Neither state schools nor Ministries of Enlightenment are likely to score smashing successes in inducing people to raise or lower their desire for children relative to other things. But we have found instead that what is of major importance is social structure: getting more education, taking a job outside the home, moving to a city. These are things over which state policy can have greater influence, though there are also cultural factors not to contend with. It may be possible to persuade Moslem women that they ought to have fewer children (or non-Moslem women to have more). But they could have more success in figuring out policies to increase the benefits and reduce the costs to Moslem women of acquiring more education and moving to the city; and in so doing, entrap them, as it were, in a new social structure in which they will choose to have fewer children.
PART I. INTRODUCTION

The health system in the USSR is a social institution which deserves careful study by U.S. scholars and policy makers because it represents an alternative model of the organization of medical care: a national health service in a socialist society. At a time of national debate over the need to reform our own health system, knowledge of the finance, organization, planning and management of the Soviet health system could be useful. Socialized medicine is thought by many to offer advantages over the mixed system of private and public medical care found in the United States. Rigorous analysis of the oldest and largest socialist health institution, that of the USSR, enables one to evaluate this premise.

The Soviet health system is also of interest because it is one of the major sectors of their national economy. In 1975 the health labor force comprised 5,790 thousand persons, or 5.7% of the national total. That year 11,114 thousand rubles, or 5.3% of the state budget, were spent on health. Total health expenditure amounted to 4.3% of national income. In the mid-1970's there were 2 billion outpatient visits annually to medical facilities and 54 million patients were hospitalized. It is therefore desirable to assess the performance of an institution which operates on this large a scale.

A third reason for examining the health system is that it has an influence on important indicators of social well-being, such as mortality rates and life expectancy. The levels and trends in these indicators provide information about the success of Soviet social policy.

* This author participated in the National Council sponsored project for two months in the summers of 1979 and 1980. Because this period of research was substantially shorter than those of the other two investigators this section of the report focuses as much on work in progress as on final results.
Previous research on medical care in the USSR has revealed the existence of serious medical, social and economic problems in this Soviet institution. Among these are:

- A substantial amount of illness does not receive medical treatment.
- Medical services are distributed inequitably between social groups.
- The quality standards of medical care and medical inputs are low.
- Shortages of some inputs, such as medicines and medical equipment mean that certain effective medical procedures are unavailable to the Soviet public.
- Flaws in planning cause an inappropriate allocation of resources in the health sector.
- Allocated resources are frequently used inefficiently by medical facilities.
- The health system is underfinanced relative to the needs of the population or the desires of medical policy makers.
- The health system has been unable to avert rises in age-specific mortality rates and declines in life expectancy since the mid-1960's.

Many of these issues are examined in the 1979 Ph.D. dissertation of this author, *The Economics of the Soviet Health System: An Analytical and Historical Study, 1921-1978.* (10) Others are covered in the 1980 Davis-Feshbach report *Rising Infant Mortality in the USSR in the 1970's.* (11)

It is not my intention to review previous work in this report on the project 'The Economics of Soviet Social Institutions.' Instead attention is focussed on the results of new research sponsored by the National Council for Soviet and East European Research during the summers of 1979 and 1980.
The major objective of this project was to employ both western theoretical approaches and economic models in the investigation of Soviet Social institutions. Accordingly, the second section of the report does not describe the health institution in the USSR along narrow 'ministerial' lines. Instead it employs the concept of 'the production of health' developed by the human capital school health economists such as Grossman and Auster. Following the overview of the production process, current health conditions in the USSR are surveyed. This fills a gap in my dissertation's coverage and provides a foundation for subsequent modelling.

Section 3 presents a mathematical model of the health production process which is based upon the approach of Professor Richard Stone and the U.N. System of Social and Demographic Statistics. Work accomplished by me to date is summarized and future research plans outlined.

The final section makes use of econometric techniques to evaluate the utility of employing western models in the analysis of health production. Linear and multiplicative models of the process determining male life expectancy are specified and parameters are estimated. The results are interpreted and relevant conclusions drawn.

PART II: The Production of Health in the USSR.

1. An Overview of Health Production

The health production process is an exceedingly complex one, a point made repeatedly by western health economists such as Fuchs, Grossman, Best, Auster and others. In most sectors of the economy it is possible to identify a production function in a relatively straightforward
manner. One can measure both the inputs of labor, capital and raw materials and the outputs of commodities and services. In the health sector, however, the task of an economist is quite challenging. One can measure inputs and the production of medical services such as dermatological consultations and appendectomies. However, these services, are only intermediate products. They are consumed by the population and interact with a continually changing illness pattern to produce positive or negative health outcomes.

Given this, it would be inappropriate to adopt a narrow approach to the examination of the institution of health in the USSR and to focus on curative medical activities. Instead an attempt should be made to evaluate the complex interaction of demographic, environmental, social, medical and economic variables which determine health outputs. This is done in Diagram 1, which presents a graphic model of the various interconnections. The diagram provides, in the first instance, a framework for describing health production. It also establishes a foundation for the quantitative modelling described in subsequent sections of the report.

The graphic model is divided into four quadrants. The first focuses on the health of the population. At any given time the population has a 'health stock' which has been determined by age, sex, and genetic variables, as well as the collective historical experience. The population consumes goods and services, an activity which has both positive and negative effects upon health. Improvements in nutrition and educational standards, and increased participation in physical exercise are beneficial. On the other hand a poor diet which results in obesity or vitamin deficiency or excessive consumption of alcohol or tobacco undermine health.
The health status of the population is further influenced by the environment, which has five dimensions: residential, family, technological, natural and microbiological. As with consumption, changes in the environment can be either good or bad for health. The current environmental situation in the USSR is discussed in detail below (pp. 13-27) so no further elaboration is made here.

The interaction of health stock, consumption and environment determines the health status of the population. Western health economists have developed elaborate indices to measure health status. For the purposes of this section it is sufficient to assume a simple partition into healthy and unhealthy groups. Those who are in the second category are afflicted by one or more diseases. The aggregate of all illnesses determines the disease pattern. Given this pattern expert medical evaluation can be used to determine the need for medical services. Of course, in any society some diseases remain untreated and therefore need is not satisfied. Other illnesses are presented to the health system and demands are made for medical services.

The diagram suggests that health outputs are a function of both the scope of medical coverage and the efficacy of medical care. If curative medicine plays a positive role in safeguarding health then obviously the outcomes of untreated illness will be worse than those of treated. Thus, all things being equal, the greater the share of cases of illness presented to the health system the better health output will be.

It is well known that there are varying technologies and quality standards in curative medicine, which have a differential impact on illness. Health output therefore is dependent both on the pattern of illnesses
and the performance of the curative sector.

Many indices have been developed for measuring health output. To simplify presentation assume there are three outcomes: full health, invalidity and death. These are shown in quadrant I. In practice, the output indicators often used, and considered most reliable, are those of mortality and life expectancy.

The Soviet health system, shown in quadrant II, produces curative medical services by combining inputs of fixed capital, commodities and labor. In addition other services are provided in the functional areas of research, preventive medicine, validation, education and administration. The scale of operation of the health system is determined in part by patient demand and in part by top-level policy decisions. Associated with a chosen activity level are derived demands for the three classes of inputs.

The supply of inputs (quadrant III) is determined in the first instance by physical availability and in the second by health finance. Manpower supply comes from the labor force and new graduates of medical school. The medical-pharmaceutical industry and other branches of the national economy produce health-related goods and services in accordance with the national plan, which is in turn an expression of governmental priorities. The state budget and other sources provide the finance for the purchase of inputs for the health system.

Quadrant IV shows another interconnection between the health system and the economy. The healthy population and a proportion of invalids engage in work or study. The economically active enter the labor force and contribute to economic production. Thus there is a rather direct and measurable link between health output and national economic performance.
In my dissertation an earlier version of diagram 1 provided a framework for an extensive description of the health production process in the USSR (see Chapters VI-VIII). No attempt is made to repeat the material in this report. However, one area which received inadequate attention was that of the determinants of health status. Accordingly, new research on health conditions, the results of which are reported below, was conducted.

   a. Determinants of Health Status

   It was argued above that health output is a function of the interaction of the illness pattern and curative medical services. Western analysts have to date devoted much attention to the evaluation of the Soviet health system and certain output indicators such as age-specific mortality rates and life expectancy. But little effort has been made to assess changes in the national disease pattern and their underlying causes. In an attempt to fill this gap in our knowledge, trends in Soviet health conditions over the period 1959-1980 were surveyed. A rigorous, quantitative assessment of all factors was not feasible in the time available. Accordingly the essay on determinants of health status presented below is more of an outline of a future research program than a complete analysis.

   Diagram 2 presents a detailed description of the determinants of health status. These can be divided into three groups: health stock, consumption and environment.* Information on changes in these factors is

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*At this point it is appropriate to observe that Diagram 2 is misleading to the extent that it suggests that consumption and the environment exert an influence on the population health status only in the current period. Obviously many factors such as smoking or air pollution have long-term effects on the population. In any given period they incrementally undermine the health of the human organism. This decline in health can continue for decades before it manifests itself in the form of disease, such as cancer. With this in mind, past as well as current aspects of consumption and the environment are discussed on the following pages.
Diagram 2: Determinants of Health Status
outlined below. Recent trends in the Soviet disease pattern are then discussed.

b. The Health Stock of the Soviet Population

Health stock, one of the major factors which determines health status, is a function of age, sex, and genetic distributions as well as the historical experience of the population. Over the period 1959-1979 the age distribution in the USSR changed markedly because of the fall in the birth rate. The share of those under 15 fell from 29.5 to 24.1%; whereas that of the elderly (over the age of 60) rose from 9.4 to 13.2%.

As there is a greater incidence and more complex patterns of illness among the elderly this would tend to worsen health status.

