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The Global Context

PART I

2

Economic and technological development and their relationships to body size and productivity

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Introduction

> From 1948 to 1998, real per capita income nearly tripled in the United States, growing at an average annual rate of 2.17% (US Department of Commerce, 2000; US Census Bureau, 2000)
>
> Between 1780 and 1979, British per capita income grew at an annual rate of about 1.15% (Maddison, 1982)
>
> The enormous increase in productivity that these figures reflect is also found when output per capita is measured in physical units. A case in point is the number of cars in the United States, which rose from eight thousand in 1900 to more than 200 million in 2000, providing on average each American adult with a car at the end of the millennium (Caplow *et al.*, 2000).

The growth in material wealth has been matched by changes in body size over the past 300 years, especially during the twentieth century. Perhaps the most remarkable secular trend has been the reduction in mortality. Between 1900 and 1998, life expectancy at birth in the United States increased by 65% for women, from 48.3 years to 79.5 years, and by 60% for men, from 46.3 years to 73.8 years (National Center for Health Statistics, 2001). Table 2.1 provides an overview of the long-term trend in life expectancy at birth for seven nations. The data show that in England life expectancy has more than doubled since the early eighteenth century. France has recorded even larger gains in longevity. French children born today can expect to live nearly three times longer than their ancestors 250 years ago.

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Table 2.1 Life expectancy at birth (years) in seven nations, 1725–1990 (both sexes combined)

Country	1725	1750	1800	1850	1900	1950	1990
England or UK	32	37	36	40	48	69	76
France		26	33	42	46	67	77
US	50	51	56	43	47	68	76
Egypt						42	60
India					27	39	59
China						41	70
Japan						61	79

Source: Fogel (1997).

Table 2.2 Estimated average final heights (cm) of men who reached maturity between 1750 and 1875 in six European populations, by quarter centuries

Date of maturity by century and quarter	Great Britain	Norway	Sweden	France	Denmark	Hungary
18-III	165.9	163.9	168.1			168.7
18-IV	167.9		166.7	163.0	165.7	165.8
19-I	168.0		166.7	164.3	165.4	163.9
19-II	171.6		168.0	165.2	166.8	164.2
19-III	169.3	168.6	169.5	165.6	165.3	
20-III	175.0	178.3	177.6	172.0	176.0	170.9

Source: Fogel (1997).

Although not as significant numerically, final heights of European men who reached maturity have also been increasing over the past two centuries, as shown in Table 2.2. In some countries, average heights increased by as much as 10 cm per century.

Body weight has also increased. Figure 2.1 shows that for some age groups, the body mass index (BMI), a measure of weight adjusted for height (equal to kg/m^2), increased by about 10–15% within the past 100 years.

This chapter aims to elucidate the long-run relationship between labor productivity and body size. In particular, it will be shown that improvements in the nutritional status of a number of societies in Western Europe since the early eighteenth century may have initiated a virtuous circle of *technophysio* evolution. The theory of *technophysio* evolution posits the existence of a synergism between technological and physiological improvements that has produced a form of human evolution that is biological but not genetic, rapid, culturally transmitted, and not necessarily stable over time. In the context of the present study, we suggest that an increase in agricultural efficiency and labor productivity improved human physiology, in turn leading to further gains in labor productivity.

The next two sections identify how the early modern advances in agriculture and the increased availability of calories per capita raised labor productivity over the course of successive generations. This is followed by an analysis of the determinants and consequences of accelerating productivity gains in American agriculture after World War II to illustrate the changing relationship among nutrition, body size, and

