results. It also influenced his followers' interpretation of the population problem. (Jamal Ismail At-Tahawi, n.d., pp. 106–107).

Based on the foregoing, we conclude that Karl Marx's population theory differs fundamentally from other theories, such as Malthus'. Marx argues that poverty and unemployment are not natural consequences of population growth, but rather products of the capitalist system. This system creates an excess supply of labour in order to reduce wages and increase profits for the capitalist class. According to Marx, population 'inflation' is a capitalist phenomenon: the use of machinery reduces the need for labour, thereby producing unemployment and a form of relative population surplus. Therefore, Marx argues that solving the problems of poverty and unemployment does not lie in limiting population growth, but in changing the economic system from capitalism to socialism in

order to achieve a balance between capital and labour, eliminate surplus population and reduce poverty. While Marx's theory offered a strong critical perspective on capitalism, it failed to provide practical solutions to the population problem, particularly in light of contemporary economic and social challenges.

Mortality decline

One of the most well-known proponents of this theory is Mi, Smith and Heier, among others. The core idea is that lower mortality rates lead to lower fertility rates. This is because couples become more confident that their children will survive to old age, reducing their need to have more children to ensure they are supported in the future. (Munir Abdallah Kradsha, 2009, p. 54).

The theory provides a dynamic explanation of demographic change by linking reductions in mortality rates (enabled by medical progress and improved living conditions) closely and over time with subsequent declines in fertility rates. The mechanism rests on changes in the economic and social calculations of households, which are no longer compelled to have large families to offset expected child deaths. While the theory provides a compelling framework for understanding the experiences of societies that have undergone demographic transition, it oversimplifies the relationship between the two variables by assuming a direct, mechanical link. It overlooks other influential factors, such as improvements in women's education, the spread of contraception, and changing gender roles. Furthermore, it fails to explain the differences in the speed of societies' responses to falling mortality rates. Therefore, this theory must be integrated with other theoretical approaches to achieve a comprehensive understanding of the mechanisms driving demographic transition.

Social Position Theory (Social Ascendancy) (1849–1902)

(As formulated by Arsen Demon): This theory is based on the idea that an individual's social progress leads to a reduction in fertility. Proponents of this perspective argue that there is an inverse relationship between social mobility and the desire to have children. Specifically, the higher an individual climbs the social ladder, the more they become preoccupied with improving their material and social circumstances, which makes it less likely that they will have a large family. This, in turn, contributes to lower fertility rates in society. (Khalil Abd al-Hadi al-Badu, 2009, p. 32).

Arsen Demon's social position theory provides a coherent explanation of the decline in fertility in terms of upward social mobility. It is assumed that individuals' increased focus on improving their economic and social status, particularly alongside the expansion of educational and employment opportunities, necessarily entails delaying marriage and having fewer children. This creates an inverse relationship between individual advancement and population growth. While the theory provides a plausible explanation for the decline in fertility in societies experiencing the expansion of the middle class, it is insufficient to explain the persistence of high fertility rates in some affluent groups (as observed in certain wealthy traditional societies), or in societies where economic growth is not accompanied by improvements in social justice. In such cases, cultural, religious and political factors intervene to modify this relationship. Furthermore, the theory neglects the impact of government policies, such as population incentives or balanced development programmes, on this equation. This underscores the need to integrate the theory with broader demographic transition

theories to achieve a more comprehensive understanding of how economic and social factors interact in shaping fertility.

Family Composition Theory

This theory was formulated by sociologists W.J. Good and others in 1963. It posits that the extended family, in which decisions about family life were made by a wider network of relatives, gradually declined as a result of industrialisation and urbanisation. These processes create new opportunities for individuals, reducing their reliance on family members and increasing the authority of spouses in decision-making, including matters relating to fertility and childbearing. Consequently, couples are more likely to make independent decisions about the number of children they want and when to have them, as well as other family-related matters. (Munir Abdallah Kradsha, 2009, pp. 61–62).

Family composition theory focuses on changes in family structures and their impact on reproductive decisions amid broader social and economic transformations. It suggests that industrialisation and urbanisation weaken traditional extended family ties, thereby diminishing the influence of relatives on family decisions. This shift leads to greater autonomy for spouses in decisions concerning fertility and childbearing, as they become less dependent on the norms and social pressures previously imposed by the extended family. Accordingly, the decline in fertility rates can be understood as a consequence of changes in power structures within the family, with spouses having greater influence over family size and the timing of childbearing. This reflects a transition towards more individualistic values and greater independence in personal decision-making.

