Technological Progress and the Decline of European Mortality

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The economic history of modern Europe between 1750 and 1914 contains two large but largely disjoint literatures: one dealing with technological change and the Industrial Revolution, the other dealing with the decline of mortality and the emergence of a new demographic regime. Despite what seems to be rather close covariation of these trends, a convincing link between them has not yet been demonstrated. Drawing such a link is the main purpose of this paper. The importance of this connection is twofold: it points to a new explanation of the decline in mortality after 1750, to supplement and enhance existing ones; and it provides a case study for the new evolutionary approach to the study of technological progress.

I. The Historical Problem

Between 1750 and 1914 mortality rates declined everywhere in Europe though not at the same time or to the same extent. Yet the phenomenon is clear-cut in its impact: life expectancy, which had been in the mid 20's in France and the mid 30's in Britain in 1750, reached the low or mid 50's in 1914. The crude death rate fell from a narrow range around 25 per thousand in 1750 to 14–15 per thousand in 1914. The *immediate* cause for this decline is not in dispute: it was the decline in infectious diseases in Europe. Yet the deeper causes are less well understood: clinical treatment in 1914 had advanced compared to 1750, but progress had been too little and too late for a satisfactory causal explanation. Instead, three major overlapping "schools" have emerged to explain the decline in mortality: the "nutritionist" school, which attributes the decline primarily to improvements in food consumption and living standards as a consequence of economic growth; the "preventivist" school, which attributed the decline in mortality primarily to public policy such as smallpox vaccination campaigns and public works; and the "exogenist" school which seeks to explain the decline in mortality by improvements in climate and a reduced virulence of major killer diseases due to changes on the microbial level.

Changes in *useful* knowledge, that is, technology, rarely figure prominently in these arguments. The Industrial Revolution, of course, led eventually to the increase in incomes and food supplies that the "nutritional" school relies upon, but that link between technology and mortality is rather indirect. What is needed is a specific theory linking changes in knowledge to changes in behavior that led directly to changes in the effects of infectious diseases. Yet economic theories of changes in *knowledge* are not easy to construct (Stanley Reiter, 1992). One possible approach is one of evolutionary epistemology in which knowledge advances by blind and mostly localized "mutations," some of which are selected for retention. Evolutionary approaches to technology are now quite commonplace, following the pioneering work of Richard Nelson and Sidney Winter (1982); for example, see Giovanni Dosi et al. (1988) and Paolo Saviotti and Stanley Metcalfe (1991).

Life expectancy and good health are goods that are primarily produced within the

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household. Good homemaking practices ("home economics") were of course of central importance here, but so were domestic implements, local public goods, and popular knowledge about basic treatment of common diseases. The household can be envisaged as a production function that transforms commodities into better health and a higher survival probability. It does so by using certain "recipes," the household-level equivalent of techniques or "routines." Households select certain recipes to transform commodities into "health." Improvements in life expectancy could have come about through higher incomes (more commodities), better "ingredients" used in the recipes (improved or new commodities), and better recipes (an increase in the efficiency of household production).

Technological change in this setup consists of the invention of better recipes through improvements in knowledge (analogous to mutations) and the diffusion of this knowledge to households that adopt the new recipes (analogous to natural selection). The selection mechanism here, however, is quite different from the selection mechanism to which firms are subject when they choose among different techniques. Households do not compete with each other and have no incentive to deny others access to more valuable information. On the other hand, it is often far more difficult for them to rank different recipes according to the selection criterion (i.e., net influence on the household members' life expectancy) because of the small number of experiments that are carried out and the difficulty in isolating the net effect of one specific recipe, due to complicated and imperfectly understood time lags.