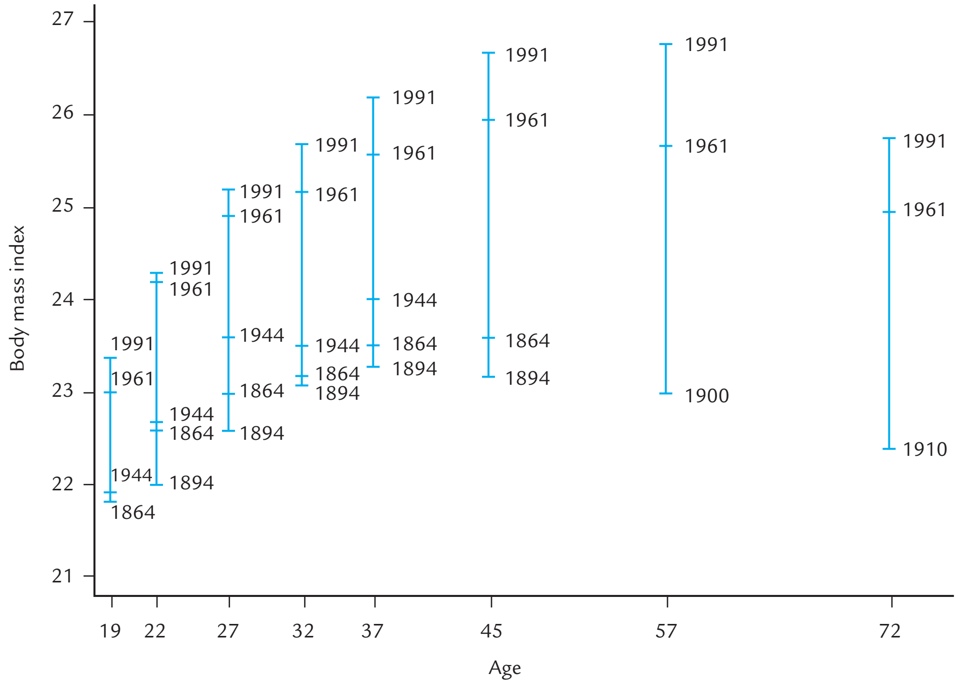

Figure 2.1 Mean body mass index by age group and year, 1863–1991 (from Costa and Steckel, 1997). The age groups, which are centered at the marks, are ages 18–19, 20–24, 25–29, 30–34, 35–39, 40–49, 50–64, and 65–79. For some years BMI is not available for a specific age group.

labor productivity. These recent changes serve as a backdrop to define and track the nutrition transition. The chapter concludes with a summary of the findings, which outlines possible scenarios for further nutrition-induced changes in body size and labor productivity.

The effect of improved nutrition on productivity and output

To understand the relationship between the secular trends in body size and productivity, it is useful to begin by examining changes in nutritional status that took place over the same period.

Energy cost accounting

Nutritional status is most commonly measured by the amount of calories available per person balanced against caloric requirements, also referred to as *net nutrition*[1].

[1] By contrast, the total amount of calories ingested is referred to as *gross nutrition*.

The principal component of the total energy requirement is represented by the basal metabolic rate (BMR). The BMR, which varies with age, sex, and body size is the amount of energy required to maintain body temperature and to sustain the functioning of the heart, liver, brain, and other organs. For adult males aged 20–39 years living in moderate climates, BMR normally ranges between 1350 and 2000 kcal/day depending on height and weight. For comparison across time and different populations, it is convenient to standardize for the age and sex distribution of a population by converting the per capita consumption of calories into consumption per equivalent adult male aged 20–39, also referred to as a consuming unit.

Since the BMR does not allow for the energy required to eat and digest food, or for essential hygiene, an individual cannot survive on the calories needed for basal metabolism. The energy required for these additional essential activities over a period of 24 hours is estimated at 0.27 of BMR or 0.4 of BMR during waking hours. In other words, a survival diet is 1.27 BMR, or between 1720 and 2540 kcal/day for a consuming unit. A maintenance diet contains no allowance for the energy required to earn a living, prepare food, or any other activities beyond those connected with eating and essential hygiene.

Whatever calories are available beyond those claimed for basal metabolism and maintenance can be used at the discretion of the individual, either for work or for leisure activities.

Chronic malnutrition in late-eighteenth century Europe

According to recent estimates, the average caloric consumption in France on the eve of the French Revolution was about 2290 kcal per consuming unit, that for England was about 2700 kcal per consuming unit. These averages, however, do not reveal the variation in caloric consumption within the French and English populations. Table 2.3 shows the probable French and English distributions of the daily consumption of kcal per consuming unit toward the end of the eighteenth century.

The principal finding that emerges from this table is the exceedingly low level of food production, especially in France, at the start of the Industrial Revolution. The French distribution of calories implies that 2.48% of the population had caloric consumption below basal metabolism, whereas the proportion of the English population below basal metabolism was 0.66%. For the remainder of the population, the level of work capacity permitted by the food supply was very low, even after allowing for the reduced requirements for maintenance because of small stature and reduced body mass. In France the bottom 10% of the labor force lacked the energy for regular work and the next 10% had enough energy for less than 3 hours of light work daily (0.52 hours of heavy work). Although the English situation was somewhat better, the bottom 3% of its labor force lacked the energy for any work, while the balance of the bottom 20% had enough energy for only about 6 hours of light work (1.09 hours of heavy work) each day.

Thus, at the end of the eighteenth century, the lack of access to sufficient calories effectively restricted the amount of activity (whether for income or leisure) that most laborers could perform, and it effectively precluded others from working at all.