Demographic Transition Theory

Demographic transition theory has not been attributed to a single scholar in particular; rather, it evolved over time through the contributions of multiple researchers across the fields of demography, economics, and sociology. The theory links its successive stages to changes in economic conditions, health, education, and culture. In the first stage, society is predominantly agrarian and characterized by a low standard of living, which results in high rates of both births and deaths. In the second stage, improvements in health and economic conditions lead to declining mortality rates. In the third stage, increases in education and health awareness, alongside shifts in cultural values, cause a reduction in fertility rates. (Jawida Amira, 2014, pp. 136–137).

Demographic transition theory is considered a comprehensive framework for understanding population changes at different stages of development. It systematically links socio-economic development to demographic patterns. In the early stages (traditional societies), high birth and death rates prevail due to reliance on agriculture and the prevalence of disease. In the transitional stage, improvements in healthcare and infrastructure lead to a sharp decline in mortality rates, while birth rates remain high. This produces what is often termed a ‘population explosion’. In the advanced stages, however, a sustained decline in fertility is brought about by the spread of education (especially for females), improvements in women’s status, rising socialisation and childcare costs, and shifts in family-related values. This brings society towards demographic equilibrium. While the theory has been successful in explaining the historical experience of many industrialised countries, it has also been criticised for its limited ability to account for differences among contemporary

societies, such as the continued high fertility rates in some affluent oil-producing countries, and for not sufficiently addressing the influence of cultural and religious factors. Furthermore, the theory does not adequately consider the roles of globalisation and migration in shaping population structures. This highlights the need to further develop the theory to accommodate the complexities of the twenty-first century.

4. The Digital Era and Demographic Thought: Reconfiguring Demographic Thought

Demographic thought is undergoing a radical transformation in the digital age, largely due to the emergence of big data and artificial intelligence (AI). These technologies allow us to collect and analyse large amounts of population-related data, providing a better understanding of demographic trends and improving our ability to anticipate future challenges. Among the leading figures in this era are:

Alex "Sandy" Pentland

Alex "Sandy" Pentland is an American computer scientist and professor at the Massachusetts Institute of Technology (MIT). He is widely recognised as a pioneer in the field of social physics, a research area that makes significant contributions to domains such as big data analytics, artificial intelligence, machine learning and human–computer interaction (Pentland, 2014). His main achievements and ideas can be summarised as follows:

1. Co-founding social physics: Pentland is considered one of the founders of social physics, a field that seeks to understand collective human behaviour by analysing data derived from diverse sources such as mobile phones, social media and sensing devices. This analytical approach helps to reveal patterns and trends in human behaviour and supports the identification of demographic dynamics.

2. Leadership in the MIT Media Lab: Pentland played a key role in the development of the MIT Media Lab, establishing and leading multiple research groups focused on technological innovation and its implications for society.

3. Advancing methods for big data analysis: Pentland developed a variety of methods and tools for analysing large-scale datasets, thereby improving our understanding of human behaviour and decision-making in areas such as health, finance, and urban planning.

4. Contributions to AI and Machine Learning: He has made substantial contributions to artificial intelligence and machine learning, particularly in developing systems capable of interpreting human behaviour and interacting with people in more natural ways.

5. Applying technology to improve urban life: Pentland emphasises the use of technology to enhance everyday life in cities through the development of smart systems for traffic management, energy optimisation and improving public services.

Using AI to forecast future demographic trends, such as population growth, migration and ageing, can help governments and organisations plan for the future. These forecasts can help governments and organisations to plan for the future and make well-informed decisions.

Pentland uses AI to understand complex social dynamics, including the spread of diseases, opinion formation and the effects of government policies on populations (as indicated in the MIT Media Lab's overview of his work).

- The "Sensible/Connected City" project (Senseable City Lab) focuses on using data collected from sensors and mobile devices to understand how people move and interact within cities. This data is then used to improve urban planning and support the design of 'smart cities'.

- Research on disease transmission: Pentland has used AI techniques to analyse mobile phone data and understand how infectious diseases spread across communities. This line of research can contribute to the development of more effective disease control strategies (Pentland et al., 2015).