The sex distribution also shifted. In 1959 45.0% of the population was male and 55.0% female. By 1979 respective shares were 46.7% and 53.3%. Because males are more susceptible to accidents, cancer, heart and respiratory disease, this development further increased the disease burden.

The genetic make-up of an individual (determined at fertilization), prenatal environmental forces and the birth experience affect his/her subsequent health history. Some diseases, such as diabetes, are genetically determined whereas others such as cancer or heart diseases, are more likely among people with a certain genetic profile. Factors which undermine the health of pregnant women have an adverse effect on the health of the fetus. An infant born prematurely or one who experiences a complicated delivery can end up with abnormalities which adversely affect its health later in life. Thus, an increase in the share of the population with this weaker health stock generates changes in the illness pattern.

The Soviet Union does not publish sufficient information to determine conclusively whether there has been a deterioration in the health stock
of the population because of genetic changes and birth-related problems. However, several Soviet authors have suggested that this is the case. (11:20)

In a 1979 book M.S. Bednyy has stated:

'In the past ten years the frequency of birth of infants with development anomalies has grown. Among the reasons for the occurrence of these anomalies, according to many authors, are genetic mutations, which are the outcome of the action on the mother of a series of exogenous factors: illnesses from epidemics of influenza, German measles, the abuse of medical preparations, alcoholic beverages, smoking, and ionospheric radiation. Diabetes, the frequency of which rose and shifted to a younger age group has had a negative effect on posterity, and has increased the prenatal death rate and the mortality rate in the first month of life.' (5:128)

In a recent article about the Davis-Feshbach report on Soviet infant mortality Professor Perevedentsev put forward as a reason for the increase the weakening of the national genetic pool. Thus it does seem that an unhealthy trend exists in the USSR.

The health stock of the population in a given time is heavily influenced by historical experiences. This observation is especially relevant with respect to a society such as the Soviet Union which has undergone rapid social change and suffered greatly from revolution and war. Many Soviet medical specialists believe that the health of those members of society who were subjected to stress and material deprivation during World War II suffered long-term damage:

'The war undermined the health of those who are now 50 years or older; those born in the period of the war were subjected to unfavorable conditions of nursing, medical care, and nutrition which were generated by the difficulties of the war period.' (5:122)

The implication is that these members of the population have a weaker health stock and that they are afflicted more frequently by illnesses and have worse disease outcomes than those born in the postwar period.
Although this is a difficult proposition to test, it is probable that a permanent deterioration in health stock of a portion of the current Soviet population was caused by the war.

c. Consumption and Health

Numerous health economists such as Grossman, Fuchs, Best and Culyer have noted that increases in real income and consumption are not always associated with improvements in health.\(^{(6, 8, 12, 15)}\) This is because consumption has both positive and negative effects. Improvements in nutrition obviously are associated with a strengthening of the body whereas overeating resulting in obesity induces strain.

Over the past two decades there have been positive consumption developments in the USSR. Real income has risen, facilitating purchase of available goods and services. The social wage, which measures collective consumption, has also risen. The diet of the population has become more varied and the share in it of meat, fruit and vegetables has gone up. The educational level has increased, which presumably facilitates more rational decision making in the health area.

On the other hand, there have been numerous unfavorable developments in consumption. Treml has shown that alcohol consumed per capita rose from 3.45 liters of pure alcohol to 6.39 over the period 1959 to 1972.\(^{(21:294)}\) Studies have shown that excessive alcohol consumption leads to obesity and the degeneration of internal organs. In any residential or technological environment those under the influence of alcohol are more prone to accidents. Thus this factor has undoubtedly had an adverse influence on the national health status. The production of cigarettes rose dramatically, from 243.4 billion in 1959 to 413.3 in 1980.\(^{(24:168)}\) Smoking has been associated
with heart disease, lung cancer and bronchitis. The growing popularity of this habit has had unfavorable consequences.

In the USSR yearly per capita consumption of sugar has risen from 24.2 kilograms in 1958 to 43.0 in 1978. Use of refined sugar has been linked to the incidence of dental cavities, diabetes and obesity. Excessive consumption of sugar, fats and carbohydrates can lead to obesity. This obviously has been a problem in the Soviet Union. Although the diet has improved and the younger generation is therefore less afflicted by this problem, many Soviet citizens over the age of 40 are overweight. This consumption-related condition has an adverse impact on health.

Deficiencies in the Soviet diet have generated other problems. Published statistics on cancer mortality rates by location in the body show that in the USSR the incidence of stomach cancer is very high relative to most other countries. Inadequate infant nutrition also undermines health status. Davis and Feshbach found evidence that the shift away from breast feeding in the USSR, in the absence of proper milk substitutes, has adversely affected infant health and facilitated the survival of rickets as an important childhood disease.

This survey of consumption in the USSR shows that in recent years there have been both positive and negative developments. On the whole it would appear that the adverse effects on health of alcoholism, smoking and obesity have more than offset gains from improvements in diet and education.

d. The environment and health

The environment in which a population lives is an important determinant of its health status and disease pattern. To clarify the effect on health of the environment in the USSR it helps to study five
environmental dimensions: residential, family, technological, natural and microbiological.

(1) The residential environment

The residential pattern has altered substantially in the USSR over the past twenty years. In 1959 100.0 million people or 48% of the population lived in cities. By 1979 there were 163.6 million urban residents comprising 62% of the total. (23:7)

Rapid urbanization has placed a considerable strain on the housing system. In the mid-1950s a severe housing shortage existed in the USSR. Housing was overcrowded in the cities, and many families shared communal flats. In rural areas most of the population lived in low quality small wooden houses. A major construction program has produced more than 2 million new housing units every year since 1958. (17:792) The amount of per capita urban living space has increased from 5.8 m² in 1958 to 8.2 m² in 1977. (17:794) However, since 1969, the annual number of new marriages, an indicator of new household formation, has exceeded that of new housing units constructed, which indicates that the gap between housing demand and supply is widening. Little has been done in recent years to raise the quality of rural housing, although the migration to the cities undoubtedly has improved indicators of space per capita in the countryside.

Another aspect of the residential environment which should be mentioned is the neighborhood. Most of the Soviet urban housing units built in the past twenty years are situated in the 'new districts' on the outskirts of cities. Typically, development in these districts is unbalanced, with housing construction completed well before the supporting facilities and services such as schools, shops, subway and bus lines, and telephone
exchanges. The quality of life in these dreary ensembles of high-rise buildings leaves much to be desired.

Water and sewage services have many deficiencies in the USSR. In the countryside the wooden houses are supplied with electricity, but very few are connected to water supply or sewage systems. (13:108) With respect to urban areas Goldman has written:

"For the country as a whole by January 1970, 1,736 out of more than 1,800 Soviet cities had at least some homes supplied with water, while only 1,205 had sewers....Major cities and regions in the USSR find themselves with seriously inadequate water supplies and sewage treatment."(13:104-105)

From available evidence it appears that water and sewage systems in urban areas have expanded since 1970. The extent to which this has resulted in health improvements is discussed below in section (4)

(2) The family environment

The family plays an important role in the determination of health status because it provides continuing care to vulnerable members of society--infants, the elderly, the ill and the disabled--and because it has an influence on consumption and safety habits. Recent family trends in the USSR have not been entirely favorable to health. Expansion of the housing stock, increased mobility and improvements in the economic status of pensioners have tended to break up the extended family. One consequence is that the number of elderly living on their own, often in infirm condition, has risen. Social and medical services for the elderly have not kept pace with the demographic changes. Another result is that younger parents are deprived of the traditional services of the babushka (grandmother), which typically includes child care, cleaning, shopping and meal preparation. Working parents cannot devote adequate attention to infants and are making greater use of child care facilities. From 1965 to 1978 the number of
children in pre-school facilities rose from 7,673 to 13,177 million. (23:417)

Since 1965 the number of marriages has risen from 8.7 to 10.7 per 1,000 and the birth rate has fluctuated around 18.0 per 1,000. However there is some evidence that rates of illegitimate birth rose in the 1970s (11:23) and divorce rates have increased from 1.6 to 3.5 per 1,000 between 1965 and 1978. It is therefore likely that the number of one-parent families has grown, as in other industrialized societies. Numerous Soviet studies have shown that the health of children in 'incomplete' families is substantially worse than in normal ones.

It is possible that the tension in the family environment may be increasing because of sex-role conflicts, growing work burdens on women and continuing housing shortages as well. Most young Soviet women, especially those in cities, work full time. This has given them financial independence from their husbands but has generated role conflict because the society supports strong male behavior patterns. This tension may explain part of the unhealthy patterns of smoking and drinking and much of the high divorce rate.

(3) The technological environment

The occupational structure and the technological level of a society have a significant influence on the population's health. Many injuries and diseases are directly linked to production processes. In addition, the technological environment, together with other environmental and consumption factors, determines the non-occupational accident rate. Finally many technologies used for production or consumption generate pollutants which cause a deterioration in the natural environment.

The Soviet Union is a rapidly industrializing society. From 1965 to 1978 the value of national income produced in industry rose from 100.1
to 216.2 billion rubles. Over the same period the share of the labor force employed in industry and construction rose from 36 to 39%.

Mechanization, electrification, chemicalization and automobilization have all increased with ensuing unfavorable health consequences.

The Soviet Union is less mechanized than advanced western societies, but in recent years progress has been made. According to the annual statistical yearbook many branches of industry recently have experienced rapid mechanization. For example, the index of mekhanovooruzhenost' (mechanization) of labor in construction (1940 = 1) rose from 6 in 1965 to 20 in 1978. In the agricultural sector large investments since 1965 have generated a rapid growth in the supply of machinery, as the following table shows:

<table>
<thead>
<tr>
<th>Machinery in Soviet Agriculture</th>
<th>(thousands of units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>1965</td>
</tr>
<tr>
<td>Type</td>
<td></td>
</tr>
<tr>
<td>Tractors</td>
<td>1,613</td>
</tr>
<tr>
<td>Combines</td>
<td>520</td>
</tr>
<tr>
<td>Trucks</td>
<td>945</td>
</tr>
</tbody>
</table>

Source: 23:208

Electrification also is proceeding rapidly in the Soviet economy. The index of elektrovooruzhenost' (electrification) of labor in industry (1940=1) rose from 4.1 in 1965 to 7.1 in 1978. This further suggests that a significant technological intensification has occurred.
The dramatic growth of the Soviet chemical industry has posed new threats to health. Production processes themselves are dangerous and result in injury, poisonings and disease among workers, and their by-products are major contributors to land, water and air pollution. Chemical products are the cause of most non-occupational accidental poisoning and much water pollution.