Table 2.3 A comparison of the probable French and English distributions of the daily caloric consumption (kcal) per consuming unit toward the end of the eighteenth century

Decile	France c. 1785 $\bar{X} = 2290$ $(s/\bar{X}) = 0.3$		England c. 1790 $\bar{X} = 2700$ $(s/\bar{X}) = 0.3$	
	Daily kcal consumption	Cumulative %	Daily kcal consumption	Cumulative %
1. Highest	3672	100	4329	100
2. Ninth	2981	84	3514	84
3. Eighth	2676	71	3155	71
4. Seventh	2457	59	2897	59
5. Sixth	2276	48	2684	48
6. Fifth	2114	38	2492	38
7. Fourth	1958	29	2309	29
8. Third	1798	21	2120	21
9. Second	1614	13	1903	13
10. First	1310	6	1545	6

Sources and procedures: see Fogel (1997).

Table 2.4 Secular trends in the daily caloric supply in France and Great Britain 1700–1989 (kcal per capita)

Year	France	Great Britain
1700		2095
1705	1657	
1750		2168
1785	1848	
1800		2237
1803–12	1846	
1845–54	2480	
1850		2362
1909–13		2857
1935–39	2975	
1954–55	2783	3231
1961		3170
1965	3355	3304
1989	3465	3149

Source: Fogel *et al.* (forthcoming).

How better nutrition raised output per capita

Table 2.4 shows secular trends in the daily caloric supply in France and Great Britain from 1700 to 1989. Per capita availability of calories more than doubled in this period in France, and increased by about 50% in Great Britain, where caloric supply was 30% larger than that in France at the beginning of the period.

Framework

How did the substantial increase in calories per capita affect labor productivity? Labor productivity can be defined as the output of marketable goods and services that a typical worker can produce over the span of one day. Daily output per worker, in turn, can be decomposed into the output per calorie expended at work and the daily amount of calories expended on the job by a typical worker. By multiplying the daily output per worker by the number of workers per inhabitant (which is called the labor force participation rate) output per worker is transformed into output per capita, which is used as a measure of the standard of living:

Output of goods and services produced per capita per day
= daily output of goods and services per calorie expended in their production
× daily amount of calories expended in production per worker
× labor force participation rate

In this decomposition, the technological breakthroughs in farming raised yields for a given effort level, represented here as increases in the output per calorie expended in production. At given levels of annual calories expended in production per worker and labor force participation rate, this must have raised the volume of agricultural output per capita. Higher levels of labor productivity in agriculture also allowed parts of the labor force to be employed in nonagricultural sectors of the economy without reducing farm output per person, thus diversifying the range of goods and services produced domestically.

To understand the full effect of gains in agricultural efficiency, however, it is necessary to take into account how the additional calories were used. Those adults who had been working before the development and diffusion of more-productive farming methods could now increase the annual amount of calories expended while working, either by performing more energy-intensive tasks or by working additional hours, or both. This increase in calories expended in production by a typical worker further increased the amount of calories produced (and ultimately consumed) per capita.

In addition to boosting the calories available to workers, the expansion of the food supply also made more calories available for members of the poorest segment of the adult population who had had only enough energy above maintenance for a few hours of strolling each day – about the amount needed by a beggar – but less on average than that needed for just one hour of the heavy manual labor required in agriculture. To the extent that these persons now had the energy to work, they raised the labor force participation rate, which led to a further increase in per capita output. Table 2.5 summarizes the daily amount of energy available for work in France, and England and Wales from 1700 to 1980. The most impressive gains are reflected by the data for France, where calories available for work increased nearly fivefold within less than 200 years.

In total, by increasing agricultural yields per calorie expended, the Second Agricultural Revolution expanded the availability of calories per capita, drawing more people into the labor force and raising on-the-job calorie expenditures of those working. This boost in the population's productive capacity in turn fueled further growth not only in food output per capita. It also helped to raise the output in all other, nonagricultural sectors of the economy that benefited from an increase in workers and hours worked.

Table 2.5 A comparison of energy available for work daily per consuming unit in France, and England and Wales, 1700–1980 (in kcal)

Year	France	England and Wales
1700		720
1705	439	
1750		812
1785	600	
1800		858
1803–12		
1840		
1845–54		
1850		1014
1870	1671	
1880		
1944		
1975	2136	
1980		1793

Source: Fogel *et al*. (in press).

Empirical estimate

Time series of anthropometric and macroeconomic statistics can be combined to estimate the contribution of better nutrition to the growth of output per person. The most reliable and complete data in this regard have been collected for England. As noted in the introduction, between 1780 and 1979 British per capita income grew at an annual rate of about 1.15% (Maddison, 1982).