II. A Simple Model of Technological Selection

To distinguish sharply between the alternatives, it is useful to set up the problem formally. As in standard theory the consumer j maximizes a utility function:

$$U_j = U_j(X_{ij} \dots X_{nj}, L_j) \tag{1}$$

where L is a composite family life-expectancy variable, subject to the usual budget constraint $\Sigma X_i P_i = Y$. Leisure should be regarded as one of the X's (requiring the appropriate reinterpretation of the budget constraint). The special characteristic of this setup is that L is determined by the household production function:

$$L_j = E_1 + E_2 + F(X_{ij}). \tag{2}$$

Because F is not fully known to the household, its behavior is determined by

$$e(L_j) = E_1 + E_2 + F[(A_i - \varepsilon_{ij})X_{ij}] \tag{2'}$$

where F is the household production function that transforms the goods consumed into longer lives, A_i is a common technology shift factor that measures improvements in the "best-practice" household technology for good i, and the term $A_i - \varepsilon_{ij}$ is the recipe with which consumer j converts X_i into L. There is a vector of best-practice recipes associated with the $\mathbf{X}$ vector, but households may not be using the best-practice technique, thus being ε below the best they can do. The environment consists of two elements: E_1, which is purely exogenous, and

$$E_2 = G(B_i - \phi_i)Z_i \tag{3}$$

constrained by $\Sigma P_i Z_i = T$, where the Z's are goods purchased by the government, B is the best-practice technology to convert local public good i into improved health for all members of the community, and ϕ is the gap between the best-practice technology and the one actually used by the local authority.

This formulation abstracts from the historical reality in a number of obvious respects. One is that it makes no distinction between the household and the individual. Another is that it abstracts from interhousehold externalities. In an age of highly contagious disease and shared kitchen and toilet facilities, neighborhood effects were of substantial importance. Third, with more and more individuals working outside their homes, L was affected by the working environment as well. Fourth, by migrating between rural and urban environments, individuals could indirectly choose among different values of E_1. Finally, the model abstracts from the often complex dynamic relation between some of the X's and L.

The influence of changes in knowledge on life expectancy can now be classified into an organizing framework of six basic categories. First, there is generic technological progress that leads to higher income per capita, thus allowing people to consume more. Second, changes on the supply side will change relative prices and the quality of goods purchased and may thus increase the effective purchase of health-enhancing goods. The third category comprises changes in best-practice recipes A_i due to innovations in science as well as in home economics. Fourth, the selection of better existing practices by households reduces the mean gap ε between best-practice and average-practice techniques. Fifth, innovations in local public-goods technology B improve the environment E_2, and sixth, these public-good innovations diffuse through different localities. Below I briefly discuss each of these in turn.

III. The Growth in Knowledge and the Mortality Decline

A. *The Rise in Income per Capita*

The increase in per capita income is the cornerstone of the theory proposed by Thomas McKeown (1977) and others who contend that improved nutrition was at the base of the decline in mortality. There are many problems with this approach, which has recently been criticized heavily (Massimo Livi-Bacci, 1991; Sheila Johannson, 1992). The most telling is that there is in fact little evidence that the standard of living was rising anywhere before 1850, and food consumption in Britain itself was quite flat before 1850 (Gregory Clark et al., 1992). It should also be noted that rising income does not guarantee an increasing L. It assumes that

$$\sum_i \frac{\partial F}{\partial X_i}\frac{\partial X_i}{\partial Y} > 0.$$

That is, the correlation between income elasticity and the health-enhancing effect of certain goods should be positive. This is not immediate: many goods were desirable but health-impairing (such as alcohol, prostitution, or tobacco), and others were healthy but had negative income elasticities (potatoes).

B. *Relative Prices*

The Industrial Revolution shifted the supply curve of certain health-enhancing goods sharply to the right, increasing their consumption. Among these, cotton cloth (easily kept clean), soap, and food-preservation technology figure prominently. At the same time, the Industrial Revolution did little for two other crucial inputs into the household production function: housing and home heating, the consumption of which did not increase much in per capita terms before the middle of the 19th century (Charles Feinstein, 1978 pp. 42–7; Brian Mitchell, 1988 pp. 11–13, 258).

C. *Best-Practice Recipes*

The most important insight into household technology that developed in the 18th century was that dirt and disease were closely related, although no one knew exactly why. The idea grew slowly and sporadically. Similarly, the idea that food should be prepared cautiously before consumption started to take root during this time. The idea that contaminated water could be a source of disease was more controversial: it contradicted the miasmatic theory of disease, which was prevalent until the middle of the 19th century. In 1836 the French doctor Parent-Duchâtelet realized that water involved some principle of infection that "defied analysis" (Richard Kirby et al., 1956 p. 427), yet could still praise the therapeutic qualities of filth, which explained in his mind the robust health of sewer-maintenance personnel (Pierre Goubert, 1989 p. 58). Certain new practices caught on, above all, inoculation and vaccination against smallpox, yet as a whole, disease was as mystifying as ever. Simple afflictions such as food poisoning and light respiratory infections often resulted in death, due to perverse treatment by well-meaning relatives and local medical personnel.