The output of the chemical industry has grown rapidly in the USSR. The index of production (1940=1) rose from 15 in 1965 to 54 in 1978, (23:120) and the chemical/petrochemical share in total industrial production went up from 4.7 to 6.9 percent. (23:121) Over the same period the supply of fertilizer to agriculture rose from 26,906 to 79,002 thousands of tons, (23:235) and the output of pesticides increased from 201 to 491 thousands of tons. (23:151) It is obvious from these statistics that the amount of chemicals in the Soviet environment has substantially risen in the past 15 years.

These recent changes in the technological environment increase the potential threats to the health of the labor force. The final effect on the disease pattern, however, is strongly influenced by occupational health programs, which consist of educating workers to use the technology and establishing and enforcing work safety standards. Therefore it is necessary to examine the trends and effectiveness of these preventive measures.

The Soviet Union claims to devote much attention to the protection of workers' health. Since the early 1920s health sub-systems have existed open only to workers in certain ministries and factories. The employed also have preferential access to public medical facilities. The Ministry of Health and the trade unions finance research institutes devoted to the study of labor hygiene and safety. At these institutes safety norms and operating rules are developed which are among the strictest in the world.
Despite this there are serious problems in the area of occupational hygiene. First, all Soviet health systems, closed or public, are oriented to the provision of curative medical services. Preventive medicine is neither well-funded nor is it a high-prestige branch of the health system. From 1965 to 1975 non-capital state budget expenditure on sanitary-prophylactic programs rose from 256 to 545 million rubles, but the preventive share of the health budget remained a stable 4%. In 1974 only 0.46% of all doctors occupying positions in the Ministry of Health System were those concerned with labor hygiene. Second, the few doctors working in this area frequently are unable to ensure that safety or environmental standards are observed. Soviet medical literature abounds with stories of factories which operate in very unhealthy conditions. Plan fulfillment pressures and capital expenditure constraints make it difficult to correct violations even after trade unions bring hazardous conditions to the attention of the party and management. As a result of these inadequacies, the rapid changes in the technological environment in industry have had an adverse impact on workers' health.

The situation is much worse in agriculture. As shown above mechanization, electrification and chemicalization have proceeded rapidly in the countryside. But the general and occupational education standards of the rural work force are much lower than that of the urban population. The rural labor force is less adaptable to new technology and more prone to engage in dangerous practices such as drinking alcohol during the workday. Agricultural laborers therefore make many mistakes with machinery or in chemical utilization. At the same time it is more difficult for health and trade union officials to inspect and monitor work habits and
conditions. Thus the recent changes in the technological environment have generated a disastrous increase in occupational accidents and poisonings in rural areas.

Technology is not only dangerous at work. Many Soviet reports show that 'home' accidents are rising more rapidly than industrial ones. Much of this has to do with the automobile. The production of motor vehicles in the USSR rose from 616 to 2,178 thousand from 1965 to 1978. (23:161) Passenger car output grew especially rapidly; its share in the total went up from 38 to 60 percent between 1970 and 1979. (26:813) In a major change of policy, the Soviet government allowed citizens to purchase these cars for private use. This has been beneficial for the state, in that car sales have reduced the cash balances of the population, and for the individual, in that automobile ownership increases social status and travel comfort.

Automobilization has its negative sides as well though. According to Welihozkiy the contemporary road system in the USSR is neither extensive nor of high quality. Substantial driving hazards exist. When this condition is combined with the Soviet propensity to consume alcohol it generates a high accident rate. (26:831) A second major automobile-related health problem is air pollution. Goldman noted that even in the 1960s, before the upsurge in production, there was an automobile pollution problem in some large Soviet cities. He claims that 'For a variety of reasons, ...Soviet automotive vehicles spew pollution far out of proportion to their numbers': (13:132) the cars are used longer than Western ones and therefore have less efficient combustion; the quality of Soviet gas is poor; and the sulphur content of gasoline and diesel fuels is high. Given this it is undoubtedly the case that the quadrupling of motor vehicle production since...
1960 has been accompanied by a substantial increase in pollutants and a lowering of air quality in urban areas.

This survey of trends in the Soviet technological environment suggests that although recent developments may have been beneficial for the economy many have had a negative influence on the health status of the population. The technological advances in production and consumption interact with drinking habits, backwardness in social infrastructure (such as roads) and inadequate education to generate rising accident rates. Further, the by-products of the continuing rapid industrialization caused a deterioration of the natural environment.

(4) The natural environment

The natural environment is made up of air, water and land. If these resources are of good quality then this has a beneficial influence on health. But in most industrial societies the environment deteriorates because of pollution. Factories discharge waste into the air and water. The by-products of automobile combustion lower air quality. Chemical fertilizers and pesticides poison land and water. This pollution directly generates forms of illness such as poisoning or cancer and indirectly raises the prevalence of cardiovascular and respiratory diseases. (6)

There is no doubt that air pollution is a growing problem in the USSR. The rapid expansion of industry, especially of the chemical sector, and of motor vehicle utilization has substantially increased the amount of gas, smoke and dust discharged into the air. Numerous Soviet studies have determined what maximum pollution levels should be and some legislation which can be used to penalize offenders has been passed.
According to Goldman, the model anti-pollution campaign in Moscow had some success until the mid-1960s, after which time 'officials have found it difficult to prevent air quality indices in Moscow from deteriorating.'(13:136) He claims that the situation in other cities and regions is worse than in Moscow. The main reasons for this failure in the fight against pollution appear to be poor location planning of industrial enterprises, inadequate expenditure on filtration equipment and the powerlessness of health officials relative to the large industrial ministries. (13)(19)

Soviet studies have demonstrated that air pollution undermines the health of affected populations. Bednyy, Gracheva, Borevich and others claim that pollution has an adverse effect on fetal health and produces birth defects and allergies in infants. (11:20) In a 1976 book on air pollution and health the specialists at an Academy of Medical Sciences institute wrote:

"The prevalence of birth defects among children in large industrialized centers with developed chemical, petrochemical and machine-building industries was studied by us....On the basis of the study it was established that the indicator of prevalence of defects (per 10,000 new born) for the years 1970-1974 was 38.7-53.9 in rural localities, but in cities with developed chemical industries ---108.5-152.2! (16:19)

Air pollution also irritates the lungs and facilitates the spread of respiratory diseases among vulnerable groups, especially the young and the elderly. (11:21) Much evidence about this effect is available. Typical is a Latvian study published in 1978, demonstrating the link between illness rates in kindergartens and pollution from an asphalt factory:

'It should be noted that in kindergartens closer to the factory children fell ill more frequently from colds, bronchitis and diseases of the ear, nose and throat than in the control group. Children of the control kindergarten did not on the whole suffer from conjunctivitis, but in one of the kindergartens near the factory the prevalence rate of this illness in 1974 was 10.6 cases per 100 infants."
The greater prevalence of illness of the upper respiratory tract, of bronchitis and of conjunctivitis in kindergartens close to the factory allows one to conclude that one of the factors which facilitates the spread of these diseases is the increased presence of dust in the air."(3:100)

In his 1979 book on morbidity and mortality trends M.S. Bednyy writes that:

'Among the factors which facilitate the rapid spread of influenza epidemics one can pick out the general pollution of the air.'(5:133)

Thus it is probably the case that over the past several decades pollution-related deterioration in air quality has had an adverse effect on health in the USSR.

As a consequence of the problems in the residential and technological environment there has been a growth in the pollution of water in the USSR. Over the years numerous official and dissident Soviet scholars, as well as Western ones, have called attention to the worsening state of rivers, lakes and reservoirs. This pollution is unfortunate not only for the fish. Low quality drinking water is a health threat to humans; it can cause chemical poisoning, cancer and various infectious diseases.

On page 15 above it was noted that the current water system in the USSR is underdeveloped because of lack of investment in earlier periods. Some urban and most rural inhabitants are not supplied with sanitary running water. Summarizing the situation in rural Kazakhstan in 1977 Voskresenskii wrote:

'25.5% of the rural population locales are provided with centralized water supply systems, 7.9% of population points (predominantly small ones) are obligated, through various circumstances, to use only imported water, and 66.4% points use water from pit or tubular wells.'(25:11)
Naturally, it is difficult to maintain health standards in a system with such disparate sources. And even where centralized systems exist the sanitary challenges posed by pollution are growing.

There are three major sources of water pollution: sewage, industrial effluent and agricultural chemical products. Rapid urbanization has greatly increased the production of sewage. In his book Goldman writes:

'It was found that in 1969, 99 million cubic meters of unclean or inadequately treated water was discharged each day into the country's rivers and other water bodies. This is equivalent to 36 cubic kilometers a year....Although the data are fragmentary, one authority estimates that the discharge of liquid wastes will total 60 cubic kilometers in 1980.'(13:83)

He further observes that in the future '....the discharge of sewage will grow at a considerably faster rate than water consumption.' Both Goldman and Pryde make the point that constraints on social investment have meant that most sewage in the USSR is not treated either mechanically or biologically before being dumped into waterways. (13:97)(19:138) Since the polluted rivers and lakes are the sources of drinking water, these unsanitary practices increase the threat of bacteriological disease.