Data are now available to measure the changes in calories available for work and the labor force participation rate. For Britain, it has been estimated that the increases in the supply of calories lifted as much as one fifth of all consuming units above the threshold required for work. As a result, the labor force participation rate increased by 25% over 200 years, contributing 0.11% to the annual British growth rate between 1780 and 1980 ($1.25^{0.005} - 1 = 0.0011$).

The increased supply of calories also raised the average consumption of calories by those in the labor force from 2944 kcal per consuming unit in c.1790 to 3701 kcal per consuming unit in 1980. Of these amounts, 1009 kcal were available for work in c. 1790 and 1569 in 1980, so that calories available for discretionary activities increased by about 56% during the two centuries. If it is assumed that the proportion of the available energy devoted to work has been unchanged between the end points of the period, then the increase in the amount of energy available for work contributed about 0.23% per annum to the annual growth rate of per capita income ($1.56^{0.0053} - 1 = 0.0023$). Thus, in combination, bringing the ultrapoor into the labor force and raising the energy available for work by those in the labor force, explains about 30% of British growth in per capita income over the past two centuries [$(0.0023 + 0.0011) \div 0.0115 \cong 0.30$].

As incomes in OECD countries have risen, the share of discretionary time devoted to working for income has declined. Consequently, it is unlikely that further increases in the amount of calories available per person in those countries will raise labor force participation rates or hours worked[2]. However, the immediate effect of better nutrition on labor productivity still holds enormous potential in poor countries where malnutrition is widespread.

The self-reinforcing cycle of greater body size and higher productivity

In addition to the direct effect of better nutrition on the growth of output per person, the conquest of chronic malnutrition has had a long-term effect on human physiology, which has taken several generations to unfold.

The role of long-term changes of nutritional status in altering body size is inferred from applying energy cost accounting to an analysis of food balance sheets. In particular, to have the energy necessary to produce the national product of either France or England c. 1700, the typical adult male must have been quite short and very light in weight. The smaller body size reduced the basal metabolic rate and thereby freed up calories that could be used for work. As per capita food supplies expanded, so did not only hours worked but also body size. The increase in body size, in turn, improved health and the capacity of individuals to raise labor productivity further, thus reinforcing the initial increase in labor productivity.

The effect of improved nutrition on body size, morbidity and mortality

The gain in weight

As was pointed out earlier, the energy that an individual takes in through food consumption will be spent to maintain body temperature and vital organ functions, as well as for eating, sleeping, and essential hygiene. The remainder is available for discretionary use, such as work and leisure. It was also shown that the additional calories that became available in the wake of the Second Agricultural Revolution were used to engage in more energy-intensive tasks and increase labor force participation. Energy not used is stored, leading to weight gain. As such, the body mass index may be interpreted as a measure of net nutrition, which is defined as the excess of calories ingested over calories claimed for maintenance and discretionary use. Figure 2.1 documents the secular increase in body mass index for white men between 1864 and 1991.

[2] In the United States, the labor force participation rate (LFPR) increased from 58.8% to 67.1% between 1948 and 1998. This trend masks important differences between men and women: while the LFPR for men fell from 86.6% to 74.9%, the labor force participation of women rose from 32.7% to 59.8%. These differences are even more pronounced for the group of 55–64-year olds and imply that men tend to retire at earlier ages than before, whereas women continue to expand their participation in the labor market. The increase of the female LFPR has been facilitated by the introduction and adoption of labor-saving technology in the household. As household work became less time consuming, women could reduce the hours spent working at home and seek paid employment in the labor market.