Systematic knowledge of what caused illness was lacking, however, due to the absence of a theory of disease. Classical medicine insisted that diseases were malfunctionings of the body and that a unified monistic causal theory would eventually be found. Yet, not surprisingly, attempts to discover such a cause were in vain and eventually abandoned. Instead, the approach was purely inductive and empirical. The correlates of infectious disease were established by collecting statistical data and searching for empirical regularities. This movement began in the 18th century with rudimentary tables of mortality but reached its peak in the 1830's with the establishment of the Royal Statistical Society and the Registrar General's office. Between 1853 and 1862 a quarter of all the papers read dealt with public-health issues. In France, around the same time, a similar idea was applied to clinical data by C. A. Louis who used a "numerical method" to discover that bloodletting failed to have a curative effect. Overall, there were significant achievements in clinical technology in the 50 years prior to the triumph of the germ theory of disease, but they were marginal compared to the stunning impact of the discoveries of Louis Pasteur and Robert Koch on best-practice recipes. Before that, the medical profession's impact on life expectancy was above all in realizing the importance of preventive medicine and championing the gospel of cleanliness and hygiene to households, and that of clean water and sewage to local authorities. Physicians learned to understand health long before they understood disease.

D. *Selection Procedures*

The choice between different recipes was made primarily at the level of the household. How did the household make these choices, given its budget constraint? Two major questions appear relevant here: first, how did the individual household acquire access to the best-practice knowledge; and how could a household intelligently select among competing innovations if its members did not understand *why* they worked? Before mass media and universal education, household techniques spread through imitation, persuasion, and social control. Imitation occurred at all levels of society, but it stands to reason that the best ideas diffused vertically: they filtered down from the aristocracy to the bourgeoisie, then to the peasants and the working class. Persuasion was equally crucial: individuals were increasingly bombarded with penny pamphlets, lectures, newspaper reports, and volunteers (such as the Ladies' National Association for the Diffusion of Sanitary Knowledge, founded in 1857), preaching hygiene, good feeding habits, and above all, good childcare and breastfeeding. Information and propaganda came down through government reports, at times based on military experience with "dirt diseases" such as typhus and dysentery (Peter Mathias, 1979). The *Chadwick Report* (Edwin Chadwick, 1842) was distributed in thousands of copies. Perhaps this explains the negative correlation between education and child mortality (Robert Woods et al., 1989). Above all, members of the medical profession were indispensable as role models, especially as the prestige of physicians gradually increased after the middle of the 18th century. The establishment of the Medical Officers of Health in Britain in the late 1840's created the institution that formalized the transmission mechanism. Finally, social control clearly had to take over when persuasion and imitation failed. Religious-sounding slogans such as "cleanliness is next to godliness" filtered down from the middle to the lower classes with religious fervor and one Victorian wrote that "we have substituted for the cult of religion that of soap and water" (Anthony Wohl, 1983 p. 67).

The difficulty the household faced in selecting the recipes was because it was limited by its inability to experiment, the smallness of the observation spaces, and by the unknown lag structure between certain practices and their effects. For example, did fresh air cure tuberculosis? Was a diarrhea patient to be given fluids or not? Should drinking water and milk be boiled before consumption? Should babies be swaddled?

How harmful are lice? How should weaned infants be fed? In all of these and similar decisions, the household was abundantly supplied with advice, some of it good, some of it bad. There were two ways to persuade them to choose the best-practice techniques: by basing the recipe on an accepted model (i.e., a causal mechanism) or by relying on empirical regularities. The model was eventually supplied by Pasteur and Koch, and once the basic nature of infectious agents was understood, the other pieces of the puzzle fell neatly into place. Before that, individuals were fed endless statistics and data, but only on a few occasions (vaccination against smallpox being the best example) were the data sufficiently conclusive for households to make easy choices. In short, the acceptance of superior recipes requires the study of the *rhetoric* of hygiene and good housekeeping.