Industrial waste, especially from enterprises of the pulp and paper, petroleum, chemical and metallurgical industries, is a major source of water pollution. Pryde reports that:

'By 1966, about 16 billion cubic metres of industrial waste was being dumped annually into the rivers and lakes of the Russian republic alone, of which only 4.5 billion had undergone purification.'(19:138)

The rapid growth of chemicals and petrochemicals since the mid-1960s has greatly increased pollutant discharge and, according to Goldman, has seemed 'to keep pace with or ahead of the completion of facilities for added industrial treatment.'(13:99) This undoubtedly has placed additional strain on the water purification system.
Since 1965 the output of fertilizer has tripled and that of pesticide has increased eight-fold. Although these products fulfill vital agricultural functions, they also have negative side-effects, because they frequently are washed into drinking-water sources. Pryde claims this is a problem in the USSR but does not discuss trends. It is highly likely though, that this threat to health is of growing importance.

In the USSR as a whole, the increase in water pollution is barely being coped with by existing sanitation and public health programs, and in some areas there is evidence that public hygiene deficiencies have raised the incidence of water related diseases.

Pryde has reviewed the programs and procedures which exist in the USSR to protect water supplies. Although these look quite good on paper he makes the point that because the Soviet government has always given highest priority to investment in the 'productive' sector the resources available for improvement of industrial and municipal waste purification facilities have been inadequate. Even when money is allocated the construction plans are often underfulfilled and the quality of work is low. The following quote from Voskresenskii, on the current situation in Kazakstan, illustrates the problems associated with safeguarding water supplies:

'Together with that, in the design, construction and use of water supply facilities in the villages there are also serious deficiencies. Thus, the plan of construction of rural water-pipes for the period 1972-1975 was only 51.3% fulfilled by the Ministry of Agriculture. As a result of the introduction into use of waterpipes without zones of sanitary safeguard, purification buildings and disinfection installations, and of the poor utilization of existing water systems in a series of places one can notice a worsening of the quality of drinking water according to bacteriological indicators.
An analysis of water-related epidemic outbreaks of intestinal infection in rural localities of the Kazakh SSR in recent years showed that the main causes are flagrant violations in the use of facilities of centralized water supply. One observes accidents in the systems, and interruptions in the supply of water, which significantly complicate sanitary-epidemiological conditions. These problems are probably common throughout rural areas. In cities water purification capabilities are better, but industrial and sewage pollution worse, so the campaign to combat health threats is undoubtedly not completely successful.

It was mentioned above that bad water can have adverse effects on health in several ways. A quick survey of Soviet literature provides no evidence linking polluted water with either poisonings or cancer. However, available information suggests that pollution of drinking water does cause bacteriological and parasitological problems. To see the effect this has on human health it is necessary to examine the microbiological environment.

(5) The microbiological environment

Among the major sources of disease are microbial agents such as viruses and bacteria. These agents are always present in the environment but their effect on man's health varies. The variation stems from changes in socioeconomic conditions, public health measures and alterations in the genetic nature of the disease agents.

Surveying trends in the Soviet Union it is evident that improvements in nutrition, education, housing and water supply have tended to hamper the spread of infectious disease, whereas increased density of living and pollution have facilitated it. Large scale public health programs have attempted, with mixed success, to combat the effects of pollution. They have been more successful when directed against certain disease agents such as malarial parasites and the poliomyelitis virus. On the other hand,
there have been genetic changes in some viruses in recent decades. The new strains are more virulent and resistant to natural immunities and medical countermeasures.

The recent history of the influenza virus in the USSR illustrates how the microbial environment can change. Influenza is caused by an extremely resilient and flexible airborne virus. Because of its bad weather conditions, polluted urban air and crowded homes and public facilities the Soviet Union frequently suffers epidemics of influenza. Complicating the situation is the fact that over time the virus undergoes antigenic shifts.* The new strains which emerge are not repelled either by acquired immunities of the body or by vaccines designed to combat previous influenza strains. In this event the epidemics are especially serious health threats. The report by Davis and Feshbach shows that in the period 1971-1976 there were influenza epidemics every year and that three new viral strains emerged. This suggests that there has been some worsening of the microbiological environment in the USSR.

Bacteria are other important disease agents. In a 1977 article Aleshin stated that 14% of all illness in the USSR was comprised of dysentery of water origin. (The prevalence of this form of illness further testifies to the inadequacy of the water supply system.) In the face of growing pollution of water from sewage and industrial wastes, existing drinking water protection and purification programs may well be inadequate. If so, then it is fully possible that the bacterial threats to the health of Soviet citizens are rising.

*Antigenic shifts refer to the changes in the genetic structure of the virus. To combat the new antigen the body must produce new antibodies naturally or through vaccination.
e. The response of the Soviet disease pattern to changing health conditions

Medical statisticians and epidemiologists have developed elaborate scientific classifications of diseases, which can be used to organize statistics about a national disease pattern. Although the Soviet Union has formally accepted the World Health Organization classifications, it has yet to publish sufficient statistics to enable one to re-construct the country's disease pattern or to measure its changes over time rigorously. Since the time constraints of this project did not enable the necessary additional research to be conducted this section presents only a subjective assessment of recent trends.

Most illnesses in a society fall into one of the following categories:
- Infectious disease - such as dysentery, malaria and influenza.
- Nutritional disease - such as rickets, scurvy and obesity.
- Degenerative disease - such as cancer, heart disease or cirrhosis.
- Accidents - such as fractures, poisonings and cuts.

The causes of diseases vary according to type but usually involve some complex interaction of health stock, consumption habits and environmental conditions. If one takes the example of lung cancer, the incidence of this form of cancer is determined by the variables measuring age, genetic stock, the prevalence of the smoking habit and air pollution. Thus it is clear that as health conditions in a society change so too will the disease pattern.

Available evidence suggests that in the Soviet Union the changes in health stock, consumption and environmental variables discussed above have significantly altered the structure of illness in the society. Among the health stock factors, the aging of the population has been especially
important. It is well known that among the elderly degenerative illnesses such as cancer, hypertension, bronchitis etc., are significant. As the share of the elderly in the total population grows, the disease pattern of a nation is altered and contains a larger share of degenerative disease. The movement of those cohorts who fought in World War II into older age is an important development. As mentioned above it is believed that the stressful experiences of these people have undermined their biological systems and have made them more susceptible to degenerative, especially cardiovascular, disease.\(^{(9:112-113)}\)

A number of the factors associated with consumption have exerted a beneficial influence on the disease pattern. During the period 1965-1978 the improvements in income distribution, housing and nutrition have been instrumental in reducing the incidence of infectious diseases. But the rises in cigarette smoking and alcohol consumption have generated more lung cancer, cardiovascular illness and cirrhosis of the liver.\(^{(9)}\)

Changes in the different dimensions of the environment have been important as well. The disease pattern of cities is different from that found in the countryside. In urban areas there tends to be more cancer, circulatory, nervous, and respiratory disease and accidents, and less gastrointestinal and infectious disease. Therefore the increase in the urban population share has had an important effect on morbidity and mortality rates.\(^{(9:12)}\)

With respect to the family environment, the decline in the practice of breast-feeding of infants, in the absence of adequate milk substitutes, has probably undermined the health of infants, making them more susceptible to gastrointestinal and respiratory diseases.\(^{(11)}\) Additionally, the high economic participation rate of mothers and increased availability of day care
centres has led to a rise in the share of Soviet infants in creches. This in turn has facilitated the spread of respiratory diseases, possibly increasing its importance in the infant disease pattern. (11)

Among the other environmental developments, the increasing mechanisation and 'automobilisation' of Soviet life, have interacted with the excessive national drinking habits to produce more accidents at home, at work and on the highway. (9:82-85) In the absence of adequate safeguards the growth of industry and the number of motor vehicles in the USSR has generated increased environmental pollution. This in turn probably has contributed to the rise in cancer and respiratory disease rates. (9)

Antigenic shifts in the influenza virus in the 1970s appear to have made the epidemics of influenza more severe. (11)

Soviet preventive medical programs have had a generally beneficial impact. Anti-epidemic measures have resulted in the eradication or reduction in the incidence of many diseases such as measles, poliomyelitis, cholera and malaria. They also may have ameliorated the effects of influenza epidemics. Improvements in public sanitation and hygiene in food processing and distribution have lowered the incidence of gastrointestinal disease. The large scale screening programmes have identified much previously hidden illness, which is then treated by the curative branch of the health system.

Summarizing available evidence, it appears that in the past two decades there have been substantial changes in the Soviet disease pattern. Because of improvements in health conditions the significance of gastrointestinal and infectious diseases has diminished. However, the mechanisation
of Soviet society together with excessive consumption of alcohol has resulted in more accidents. The most important development, though, has been the rise in the share of degenerative diseases, brought about by the aging of the population, urbanization, pollution, etc. These diseases are more difficult and expensive to treat successfully. Therefore, throughout this time period, the tasks confronting the Soviet health system have become more complicated and challenging.
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PART III. An Accounting Model of the Soviet Health Production Process

1. Introduction

Since World War II the use of quantitative modelling of national economies has developed rapidly in both capitalist and socialist countries. Advances in empirical analysis can in part be attributed to the substantial improvements in national economic accounting in the same period. On the basis of the new accounts it was possible to make better use of econometric, input-output, flow-of-funds and income distribution models in empirical investigations.

In recognition of the important role played by accounting in economic analysis the first stage of the quantitative investigation of the Soviet health production process is devoted to the development of an appropriate accounting model. Section 2 reviews the relevant literature and identifies the most interesting approach. An accounting model of health production in the USSR is presented and discussed in section 3. Work accomplished during the project period is described. Finally areas of future research are identified.

2. The Development of Social and Demographic Accounting

An earlier paper by this author surveys the history of economic and sociodemographic accounting. It was found that during the 1960s there was substantial progress in the development and utilization of individual social indicators but few advances were made in the elaboration of systems of national sociodemographic statistics.