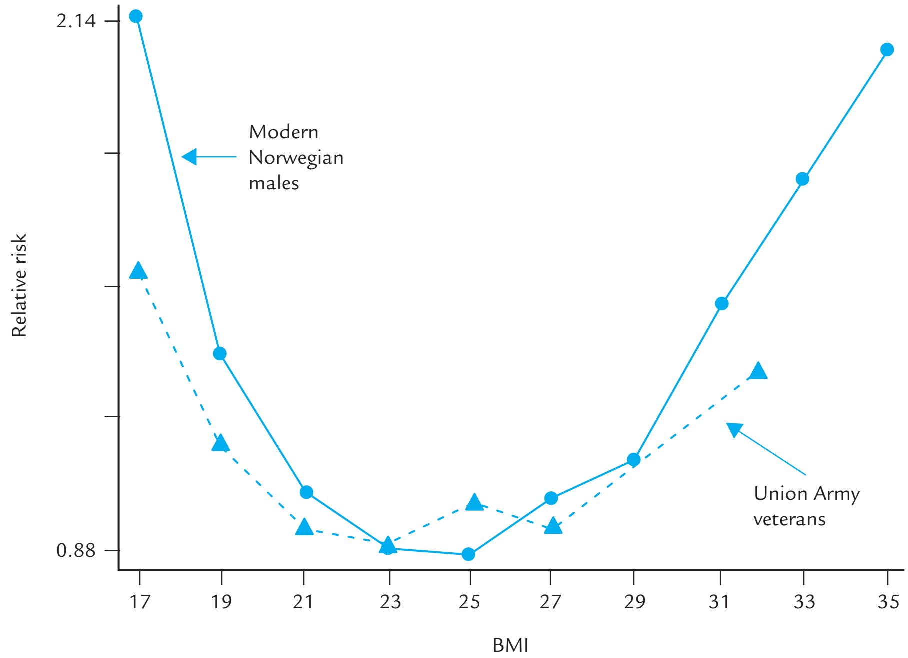

Figure 2.2 Relative mortality risk by BMI among men 50 years of age, Union Army veterans around 1900 and modern Norwegians (from Costa and Steckel, 1997). In the Norwegian data BMI for 79 084 men was measured at ages 45–49 and the period of risk was 7 years. BMI of Union Army veterans was measured at ages 45–64 and the observation period was 25 years.

It has been shown that eliminating chronic hunger will strengthen the body's defenses against infectious diseases, thus lowering the risk of contracting diseases and premature death. The relationship between weight, as measured by the Body Mass Index, and mortality was established empirically by Hans Waaler (1984) for Norwegian men aged 45–49 and confirmed for a sample of Union Army veterans measured at ages 45–64 and followed for 25 years. Figure 2.2 shows a U-shaped relationship between BMI and the relative risk of death for both samples. Among both modern Norwegians and Union Army veterans the curve is quite flat within the range 22–28, with the relative risk of mortality hovering close to 1.0, which represents the average risk of death in the population. However, at BMIs of less than 22 and over 28, the risk of death rises sharply as BMI moves away from its mean value.

The gain in height

A larger and better survival diet allowed adult members of the generation that first witnessed the rise in agricultural efficiency to increase weight, and, consequently, to improve health and extend life. Better nutrition of pregnant women also improved the nutritional status of fetuses and infants. Access to sufficient amounts of calories and other vital nutrients *in utero* and developmental ages has been shown to affect the offspring's final height. Thus, whereas the immediate effect of the improvements in food

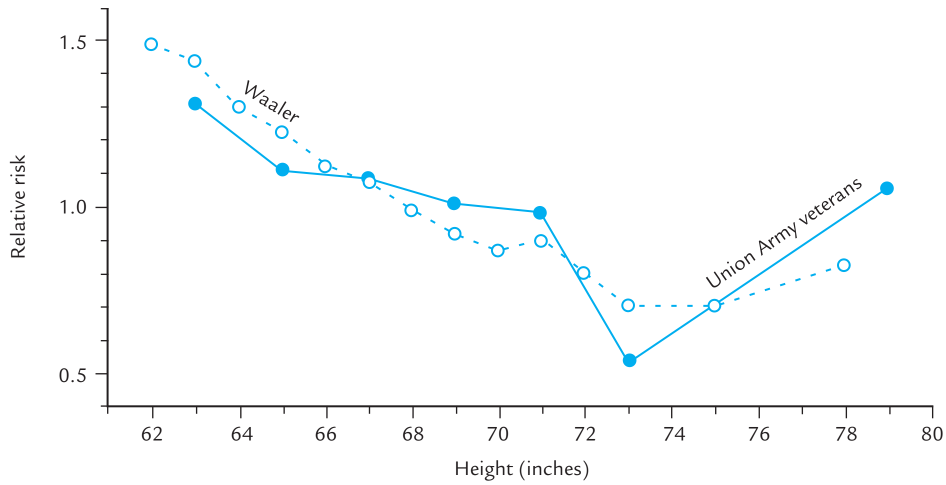

Figure 2.3 Relative mortality risk among Union Army veterans and among Norwegian males (from Costa and Steckel, 1997).

supply was to raise the amount of energy spent at work and to boost body *weight*, the long-run impact over the course of several generations has been an increase in *stature*. This conclusion is supported by the time series on mean final heights for various European populations, shown in Table 2.2.