Ultimately, it could be argued that Alex 'Sandy' Pentland's work successfully combines demography and artificial intelligence. He uses AI techniques to analyse population-related data, understand complex social dynamics, predict demographic trends and develop applications that improve people's lives and strengthen communities. In the field of social data science (social physics/social computational approaches), his work marks a significant shift in our understanding of human behaviour and social dynamics in the digital era.

By leveraging big data and computational analysis, Pentland offers an approach that differs from traditional sociological methods, which rely on relatively limited datasets and opinion surveys. His work emphasises the importance of analysing large-scale data to understand collective human behaviour and identify patterns and trends that may not be visible through conventional approaches. Furthermore, social data science explores how social networks facilitate the diffusion of ideas and shape collective intelligence, thereby influencing opinions regarding reproductive behaviour.

Additionally, Pentland's research has practical applications in areas such as urban planning and governance. Nevertheless, his approach is not without limitations. Some critics argue that the emphasis on quantitative data and the underrepresentation of qualitative factors may prevent a comprehensive understanding of demographic phenomena.

Katharine Ognyanova: Key Contributions

The most important contributions of Katharine Ognyanova can be summarised as follows:

- applying machine-learning algorithms to track the spread of information (e.g. misinformation) and its effect on demographics and social behaviour, particularly during crises such as the 2020–21 global pandemic.

Studying the effects of social media on migration, linking migrants' online activity on platforms such as Facebook to patterns of their incorporation/assimilation in new societies.

- Research on 'Social Media and Migration Decisions' (2021), which examined how digital platforms influence migrants' destination choices (Ognyanova, K., Lazer, D., Robertson, R. E., & Wilson, C., 2020).

Overall, Ognyanova's contributions are valuable for understanding how digital technology shapes social and demographic behaviour. Through AI-based analysis of social networks, she

identifies the mechanisms underlying the diffusion of information, including misinformation, and its impact on behaviour related to demographics, especially during periods of crisis such as the pandemic. Her studies also address the effect of social media on migration, and how digital platforms influence migrants' patterns of integration in host communities and their destination-related decisions.

This body of work therefore contributes to a deeper understanding of how digital technology reshapes social relationships, identities and population mobility in the modern era. It also opens avenues for future research on the effects of technology on social cohesion and cultural diversity.

Esteban Moro's most notable contributions include:

- Urban analysis using artificial intelligence: He developed models that analyse mobile phone data to track population movement in cities, helping to improve infrastructure and reduce congestion.

- A research paper (Urban Mobility and Energy Consumption, 2022) that examined the relationship between population mobility and energy consumption in smart cities.

- A study of social interactions: He used unsupervised learning to understand how everyday interactions, such as using public transport, shape demographic patterns (Lenormand, M., Picornell, M., Cantú-Ros, O. G., Tugores, A., Louail, T., Herranz, R., Barthelemy, M., Frias-Martinez, E., Ramasco, J. J. & Moro, E., 2015).

Overall, Moro's work provides an innovative analytical framework by leveraging artificial intelligence and big data analytics to understand population mobility and spatial distribution in urban settings. It connects research on urban travel patterns with energy consumption, thereby revealing complex relationships between human behaviour and environmental resources. Using unsupervised learning, Moro identifies demographic patterns that emerge from everyday interactions (e.g. transport use), offering valuable insights into how population structure forms and evolves over time. This approach enables a deeper understanding of demographic changes and their implications for urban planning and the sustainability of smart cities.

Joseph H. Davis, Luca Brand-Chung and Kevin Khang presented a research paper titled Big Trends and the U.S. Economy, 1890–2040, published on 10 July 2024.

The paper offers a quantitative analysis of the effects of four major forces — technology, demographics, the fiscal deficit and globalisation — on the US economy. It uses newly constructed quarterly data dating back to 1890 and an advanced statistical framework: a Bayesian structural vector autoregression model. The analysis also includes forecasts extending to 2024.

The authors address several key questions, including: Will the future be characterised by job scarcity due to artificial intelligence, or labour scarcity driven by demographic change? Is higher inflation inevitable in an ageing society alongside an increasing fiscal deficit? They attempt to answer these questions by developing a framework that quantifies the impact of four 'major trends' — technology, demographic composition, structural fiscal deficits and globalisation — on US real GDP growth, inflation, interest rates and the stock market over the past 130 years, and how these trends are likely to interact in the coming decades.