The work done in this area by Professor Richard Stone over the past decade has been of fundamental importance and provided the basis for
the accounting model of the Soviet health process. It is therefore appropriate to briefly survey the characteristics of this approach.

Stone has been interested since 1969 in using the absorbing Markov Chain Model in social analysis. To clarify the reasons for this it might be helpful to briefly describe the features of this model.*

Let \( n_t \) be a vector describing the distribution of a population across \( m \) states. Suppose there exists a Markov process defined by the equations:

\[
 n_t = n_{t-1} \cdot S
\]

where \( S \) is the \( m \times m \) partitioned transition matrix.

\[
 S = \begin{bmatrix}
 I & 0 \\
 D & C
 \end{bmatrix}
\]

\( I \) = a \( (m-q) \times (m-q) \) identity matrix

\( 0 \) = a \( (m-q) \times q \) zero matrix

\( D \) = a \( q \times (m-q) \) absorption or 'death' matrix which describes transitions from life to death states.

\( C \) = a \( q \times q \) 'survivors' matrix which describes transitions between life states.

If it is assumed that the matrix of transition probabilities is stable over time then the process is a finite Markov chain.

The chain is absorbing if these additional conditions hold:

*A Complete discussion can be found in the book by Kemeny and Snell Finite Markov Chains.
1. For any of the \( q \) rows of \( D \) there is a coefficient greater than zero
\[
d_{ij} > 0 \text{ for any } i \text{ and at least one } j
\]

2. For any of the \( q \) rows of \( C \) the sum of probabilities is less than one
\[
\sum_j C_{ij} < 1
\]

3. For the rows \( i = 1 \ldots (m-q) \) the coefficients are either one or zero
\[
S_{ij} = \begin{cases} 
1 & \text{if } i = j \\
0 & \text{if } i \neq j 
\end{cases}
\]

For a given live population \( n_0 \), the survivors vector in the next period is determined by
\[
\tilde{n}_1 = \tilde{n}_0 . C
\]

and at some future period by
\[
\tilde{n}_t = \tilde{n}_0 . C^t
\]

However because the sum of life transition probabilities for any given state is < 1, then as \( t \to \infty \), \( C^t \to 0 \) and thus \( n_t \to 0 \). So the population is absorbed (or 'dies out') over time.

Thus the history of the population can be summarized by the series
\[
\tilde{n}_0 . \sum_{t=0}^{\infty} C^t = \tilde{n}_0 \left( I + C + C^2 + \ldots + C^t \right)
\]

Since \( C^t \to 0 \) as \( t \to \infty \) the series on the right converges and its solution in the limit is
\[
\sum_{t=0}^{\infty} C^t = (I - C)^{-1} = N
\]
This limit solution is called the fundamental matrix of the absorbing Markov chain. It can be employed as a powerful social indicator describing the behavior of the Markov process in the transient ('life') states, before eventual absorption into the ergodic ('death') states (see pp. 46-47).

The Markov Chain Model and its associated fundamental matrix have been used by Stone to analyze individual demographic, educational, health and other social processes. However he has also made use of them in developing a new system of sociodemographic accounts. This work provided the foundation for a 1970 report to a U.N. Expert Group on 'An integrated system of demographic, manpower and social statistics and its links with the System of National Accounts.' After further development the U.N. accepted this approach and proposed a new set of national accounts in the document Toward a System of Social and Demographic Statistics.

This U.N. report describes a framework for the integrated accounting of those sectors of society given inadequate coverage in traditional economic accounts: population reproduction and migration, family formation, housing, social security and welfare, education and health. For each sector appropriate social indicators and models are identified and linkages are discussed. Some examples are given.

The U.N. sponsored sociodemographic accounting is still in an early phase of development. No scholars have used this approach to model an important sector of any society and no application of it, even on a microlevel, has been made in a socialist country. Despite this, it was decided to develop the accounting model of the Soviet health production process on the basis of the U.N. system.
3. An Accounting Model of the Soviet Heath Production Process

Construction of the accounting model began with the graphic elaboration of the interrelationships between demographic, health and economic processes in the USSR. This produced a diagram similar to that presented above in this report (see pg. 5). Subsequently the procedures and models associated with the U.N. approach were used to describe the processes in mathematical form. (2) The data collection effort for my Ph.D. research was organized around this first model. A later four-quadrant version provided the framework for the analysis of the economics of the Soviet health system presented in my dissertation. (3)

In 1979 the accounting model was reviewed and future development tasks were identified in the areas of model specification, data collection, parameter estimation and system simulation. During the project period progress was made in each of these areas.

The first task was to improve the specification of the model. Earlier variants of the model were evaluated and new literature examined. (10) On the basis of this certain aspects of the model were reformulated. The latest version is shown in Diagram 3. The accompanying table explains the notation. The complete mathematical elaboration of this model requires about 70 pages (3), so it was decided not to include this material in the summary project report. Only a brief description is given here.

As in Diagram 1 the mathematical model of the health production process is divided into four quadrants. In the first, the population with a given health stock, n, is influenced by a health status determination matrix, h, which in turn is a function of consumption, environmental and preventive medical variables. The result of this interaction is the
Notation of Accounting Model of Health Production in the USSR

Quadrant I  Health Status and Health Output

n = population of given health stock at beginning of period
h = health status determination
CON = consumption influence
ENV = environmental influence
H = health status
d* = persons dying outside health system
q* = persons remaining healthy
l = persons suffering illness
α, α*, α** = cases of illness already reported
p, p* = new cases of illness
 w = new demand for medical services
u = total demand for medical services
d** = persons dying after medical treatment
β = persons becoming invalids after treatment
q** = persons recovering health after treatment
q = total stock health persons
ΣD = total deaths in period
Σq = total healthy in period
Σβ = total invalids in period

Quadrant II: The Health System

CS = curative medical sector Markov Chain Model
I = identity matrix
D = absorption matrix
O = null matrix
M = curative medical sector transition matrix
CUI = inputs of curative sector
PA = Policy/Administrative sector
ED = Educational sector
VA = Validation sector
PR = Preventive medical sector
Bi = Biomedical research sector
DDMA = Derived demand for manpower
DDFA = Derived demand for facilities
DDCO = Derived demand for commodities

Quadrant III: Supply to the Health System
SMA = Supply of manpower
SFA = Supply of facilities
SCO = Supply of commodities
MM = Medical manpower markov chain model
E = Medical manpower survivors matrix
MC = Medical construction markov chain model
T = Medical construction survivors matrix
MAC = Medical manpower cost
FAC = Medical facilities cost
COC = Medical commodities cost
TCHS = Total cost of health system
TFHS = Total finance of health system
Quadrant IV: Activities of Healthy Population

PD = Permanently disabled population
TI = Temporarily inactive population
ECA = Economically active population
EDA = Educationally active population
LF = Labor force
MLF = Medical labor force
$X_i$ = Industries supplying commodities
$X_j$ = Industries using commodities
$X_{Oj}$ = Labor utilization by industries
Y = Final demand
X = Total output
GED = General educational system
MED = Medical educational system
health status matrix $H$. Those who fall ill generate a demand for medical services, $u$. Others die outside the health system ($d^*$) or remain healthy ($q$).

Quadrant II models the Soviet health system. Its activities are divided into six functional areas: biomedical research, preventive medicine, validation, education, policy/administration and curative medicine. A markov chain is used to represent the treatment of patients in the curative medical sector. Patients entering the curative system either remain in one of the treatment states or are absorbed into one of the three output states: health ($q^{**}$), invalidity ($\beta$) or death ($d^{**}$). All the functional sectors require inputs of manpower, facilities and commodities. Activity levels determine the derived demands for inputs (DDMA, DDFA, DDCO).

The health sector supply system is described in quadrant III. The processes producing medical manpower and medical facilities are represented by absorbing markov chains. The manpower and materials supplied have associated costs (MAC, FAC, COC). Their total (TCHS) should be in balance with total available finance (TFHS).

The fourth quadrant shows another link between the health system and the economy. Activities of the health system influence the composition of the labor force (LF), which in turn provides the labor input to the various branches of the Soviet economy, described by an input-output model.

The second task of the project with respect to the accounting model was improvement of the data base. In the dissertation there were
discussions of data availability and estimation in the following four areas: population reproduction, health status, medical sector and health output. One problem identified was the instability of demographic coefficients, especially birth and death rates, in the USSR. This suggested that a Markov chain model of population reproduction with its stringent stability assumptions would be inappropriate. As a consequence, revisions in specification were made. A second recurring problem was lack of data. In an effort to ameliorate this, attempts were made during 1980 both to collect additional Soviet data and to explore the possibility of using information from other countries to fill the gaps in published Soviet material.

Most additional Soviet material was collected during a two-month IREX-sponsored trip to Moscow in Spring 1980. Over 200 additional references on health issues were obtained and several relevant candidate dissertations examined.

Demographic and health statistics published in the U.S. and U.K. have also been evaluated to determine the feasibility of 'splicing' this information with Soviet to expand the data base. Consultations during the summer, 1980, with faculty of the Harvard School of Public Health and with members of the Analysis Division of the National Center for Health Statistics were especially helpful.

Parameter estimation was a third area of project research. Experience with the Markov chain model in other areas demonstrates that parameter estimation is feasible if the process under study is reasonably stable and data on transition coefficients or state histories exist. In many
cases raw data exist on stocks and flows from which transition proportions can be calculated. These can then be used as the estimates of coefficients of the S matrix (see pg. 35). If this matrix of proportions is constructed from aggregation of life sequences over the history of the process then the coefficients may be viewed as consistent, asymptotically unbiased maximum likelihood estimates of the true transition probabilities. (7:23-25) If 'prior' information about the structure of the transition matrix is available in addition to sample information, then Bayesian techniques can be used to estimate transition probabilities. (7:25-30) In many cases, however, time-ordered observations of individual state histories are unavailable, thus preventing the calculation of transition proportions. Instead one might have sample aggregate proportions which measure the distribution of the population over states for each time period.