Waaler (1984) also identified the role of body height as a factor influencing morbidity and mortality. Figure 2.3 plots the relationship between relative mortality risk and height found among Norwegian men aged 40–59 measured in the 1960s and among Union Army veterans measured at ages 23–49 and at risk between ages 55 and 75. Short men, whether modern Norwegians or nineteenth-century Americans, were much more likely to die early than tall men. Height has also been found to be an important predictor of the relative likelihood that men aged 23–49 would be rejected from the Union Army between 1861 and 1865 because of chronic diseases. Despite significant differences in ethnicity, environmental circumstances, the array and severity of diseases, and time, the functional relationship between height and relative risk are strikingly similar in the two cases.

To gauge the relative importance of height and weight for an individual's risk of mortality, an isomortality surface that relates the risk of death to both height and weight simultaneously is needed. Such a surface, presented in Fig. 2.4, was fitted to Waaler's data. Transecting the isomortality map are iso-BMI lines that give the locus of BMI between 16 and 34. The heavy line transecting the minimum point of each isomortality curve represents the weight that minimizes mortality risk at each height.

Since an individual's height cannot be varied by changes in nutrition after maturity, adults can move to a more desirable BMI only by changing their weight. Therefore, the x-axis is interpreted as a measure of the effect of the current nutritional status of mature males on adult mortality rates. Moreover, since most stunting takes place before age three, the y-axis is interpreted as a measure of the effect of nutritional

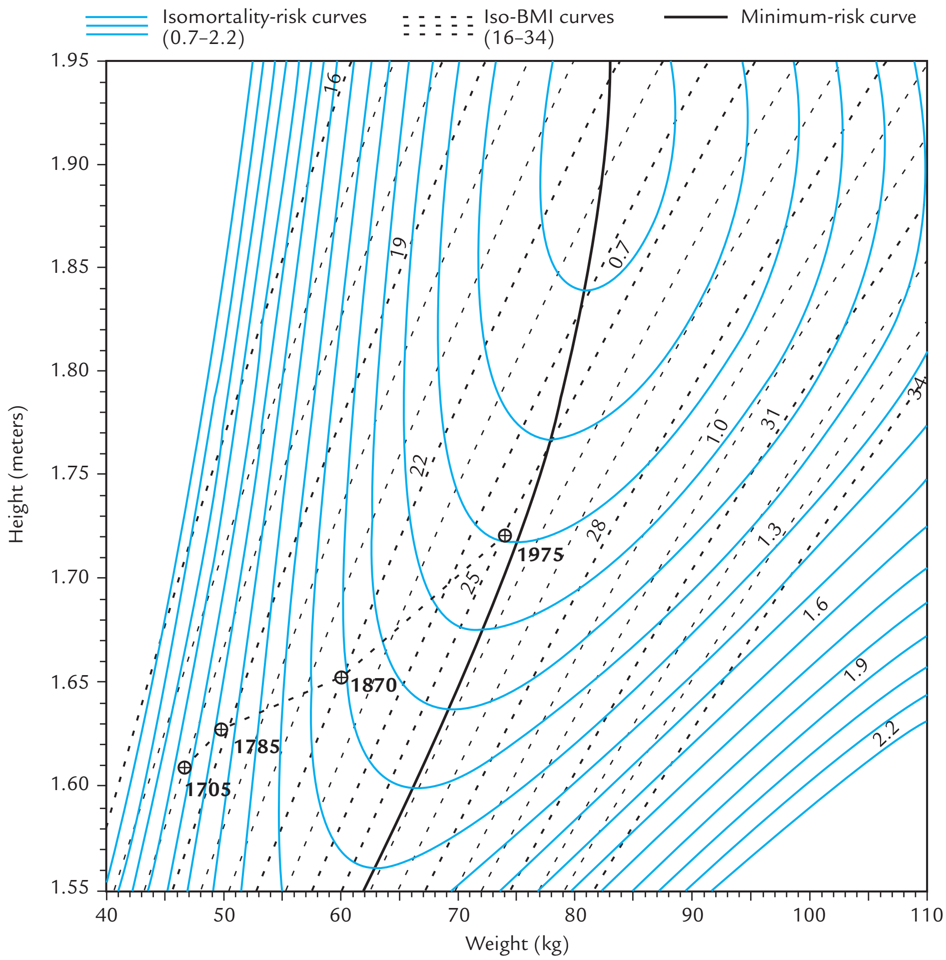

Figure 2.4 Isomortality curves of relative risk for height and weight among Norwegian males aged 50–64 years, with a plot of the estimated French height and weight at four dates (from Fogel and Costa, 1997).

deprivation during developmental ages (including *in utero*) on the risk of mortality at middle and late ages.