Methodologically, the authors proceed in three main steps. First, they construct a new quarterly dataset starting in 1890 to capture the effects of slowly moving trends with greater precision.

The authors argue that this model provides critical clarity on how major trends in the economy and financial markets have formed up to now and will shape the economy's future trajectory in the coming decades. They conclude that the United States' economic future depends on a 'tug-of-war' between the transformative impact of AI and demographic pressures arising from an ageing population.

Key takeaways from the findings are as follows:

- Impact of major trends: Major trends — technology, demographics, structural fiscal deficits and globalisation — have played a substantial role in shaping key economic variables (real GDP per capita growth, inflation, the federal funds rate and financial-market valuations) over the past 130 years, and are expected to continue influencing these variables in the coming decades.

- Technology and artificial intelligence (AI): If AI succeeds in sufficiently boosting productivity, it could offset demographic pressures and keep inflation under control, with the federal funds rate at around 4%. However, if AI fails to meet expectations, the structural fiscal deficit linked to population ageing may dominate, leading to weak economic growth and inflationary challenges.

- Fiscal deficits and inflation: Structural fiscal deficits, driven by spending associated with an ageing population, have become a key factor fuelling inflation. The authors also suggest that these deficits may compete with the role of monetary policy in influencing prices.

- Globalisation and demographics: Globalisation has had a moderate effect in reducing inflation, but its prospective impact is considered limited. In contrast, demographic shifts have had only a small effect on inflation in the past and are not expected to have much of an impact in the future.

- Neutral interest rate and monetary policy: The neutral interest rate (r-star) has recently increased, primarily due to structural fiscal deficits and a slowdown in efficiency gains from technological progress. Consequently, monetary policy may require higher interest rates to counter inflationary pressures.

- Financial markets: Major trends affect financial-market valuations, but the main drivers of these changes differ depending on the time period. AI could positively impact valuations, though fiscal deficits could offset some of these benefits.

- Future scenarios: The authors foresee a two-track future. The optimistic scenario assumes productivity gains from AI, whereas the pessimistic scenario is characterised by weak growth and fiscal deficit dominance. They regard the 'mixed' scenario — low growth, low inflation and low interest rates — as unlikely.

Reference (as provided): Davis, Joseph H., Luca Brand-Chung and Kevin Khang, 'Big Trends and the U.S. Economy, 1890–2024' (10 July 2024), available on the Social Science Research Network (SSRN): https://ssrn.com/abstract=4702028 or http://dx.doi.org/10.2139/ssrn.4702028.

Finally, this paper provides an in-depth analysis of the interaction between major economic trends and America's social structures. It demonstrates how population ageing reshapes the state's role in welfare provision and exacerbates inequality across generations, while AI threatens to redefine production relationships and generate new skill gaps. Meanwhile, fiscal deficits intensify crises of political legitimacy and weaken social cohesion, creating a new arena of conflict among different social forces over the distribution of scarce resources. These dynamics necessitate a radical reappraisal of the existing social contract in order to address the challenges posed by class fragmentation and the erosion of the middle class — trends that could potentially destabilise the American social system in the decades to come.

Conclusion

The way population-related issues are viewed has undergone a radical shift — from Malthusian pessimism, rooted in fears of resource scarcity, to technological optimism based on the potential of artificial intelligence and scientific progress. Following Malthus's warnings about population growth outstripping available resources, the agricultural and industrial revolutions demonstrated humanity's ability to increase productivity. Today, it is expected that AI will increase efficiency in both agriculture and administration.

Additionally, the focus has shifted from population quantity to quality: indicators of education, health, and welfare have become more important than mere demographic numbers. The perspective has also broadened to include demographic, geographic, and cultural diversity.

Furthermore, models have evolved from simple linear approaches to more complex dynamic frameworks that connect demographic, economic, and environmental factors.

Artificial intelligence is pivotal in this transformation. AI offers promising possibilities by reshaping the labour market, improving the efficiency of healthcare, managing natural resources, and enhancing urban planning. However, with these opportunities comes the need to implement such technologies ethically and responsibly in order to balance the opportunities and challenges of the digital era.

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