Lee, Judge and Zellner have shown in their book *Estimating the Parameters of the Markov Probability Model from Aggregate Time Series Data* (7) that even with this limited data it is possible to estimate transition coefficients. They present eight estimators of transition probabilities which can be used with such data: unrestricted least squares; restricted least squares; weighted inequality restricted least squares; Aitken's generalized least squares; minimum chi-square; macro-maximum likelihood, Bayesian and minimum absolute deviations. In addition the authors have developed programs for actual estimation and provide numerous examples. More information of Markov coefficient estimation can be obtained from the work of Kosubud and Stokes. (5)(8) They use the minimum absolute deviation estimator to calculate the coefficients of a Markov chain describing oil market share dynamics.
The conclusion can be made therefore that given a reasonable amount of data the estimation of parameters of a Markov chain model is a feasible proposition. Once the transition probabilities of a Markov chain model are estimated it can be used in simulation studies of system behavior. To advance project work in the estimation area the programs in the Lee, Judge and Zellner book were debugged by a computer specialist (Ralph Bailey) at the University of Birmingham. When tested on hypothetical control data the program was found to estimate parameters properly.

One original estimation program named 'ESTTRAN' was developed in 1979 by Mr. Bailey for my use in the project. (This work was not funded by the National Council, however). For any matrix of Markov chain transition probabilities the program calculates the fundamental matrix (see pg. 37 above). The coefficients $N_{ij}$ of this matrix give the mean number of time periods the average member of state $i$ will spend in state $j$. In addition the program calculates the seven social indicators associated with the Markov chain. (3:117-118)

1. $\tau = N \cdot \xi$, where $\xi$ is column unit vector. The row elements of column vector $\tau$ give the number of units (say years) of life a member of initial state $i$ can expect. (These interpretations of $N$ and $\tau$ illustrate the link between the fundamental matrix and the more traditional demographers tool, the life table).

2. $N_2 = N(2N_{dg} - I) - N^2$, where $N_{dg}$ is the diagonal matrix of $N$. The $ij$ coefficients of this matrix indicate the variance of the number of years the average member of state $i$ will spend in state $j$ before absorption. (4:49-50)
3. $\zeta_2 = (2N-I) \cdot \zeta - \zeta^2$. This vector gives the variance of the state-specific expectations of life given in $\zeta$. (4:51)

4. $B = ND$, where $D$ is the absorption matrix. This shows the state-specific expectations of absorption. (4:52-53) Thus it is the complement of $\zeta$.

5. $TR = (N-I) N_d^{-1}$ shows the probability that a member of $i$ will move to transient state $j$ during the history of the process. (4:61)

6. $ME_i = \frac{1}{(1-c_{ii})}$ measures the mean number of 'years' a member remains in transient state $i$ once that state is entered. (4:61)

7. $QS = \frac{c_{ij}}{(1-c_{ii})}$ shows the conditional probability of moving to transient state $j$ given that a member has left state $i$. (4:61)

This program was used successfully to estimate, using hypothetical data, these indicators for the 12x12 transition matrix of population reproduction specified in my dissertation. (3:158)

One final related topic of research was system simulation using the accounting model. Some progress has been made in this area. During winter 1980, outside the project period, I revised the accounting model and Mr. Bailey programmed a computer representation of the first two quadrants. This work was interrupted by my recent trip to the USSR. However, it should be completed in the near future.

4. Conclusions and Future Research

The accounting model of the health production process is still being developed at the conclusion of the National Council sponsored project (September 1980). The approach adopted appears to be of great
value and merits further attention. Progress has been made in the areas of model specification, data collection, estimation and system simulation. However, to date the revised model has not been estimated and tested. Therefore there are no concrete results from empirical analysis to be reported.

I plan to continue research in this area during the next academic year. In October 1980 a paper on the model will be presented at a conference in Poland of the Editorial Board of the journal, The Economics of Planning. Work will continue on improvement of the data base. This should enable estimation to begin next spring. Following that, efforts will be made to use the model for structural analysis and system simulation.
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PART IV: Econometric Modelling of the Soviet Health Production Process

1. Introduction

The health production process in the USSR was described in Section II of this report. Previous research by this author has identified a number of problems associated with it. One of the most serious is the rise in age-specific mortality rates and the accompanying decline in life expectancy. An important issue of concern to health policy makers is the responsibility of the health system for these unfavorable trends in mortality. In an attempt to clarify this issue, two Western models were estimated by econometric techniques using Soviet time series data for the period 1959-1976. This section of the report discusses the results of the econometric research carried out in summer 1980.

The econometric approach involves the use of economic models, data, and statistical techniques to estimate and evaluate relationships between economic variables. The estimated econometric model can then be used for structural evaluation, forecasting and policy evaluation.

The discipline of econometrics has developed rapidly in the past several decades. Many advances have been made in the specification of models, the collection and processing of data and the development of estimation techniques. Applications of econometrics have been made in most branches of economics. In recent years two areas relevant to the topic of this report have been analyzed by econometricians: health economics and Soviet economics.

Econometric models have been used by health economists since Feldstein's pioneering work was published in 1967. Most studies have
involved the estimation of single-equation models derived from neoclassical microeconomic theory.\(^{(14)}\) For example, there have been numerous estimates of cost curves of hospitals and of demand functions for medical services. Grossman, Fuchs, and others associated with the National Bureau of Economic Research have developed models for the health sector, which are based on the theory of human capital, and have used econometrics to estimate them.\(^{(1)}(13)\) Finally some simultaneous equation models of the whole health care system have been employed in econometric investigations.\(^{(14)}(23)\) However, little attention has been devoted to the analysis of the health production process at the national level.

Analysts of the Soviet economy have also turned to econometric models in the past 15 years. Initial research was concentrated on the estimation of sectoral and branch production functions.\(^{(16)}\) In the 1970s, however, there was a rapid expansion of econometric modelling.\(^{(15)}\) A serious effort has been made to create a macroeconometric model (SOVMOD) of the Soviet Union. The first variant of SOVMOD is described in the 1977 book of Green and Higgins.\(^{(12)}\) Subsequently this model and others have been further refined. Despite this, no effort has been made to econometrically examine the institution of health in the USSR.

Since econometric techniques have proved useful in both health and Soviet economics it seems likely that the same outcome would obtain in the field defined by their intersection: the economics of the Soviet health system. During the summer 1980 project period this author carried out initial econometric research in this area. Two western models were adapted to describe the health production process in the USSR. On the basis of published Soviet and Western data the parameters were estimated and econometric results discussed.
2. The Problem

One of the most important problems confronting Soviet health policy makers is that of rising mortality and falling life expectancy. The recent literature on mortality trends in the USSR suggests that few simple solutions exist. From the description of the health production process presented above in section II it should be clear that the mortality output is the joint product of illness pattern and curative medicine variables. Until now, though, no attempt has been made to determine, through the use of quantitative methods, the relative influences of these two factors on mortality/life expectancy and the consequences for Soviet policy in the health sector. In this section of the report an attempt is made to employ econometric techniques to address this issue.

3. The Models

Section II of the report on the Soviet health system to the National Council for Soviet and East European Research argued that health output \( H \) is a function of illness pattern \( IP \) and medical services \( MS \)

\[
H = h(IP, MS)
\]

The precise shape of this function varies according to the variables chosen and assumptions about the nature of their interaction.

One simple model of health production would be the linear one

\[
H = A + \beta_1 IP + \beta_2 MS
\]

where \( A = \text{constant} \)

\( \beta_1, \beta_2 = \text{coefficients} \)

In this case \( A \) measures the intercept of the \( H \) axis. The coefficients which are the partial derivatives of the \( H \) function
\[ \beta_1 = \frac{\partial H}{\partial IP}, \quad \beta_2 = \frac{\partial H}{\partial MS} \]

Measure the marginal contributions to health of changes in illness pattern and medical services.

An alternative simple model of health production is the multiplicative one

\[ H = A IP^{\sigma_1} MS^{\sigma_2} \]

where \( A, \sigma_1, \) and \( \sigma_2 \) are constants

The parameters \( \sigma_1, \sigma_2 \) can be determined as follows

\[ \frac{\partial H}{\partial IP} = A(\sigma_1 IP^{\sigma_1 - 1} MS^{\sigma_2}) \]

\[ \sigma_1 = \left[ \frac{\partial H}{\partial IP} \right] \left[ \frac{1}{AIP^{\sigma_1 - 1} MS^{\sigma_2}} \right] \]

\[ = \left[ \frac{\partial H}{\partial IP} \right] \left[ \frac{IP}{AIP^{\sigma_1 - 1} MS^{\sigma_2}} \right] \]

\[ = \left[ \frac{\partial H}{\partial IP} \right] \left[ \frac{IP}{H} \right] \]

Similarly,

\[ \sigma_2 = \left[ \frac{MS}{H} \right] \left[ \frac{\partial H}{\partial MS} \right] \]

These of course are measures of the elasticity of the output \( H \) with respect to the inputs \( IP, MS \).

It was shown above in section II that the health production process is more complex. To enrich the simple models one can recognize that \( IP \) and \( MS \) are themselves functions of other variables:

\[ IP = g(HS, C, E) \]

\[ HS = \text{health stock} \]
C = consumption
E = environment
MS = f(MM, CS, S)
MM = medical manpower
CS = health facilities
S = health commodities

It is now possible to express health output in terms of the other variables.