Superimposed on Fig. 2.4 are rough estimates of heights and weights in France at four dates. In 1705 the French probably achieved equilibrium with their food supply at an average height of about 161 cm and BMI of about 18. Over the next 270 years the food supply expanded fast enough to permit both the height and the weight of adult males to increase. Figure 2.4 shows that the increase in available food per person translated mostly into weight gain during the eighteenth and nineteenth centuries. During the twentieth century the gains in calories per capita served mainly to increase height. Between 1870 and 1975 height increased at more than twice the rate that it did during the previous 165 years.

Figure 2.4 implies that although factors associated with height and weight jointly explain about 90% of the estimated decline in French mortality rates over the period between 1785 and c. 1870, they only explain about 50% of the decline in mortality rates during the past century.

The effect of lower morbidity and mortality on labor productivity

The unprecedented gains in life expectancy over the past 300 years, the reductions in disease prevalence, and the increasing age at onset of disability have all contributed to raise the number of years free of disease and disability that a person born today can expect to live. In addition, the development of cures for many conditions and the provision of effective symptom management for those conditions that cannot be cured have eliminated or reduced significantly the age-specific rates of functional impairment that used to be associated with many diseases.

The immediate effect of longer lives is that now more people will be able to use their accumulated experience longer, and that they are more likely to share more of their life span with their children and grandchildren.

As a result of improvements in human physiology and major advances in medicine, the number of disability and symptom-free years of life that remain at any given age is now much larger than it has ever been. This creates strong incentives for individuals to undertake measures aimed at preserving physical functioning and cognitive ability, also referred to as investments in human capital. Individuals respond by undertaking more of these investments, which include purchases of preventive and rehabilitative medical services as well as the acquisition of new skills and knowledge. For instance, in 1910, only 13% of adults in the United States were high school graduates and only 3% were college graduates. By 1998, the comparable percentages were 83 and 24, respectively (Caplow *et al*., 2000). It is no coincidence that, at the beginning the twenty-first century, healthcare and educational services constitute two of the fastest growing sectors of the US economy, as they do in most other OECD nations. Not only do these activities maintain or improve the quality of life but they also enhance labor productivity.

Productivity-induced demographic and economic change in the USA

The relationships between technological development, nutrition, body size, and economic change have become most apparent over the course of the past century. They are perhaps best illustrated by examining the consequences of the dramatic improvements in labor productivity experienced by the agricultural sector in the United States since the end of World War II.

From 1948 to 1994, agricultural output more than doubled, expanding at an average annual rate of 1.9% (Ahearn *et al*., 1998). During the same period, total hours worked in agriculture, adjusted for quality, fell by more than two-thirds, or 2.7% annually.

These figures imply that between 1948 and 1994 US agricultural output per hour rose at an average rate of 4.6% per annum, a more than ninefold increase over the span of fifty years[3].

This surge in agricultural labor productivity is attributable to steadily improving yields and an increase in the acreage cultivated per hour. For instance, the introduction of pesticides, herbicides, and fertilizer, combined with higher-yielding crop varieties raised the amount of potatoes per harvested acre by a factor of almost 2.5 between 1948 and 1994 (US Department of Agriculture, 2000). Similarly, the number of acres cultivated per hour has been raised dramatically by the mechanization of agriculture, at an average annual rate of about 3%.

As agricultural labor became more productive, the number of annual hours per worker as well as the number of workers were cut without curtailing agricultural output. Although annual hours per agricultural worker declined by 1% per year, the number of agricultural workers fell even more rapidly, by 1.7% per year (Ahearn *et al*., 1998).

Those workers who were released from the agricultural sector found employment in other sectors of the economy, where they helped to raise output of other goods that consumers wanted, or they stopped working altogether. The fraction of the labor force employed in agriculture fell from 13% in 1948 to 3.2% in 1998 (US Bureau of the Census, 1976; Braddock, 1999; Bureau of Labor Statistics, 2001)[4].

Despite the sharply declining number of hours worked, the growth of US agricultural output has been outpacing the growth of the population during the past 50 years. Whereas from 1948 to 1994 agricultural output grew by 1.9% annually, the population of the United States grew on average by 1.2% per annum (US Department of Commerce, 2000). As a result, agricultural output per capita increased at an annual rate of approximately 0.7%. Compounded over the second half of the twentieth century, therefore, agricultural output per capita, which can be used to assess a country's capacity to supply its inhabitants with calories, increased by about 40%.

Conclusion and outlook

The sections above have documented how advances in agricultural efficiency after 1700 allowed the societies of Europe and North America to expand and improve their diets by an unprecedented degree. The rise in agricultural efficiency set off a self-reinforcing cycle of improvements in nutrition and gains in labor productivity, leading to a substantial increase in per capita output, which has come to be known as "modern economic growth". It was shown how the initial increase in agricultural

[3] A century earlier, output per man-hour had increased 2.16 times in 60 years, or 1.3% annually: whereas in 1840 the production of 100 bushels of wheat required 233 man-hours, in 1900 the same output could be produced with less than half that amount, 108 man-hours. It follows that growth in agricultural productivity accelerated, perhaps doubled, after World War II (cf. Clark, 1993).