Resistance to the new techniques came not only from religious prejudice, which felt that intervention in the divine scheme was somehow sinful and that vaccination against smallpox was an abomination because of the injection of fluids from a beast into the sacred bodies of people, but also from vested interests and people who realized that certain practices, if useful, implied that the entire body of medical knowledge was under criticism. The tragic case of Ignaz Semmelweiss, the discoverer of the antiseptic method of surgery who was ostracized by his colleagues, is a case in point.

E. *Innovations in Local Public Goods*

In infectious disease, local public goods were as important as private goods. Here, too, not much was known, and often what was known was not understood fully. Thus the desire for "cleanliness" was based on a "miasmatic" theory which held that all infectious diseases were spread through dirty air. Consequently, human refuse, cleared from the streets and yards of the cities, was dumped in rivers and lakes from which the water supplies came, at best replacing one set of diseases with another. Clearly, however, the work of Edwin Chadwick and his associates in England led to a growing understanding of the health hazards of rapid urbanization. Yet without an exact understanding of the causes and etiology of disease, shifts in B were slow. A major breakthrough came in 1854 when John Snow and William Farr, through a purely empirical investigation, demonstrated that cholera was spread through infected water, a finding that flew in the face of the "model" of prevailing medicine of the time. Yet, as in the case of consumers, it was difficult to select the better techniques and to weed out mistakes. Selection criteria often included political considerations, personal reputations, and class prejudice. Such criteria became especially important when the engineering problems were not fully understood. An example is the "pipe-and-bricks sewer war" between Edwin Chadwick and his opponents in the early 1850's, which dealt with the correct way of building sewage systems (Christopher Hamlin, 1992).

As in the recipes chosen by households, the techniques embodied in the variable B do not require that the authorities know how and why they work, or even consciously be aware that they do at all. Thus, the "war against insects" (James Riley, 1986), in which local authorities drained swamps for economic or aesthetic reasons, brought the decline in malaria as an unintended side-benefit. Similarly, when finally convinced that cholera was spread through contaminated water supplies authorities all over Europe set out to clean up water supplies and in the process sharply curtailed the incidence of typhoid and dysentery.

F. *Diffusion of Best-Practice Public-Health Techniques*

It is striking how different localities, which superficially were quite similar, often selected radically different solutions. An example is the difference between Hamburg and Bremen. Bremen was among the pioneers in water filtration and food-preparation education. Hamburg, on the other hand, resisted most measures of public health and consequently suffered a major cholera epidemic in 1892 (Patrice Bourdelais, 1991). Differences in ideology as well as in political structure affected the decisions made here (John Brown, 1989). In the long run, however, the best-practice techniques were adopted everywhere. This is not surprising: municipal authorities were in a more stringent selection environment than individuals, because their constituency could vote them out of office or emigrate. This process of convergence to a best-practice technology, uneven and slow as it was, accounts for a substantial portion of explained mortality decline after 1875 (Brown, 1993).

IV. Conclusion

Change in knowledge as an autonomous force has in recent times lost its appeal as an historical force and is often assumed to be in elastic supply, waiting for conditions to be "ripe." Knowledge is believed to *respond* to market signals, social and political pressures, changes in incentives, institutions, and so on. Without denying that there is a large endogenous element in the generation and acceptance of new knowledge, one should not minimize the autonomous element either. To be sure, the selection mechanism incorporated what society needed and wanted and determined whether the powers that be allowed society to take advantage of the opportunities proffered. Yet in medical technology, more than in any other, there can be little doubt that potential demand has always existed, as the desire to remain healthy and survive is as instinctive as other basic needs. How much new knowledge actually arrived, and when, and what kind, are questions that remain to some extent beyond our economic models (Nathan Rosenberg, 1976). Instead, new knowledge, like new forms of life, follows its own unpredictable Darwinian path, full of contingencies, dead ends, and unfulfilled promises, understandable *ex post*, but unpredictable *ex ante*. Given this, the explanation of the great mortality decline requires an analysis of the autonomous evolution of human understanding of natural processes.

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