Substituting one obtains

\[ H = h(g(HS, C, E), f(MM, CS, S)) \]

As above the character of the production function is dependent upon assumptions. Assume once more that we have a linear system.

\[ H = A_1 + \beta_1 IP + \beta_2 MS \]
\[ IP = A_2 + \alpha_1 HS + \alpha_2 C + \alpha_3 E \]
\[ MS = A_3 + \gamma_1 MM + \gamma_2 CS + \gamma_3 S \]

Substituting

\[ H = A_1 + \beta_1 (A_2 + \alpha_1 HS + \alpha_2 C + \alpha_3 E) + \beta_2 (A_3 + \gamma_1 MM + \gamma_2 CS + \gamma_3 S) \]
\[ = A_1 + \beta_1 A_2 + \beta_1 \alpha_1 HS + \beta_1 \alpha_2 C + \beta_1 \alpha_3 E + \beta_2 A_3 + \beta_2 \gamma_1 MM + \beta_2 \gamma_2 CS + \beta_2 \gamma_3 S \]
\[ = A_1 + \beta_1 A_2 + \beta_2 A_3 + \beta_1 \alpha_1 HS + \beta_1 \alpha_2 C + \beta_1 \alpha_3 E + \beta_2 \gamma_1 MM + \beta_2 \gamma_2 CS + \beta_2 \gamma_3 S \]

let

\[ A_1' = A_1 + \beta_1 A_2 + \beta_2 A_3 \]
\[ \beta_1' = \beta_1 \alpha_1 \quad \beta_3' = \beta_2 \gamma_1 \]
\[ \beta_2' = \beta_1 \alpha_2 \quad \beta_4' = \beta_2 \gamma_2 \]
\[ \beta_3' = \beta_1 \alpha_3 \quad \beta_5' = \beta_2 \gamma_3 \]
then
\[
H = A_1' + \beta_1' HS + \beta_2' C + \beta_3' E
+ \beta_4'MM + \beta_5'CS + \beta_6'S
\]
So \( H \) is a linear function of the new exogenous variables.

An alternative non-linear model can be derived from the multiplicative function given above. Assume
\[
H = A_1 IP \sigma_1 MS \sigma_2
\]
\[
IP = A_2 HS \sigma_3 C \sigma_4 E \sigma_5
\]
\[
MS = A_3 MM \sigma_6 CS \sigma_7 S \sigma_8
\]
Then by substitution
\[
H = A_1 (A_2 HS \sigma_3 C \sigma_4 E \sigma_5) (A_3 MM \sigma_6 CS \sigma_7 S \sigma_8)
= (A_1 A_2 A_3) (HS \sigma_3 C \sigma_4 E \sigma_5 MM \sigma_6 CS \sigma_7 S \sigma_8)
\]
let
\[
A'_1 = A_1 A_2 A_3
\]
then
\[
H = A'_1 HS \sigma_3 C \sigma_4 E \sigma_5 MM \sigma_6 CS \sigma_7 S \sigma_8
\]
Again, the health output variable is a function of the exogenous variables of the illness pattern and medical service functions.

One can, of course, develop an even richer model by taking into account the dependence of the six current exogenous variables on others. From section II of this report it is clear that the variables HS, C and E, as well as the input variables of the medical services function, are determined by a complex interaction of other factors. For example, the health stock depends upon age, sex, genetic and historical experience variables. By expressing these dependencies in mathematical form and
substituting as above a revised, more complicated model is determined. In practice, the choice of degree of complexity is often determined by the availability of data. With respect to the Soviet health production this issue is discussed in the following section.

Two models were specified to carry out the first econometric investigations of health production. The first of these is linear and is in the spirit of the one proposed by Dutton in his analysis of recent Soviet mortality trends. (7) This author hypothesized that variation in regional-level crude mortality rates was a linear function of variables of alcohol consumption, age, sex, education, population density, rural population share, provision of doctors and nationalities. A weighted least squares procedure was used to estimate parameters.

In order to test the utility of the linear model in describing health production in the USSR a function was chosen of the form

\[ H = A + \sum_{j=1}^{M} \beta_j M_j + \sum_{j=M}^{N} \beta_j X_j + \epsilon \]

where

- \( H \) = health output
- \( A \) = constant
- \( \beta_j \) = coefficients
- \( M_j \) = medical service variables (\( j = 1 \ldots m \))
- \( X_j \) = health condition variables (\( j = m \ldots n \))
- \( \epsilon \) = random error term

The precise nature of the variables and the data used in estimation is described below.
The second model has a multiplicative production function. A model of this type was used by Auster et. al. to analyze variation across states in the U.S. of age-sex-adjusted mortality rates. (1) Their model was of the form described above.

\[ H = A M \sigma_0 \prod_{j=1}^{9} \frac{\sigma_j}{\sigma_0} X_j e \]

where

- \( H \) = age-sex-adjusted mortality
- \( A \) = constant
- \( M \) = medical expenditure per capita
- \( \sigma_0 \) = elasticity of \( H \) with respect to \( M \)
- \( \prod \) = multiplicative index
- \( X_j \) = health environment variables
- \( e \) = exponential
- \( \varepsilon \) = random error term.

A logarithmic transform was used to put this function into linear form

\[ \ln H = a + \sigma_0 \ln M + \sum_{j=1}^{9} \sigma_j \ln X_j + e \]

where \( a = \ln A \)

The method of two-stage least squares was then used to estimate the constant and the elasticities.

A multiplicative model very similar to that of Auster et. al. was specified for the health production process in the USSR. The variables chosen are described in the next section.
4. Choice of Variables and Availability of Data

To estimate the parameters of the two models measureable endogenous and exogenous variables must be chosen and appropriate data gathered. Given the limited information published in the U.S.S.R. the selection of model variables inevitably involves compromise. This section discusses the choices made and presents the data used.

The problem under investigation is that of explaining rising mortality (or falling life expectancy) over the period 1959-76 in the USSR. The appropriate data for estimating the models are therefore time series. However, it would be of interest at a later date to analyze regional mortality variations using cross-section data.

The variables for which time series data are desired are those associated with health output, illness pattern and medical services.

**Health Output**  Several mortality-based indicators were considered as candidates for the output indicator: crude mortality, age-sex-specific mortality, life expectancy, sex-specific life expectancy. It was decided that the best dependent variable for this investigation would be male life expectancy. Data for the years 1959-1969 were obtained from a published U.S. Bureau of the Census document.\(^2\) Supplemental information was obtained directly from Godfrey Baldwin. The series is shown in column 2 of Table 1.

**Medical Services**  Ideally one would like a variable which measures the output of a medical service production function. In natural terms this could be a weighted index measure of provision of bed-days and outpatient consultations. Alternatively Auster et. al. chose as a summary variable expenditures on medical care. To date the necessary production function
<table>
<thead>
<tr>
<th>Year</th>
<th>Male Life Expectancy (years)</th>
<th>Number of Doctors per 10,000 population</th>
<th>Annual per capita meat consumption (Kilograms)</th>
<th>Age of population over age 15 with higher secondary education (years)</th>
<th>Total Cigarette and Cigarette Butts Produced (Billions)</th>
<th>Annual per capita consumption of alcohol (Liters)</th>
<th>Total population in urban areas (in 1000)</th>
<th>Total population per capita (in 1000)</th>
<th>Total population available for consumption of alcohol (in 1000)</th>
<th>Population in housing space (in 1000)</th>
<th>Population in housing space (in 1000)</th>
<th>Population in housing space (in 1000)</th>
<th>Population in housing space (in 1000)</th>
<th>Population in housing space (in 1000)</th>
<th>Annual production of motor vehicles (thousands)</th>
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<td>11.9</td>
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<td>6.7</td>
<td>61</td>
<td>6.7</td>
<td></td>
</tr>
</tbody>
</table>

*Interpolated
**Extrapolated

Table 1: Data Used in Parameter Estimation
analysis of the health sector has not been carried out. Accordingly a proxy variable was chosen: the number of doctors per 10,000 population (See column M of Table 1). Since this indicator is of fundamental importance in Soviet health planning, its trends probably reflect those of the health system in general. It is therefore an acceptable variable for these first econometric exercises.

**Illness Pattern** In section II.2 of this report trends in Soviet health conditions and the illness pattern are surveyed. It is noted there that there has been insufficient analysis of the structure of Soviet illness and therefore summary variables are unavailable. To continue the quantitative analysis one must assume that the illness pattern is a linear or multiplicative combination of health stock, consumption and environmental variables, and then attempt to gather data on these secondary variables. This strategy was adopted for the project work.

**Health Stock** Because the output indicator is male life expectancy neither age nor sex distribution variables are relevant. It was assumed that there were no significant changes in genetic stock and that historical experience variables were neutral. Thus there are no health stock variables in the model.

**Consumption** Conventional economic measures of income and consumption were eliminated from consideration as variables because they do not express the ambiguity of the consumption-health status relationship. Both positive and negative health effects should be included in any model. To this end the four consumption variables shown in Table 1 were chosen. Per capita meat consumption ($X_1$) reflects the improvement in the average Soviet diet over the past two decades. The rise in the general educational
standard of the population, measured by $X_2$, should also exert a beneficial impact on health status. On the other hand, cigarette smoking and drinking alcohol are unhealthy habits. The time series of variables $X_3$ and $X_4$ suggest that both forms of consumption have significantly increased.

Environment No adequate summary indicators of the health environment in the USSR are given. Again one must consider the variables determining the values of the environmental influence function in order to find published data.

The environment was shown above to consist of five dimensions. In the models of this study the residential environment is measured by housing space per capita ($X_5$) and per cent urban population ($X_6$). Trends in the family health environment are assumed to be reflected by the rate of net family formation. In this case there is little doubt that one could think of better variables, but for few of the alternatives would one be able to find published data.

Section II.2.d argued that the rapid mechanization of Soviet society and the rapid growth in chemical and automobile production are having adverse health consequences for the population. Variables $X_8$ and $X_9$ are assumed to measure important developments in the technological and natural environments. One would expect the large increases in both indicators to undermine health status.