[4] This drop in agriculture's employment share was already underway in the nineteenth century; from 1870 to 1920, the fraction of the labor force employed in agriculture fell from 53% to 27%.

efficiency was magnified by providing the population with enough additional calories to boost the number of acres cultivated per hour, annual hours worked, and the labor force participation rate. Based on the notion that variations in the size of individuals have been a principal mechanism in equilibrating the population with the food supply, improved net nutrition has been identified as the primary long-term determinant of the sharp increase in the number of disability-free years of life. The gains in longevity, in turn, have created an incentive for individuals to maintain and upgrade skills and personal health. This line of argument underpins the prediction that the conquest of malnutrition may continue to raise the productivity and innovative capacity of the labor force in the West.

The time series of various components of agricultural output per capita in the United States since World War II has been analyzed and combined with the data presented the following conclusions emerge for the advanced economies of Western Europe and North America.

- Output per acre cultivated has been increasing throughout the period under study.
- Acres cultivated per hour have been increasing throughout this period, first because human energy available for work increased, then because animal and inanimate power complemented and eventually substituted for human energy.
- Annual hours worked per agricultural worker increased at first, as more calories became available for discretionary use, but have been declining recently and are expected to continue to decline.
- The rise in agricultural labor productivity has permitted the number of agricultural workers per inhabitant to decline without lowering the amount of calories available per person.
- The declining share of agricultural workers in the labor force permitted other sectors of the economy to grow, thus greatly diversifying and expanding the range of nonagricultural goods and services.

The recent reversal of some key trends in energy intensity of work and labor force participation rates suggests that the economic and epidemiologic consequences from the unprecedented improvement of human nutrition in the rich countries are still being played out.

Up to World War II the energy intensity and quantity of work in Europe was limited by the availability of food per capita, since then, however, caloric intake has not only matched individual caloric requirements but tends to exceed calorie expenditure in an increasing portion of the population. One indicator of this tendency is the growing prevalence of obese adults in the United States, which between 1960 and 1994 increased from 13.3% to 23.3% (National Center for Health Statistics, 2001)[5].

This trend is compounded by the fact that the progressive substitution of human energy by inanimate power and the concomitant expansion of sedentary work have led to a gradual reduction of calories expended per hour worked. The continued increase in agricultural output per person coupled with lower energy requirements on the job

[5] A person is considered to be obese if that individual's Body Mass Index is equal to or greater than 30 (National Center for Health Statistics, 2001).

may portend two, not mutually exclusive, scenarios for the next stage of the nutrition transition in the world's richest countries.

1. As more and more people work in occupations that do not place high demands on calorie supply, they may decide to increase energy spent during leisure hours. In addition, further gains in stature will raise the calories needed for maintenance.
2. Alternatively, workers may decide to reduce their overall calorie intake to bring it into line with the decreased amounts of calories at work. Although expenditure on food may not decline in absolute terms, consumers may opt to substitute increasingly away from quantity toward quality of calories and become choosier regarding those calories that they decide to purchase and ingest. To the extent that pressure for advances in productivity and greater per capita supply of calories wanes in rich countries, it is conceivable that forms of agriculture that are less productive in calories will gain popularity to accommodate other criteria in the selection of agricultural products and processes. For example, organic agriculture, which renounces the use of certain herbicides, pesticides and fertilizers, accepts lower yields per acre in order to reduce environmental hazards. Similarly, a shift in consumer preferences may prompt the cultivation of crops that sell at a premium but require more care or are less nutritious, thus lowering the amount of calories per hour worked.

The situation is very different in poor countries where more than 800 million people are chronically undernourished (FAO, 1999). Progress in agricultural productivity remains the focus of most programs aimed at raising the per capita supply of calories and other vital nutrients. Yet even in countries where average food consumption is deemed adequate, an unequal distribution of income may effectively preclude the poorest parts of the population from obtaining sufficient calories, as was shown for late eighteenth-century England and France. Recent data from developing countries confirm the association of greater income inequality with increased food insecurity and smaller body size (Steckel, 1995; Shapouri and Rosen, 1999).

Whatever the approach to alleviating chronic hunger in developing countries, improving the food supply could unlock the short-term and long-term effects of better nutrition on labor productivity that have had such a lasting impact on the growth trajectories of Europe and North America.

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