One approach to measuring the influence of the microbiological environment would be to use a dummy variable for influenza epidemics. It was decided, however, to assume that no significant changes had occurred in this dimension. Given this it was not necessary to specify a microbiological variable.
Examination of the time series data in Table 1 reveals that trends in most variables are similar, presumably reflecting the general economic and social development of the USSR over the period 1959-76. Ideally one would want to 'smooth' these series, using various adjustment techniques, before estimating parameters. However, time constraints of the project did not allow this additional work to be done. Therefore the estimation was based on unadjusted data.

5. Estimation of the Models and Econometric Results

With the general forms of the models and the variables chosen, and the data gathered, it is possible to proceed with estimation. The two models to be estimated are:

\[(1) \ H = \alpha + \beta_0 M + \sum_{j=1}^{g} \beta_j X_j + \varepsilon\]

The data on the endogenous variable (H) and the exogenous ones (M, X_j) are given in Table 1.

From the multiplicative model

\[H = \alpha M \prod_{j=1}^{g} X_j^\sigma \varepsilon\]

the logarithmic one is derived.

\[(2) \ \ln H = a + \sigma_0 (\ln M + \sum_{j=1}^{g} \sigma_j \ln X_j) + \varepsilon\]

The data on these variables is obtained by taking the logarithms of the time series in Table 1.

The usual degrees of freedom and rank assumptions about the linear equations are made. These require that the number of data points be greater than that of the parameters to be estimated and that the explanatory variables be linearly independent. With respect to the error term it is assumed to be normally distributed with zero mean, stable finite variance (homoskedasticity) and zero covariances (absence of serial correlation).
Estimation was carried out using CORR, GLM and SYSREG programs from SAS (Statistical Analysis System).* The computational work was done at the Harvard University Computing Center in September 1980.

The first step involved estimation of correlation coefficients between variables. The results for equation (1) are shown in Table 2 (The correlation matrix for the variables in logarithmic form is approximately the same):

Table 2: Correlation Coefficients of Variables in Model (1)

<table>
<thead>
<tr>
<th>Variables</th>
<th>H</th>
<th>M</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>1.00</td>
<td>-0.70</td>
<td>-0.81</td>
<td>-0.74</td>
<td>-0.68</td>
<td>-0.73</td>
<td>-0.68</td>
<td>-0.71</td>
<td>0.02</td>
<td>-0.80</td>
<td>-0.82</td>
</tr>
<tr>
<td>M</td>
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<td>1.00</td>
<td>0.96</td>
<td>0.99</td>
<td>0.97</td>
<td>0.98</td>
<td>0.99</td>
<td>0.99</td>
<td>-0.62</td>
<td>0.99</td>
<td>0.93</td>
</tr>
<tr>
<td>X1</td>
<td>-0.81</td>
<td>0.96</td>
<td>1.00</td>
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<td>0.93</td>
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<td>0.96</td>
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<tr>
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<tr>
<td>X4</td>
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<td>1.00</td>
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<td>0.99</td>
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<td>0.99</td>
<td>0.96</td>
<td>0.99</td>
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<tr>
<td>X6</td>
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<td>-0.57</td>
<td>-0.64</td>
<td>-0.66</td>
<td>-0.64</td>
<td>1.00</td>
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<tr>
<td>X8</td>
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<td>0.97</td>
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<td>-0.51</td>
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</table>

It shows that virtually all variables are highly correlated, with the exception of X7 (family formation). This confirms the impressions based upon visual inspection (pg. 62) and points to the necessity of adjusting the series to remove 'social progress' trends. Analysis of the relationships between variables also suggests the existence of multicollinearity. For example the growth in automobile production (X9) has undoubtedly caused an increase in the output of

petroleum products (X8). Thus these two variables are not independent. Other
causal relationships probably exist between alcohol consumption (X4) and family
formation (X7) and between urbanization (X6) and educational standards (X2).
Indirect causal links may also exist which would produce correlated movements in
time series. The development of agriculture obviously affects per capita meat
consumption (X1), cigarette production (X3) and alcohol consumption (X4). Similarly,
the expansion of Soviet industry strongly influences variables X5, X8 and X9.
Thus the correlation analysis raises questions not only about the use of unad-
justed data, but also about the specification of the model.

The results of the econometric estimations are shown in Table 3:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>77.54</td>
<td>17.59</td>
<td>4.41</td>
</tr>
<tr>
<td>M</td>
<td>.60</td>
<td>.41</td>
<td>1.48</td>
</tr>
<tr>
<td>X1</td>
<td>.15</td>
<td>.15</td>
<td>1.02</td>
</tr>
<tr>
<td>X2</td>
<td>-.06</td>
<td>.05</td>
<td>-1.15</td>
</tr>
<tr>
<td>X3</td>
<td>.01</td>
<td>.01</td>
<td>.99</td>
</tr>
<tr>
<td>X4</td>
<td>-.75</td>
<td>.70</td>
<td>-1.06</td>
</tr>
<tr>
<td>X5</td>
<td>.08</td>
<td>1.54</td>
<td>.05</td>
</tr>
<tr>
<td>X6</td>
<td>-.02</td>
<td>.42</td>
<td>-.06</td>
</tr>
<tr>
<td>X7</td>
<td>-.47</td>
<td>.25</td>
<td>-1.86</td>
</tr>
<tr>
<td>X8</td>
<td>.11</td>
<td>.26</td>
<td>.45</td>
</tr>
<tr>
<td>X9</td>
<td>-.003</td>
<td>.003</td>
<td>-.85</td>
</tr>
</tbody>
</table>

Table 3: Econometric Estimates of the Parameters of Models (1) and (2)

<table>
<thead>
<tr>
<th>Model</th>
<th>$H = A + \sum_j \beta_j X_j + \epsilon$</th>
<th>$\ln H = a + \sum_j \ln \beta_j \ln X_j + \epsilon$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>.94</td>
<td>.95</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>t Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.47</td>
<td>1.42</td>
<td>4.55</td>
</tr>
<tr>
<td>$\ln M$</td>
<td>.18</td>
<td>.10</td>
<td>1.69</td>
</tr>
<tr>
<td>$\ln X_1$</td>
<td>.13</td>
<td>.08</td>
<td>1.60</td>
</tr>
<tr>
<td>$\ln X_2$</td>
<td>-.55</td>
<td>.26</td>
<td>-2.10</td>
</tr>
<tr>
<td>$\ln X_3$</td>
<td>.06</td>
<td>.04</td>
<td>1.28</td>
</tr>
<tr>
<td>$\ln X_4$</td>
<td>-.10</td>
<td>.08</td>
<td>-1.35</td>
</tr>
<tr>
<td>$\ln X_5$</td>
<td>.02</td>
<td>.33</td>
<td>.07</td>
</tr>
<tr>
<td>$\ln X_6$</td>
<td>-.01</td>
<td>.31</td>
<td>-0.02</td>
</tr>
<tr>
<td>$\ln X_7$</td>
<td>-.05</td>
<td>.02</td>
<td>-2.25</td>
</tr>
<tr>
<td>$\ln X_8$</td>
<td>.07</td>
<td>.08</td>
<td>0.97</td>
</tr>
<tr>
<td>$\ln X_9$</td>
<td>-.04</td>
<td>.03</td>
<td>-1.13</td>
</tr>
</tbody>
</table>
The $R^2$ statistic, a measure of total variation explained by the model, is high in both cases: 0.94 and 0.95. The F tests show that the hypothesis that all coefficients are zero can be rejected with a very high level of confidence. However, these results are not meaningful in isolation. To properly evaluate the adequacy of the estimated model the parameters must be examined closely.

The estimated parameters are shown in columns 2 and 6. The signs of six out of the ten parameters are as expected. The variable M (doctors per 10,000) has a positive influence on life expectancy whereas alcohol consumption has a negative effect. Looking further, though, it is evident that the standard errors are relatively large and the t-ratios small. Consequently the t-tests of the parameter estimates do not show them to be statistically significant.

This outcome, in conjunction with the high $R^2$ for the model as a whole, indicates the presence of multicollinearity. To correct this problem would require re-specification of the models, removing linearly dependent variables, as well as data supplementation.

Questions about the specification of the model and the influence of unobserved variables suggest that the assumption of independent stochastic disturbance terms may not be justified. Therefore the Durbin-Watson test for serial correlation was carried out. The Durbin-Watson statistics are 2.71 for the linear model and 2.57 for the log-linear one. These values indicate the presence of negative first-order serial correlation. To treat this problem one would want to redefine the model so that possible hidden explanatory variables were included.

In light of the linear dependence of some variables in the model one final econometric exercise was to employ stepwise linear regression to find the most parsimonious model. The SAS STEPWISE program with option MAXR (maximum $R^2$ improvement) was used. This shows that a five variable model could be chosen with an $R^2$ of 0.93 in the linear case and 0.92 in the log-linear.
The econometric evaluation of the estimated model reveals that little confidence can be placed in the parameters. Therefore any attempt to analyze the structure of the Soviet health production process using these estimates would be speculative and ill-founded. Additional research clearly must be done in the areas of data collection and treatment, and of model construction. However, the project period ended before this supplemental work could be accomplished. Econometric modelling of the health production process in the USSR will undoubtedly become a component of a future research program.

6. Summary and Conclusions

During summer 1980 research commenced on econometric modelling of the Soviet health production process. Previous health economics literature was examined and two models of life expectancy determination were chosen. Available Soviet time series were surveyed and measureable explanatory variables identified. Data were gathered from various sources and parameters of the models estimated. Although statistical evaluation of the econometric results indicates several problems with these first variant models, the theoretical approach appears to be sound. Therefore work will continue in this area. An attempt will be made to build upon the research foundation laid during the period of my participation in the National Council project and to eventually develop a reliable econometric model of the Soviet health sector which can be used for structural analysis, projection and policy evaluation.


18. Tsentral'noye Statisticheskoye Upravleniye SSSR Narodnoye Khozyaistro SSSR v...., Moscow, Statistika, Various years.


1. R. Auster, I. Leveson, D. Sarachek 'The production of health, an exploratory study' in ref. 11.


