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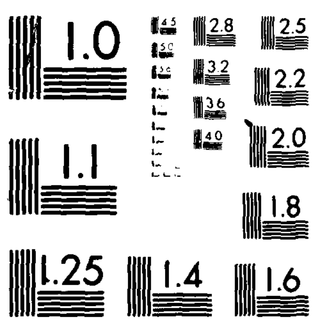
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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER AFIT/GOR/OS/81D-8	2. GOVT ACCESSION NO. AD-A111 441	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A HEURISTIC MODEL FOR EVALUATING SENSITIVITY TO LABOR AND CAPITAL INPUTS, ALLOCATIONS, AND GROWTH RATES IN A FOUR-SECTOR SOVIET ECONOMY FOLLOWING A NUCLEAR ATTACK		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Edward J. Perry II, Captain		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology(AFIT-EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE December 1981
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

FEB 22 1982

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release; IAW AFR 190-17

Frederick Lynch, Major, USAF 28 JAN 1982

Director of Public Affairs

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

USSR Economic Recovery
Postattack Recovery
Economic Recovery Modeling

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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A HEURISTIC MODEL FOR EVALUATING SENSITIVITY TO LABOR AND CAPITAL INPUTS, ALLOCATIONS, AND GROWTH RATES IN A FOUR-SECTOR SOVIET ECONOMY FOLLOWING A NUCLEAR ATTACK

THESIS

AFIT/GOR/OS/81D-8 Edward J. Perry II
Capt USAF

AFIT/GOR/OS/81D-8

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Edward J. Perry II
Capt USAF
Graduate Operations Research

December 1981

Approved for public release; distribution unlimited.

Preface

The purpose of this paper was to develop a detailed model of the Soviet effective labor force as determined by educational attainment and integrate these results with a four-sector model of the Soviet economy. Data is set in the model based on a hypothetical nuclear attack and economic recovery rates are predicted.

The study is an extension of work done by Major Robert J. Wasilewski in his thesis in 1979. Both the education model and economic growth model have been expanded. This model should provide further insight into the subject of targeting strategies and the effect of skilled labor losses on economic recovery.

I wish to thank Dr. Joseph Cain, my thesis advisor, for his help in clarifying the economic issues involved in this study and for his encouragement and advice throughout this effort.

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Abstract

This research was conducted to investigate the sensitivity of economic growth in the USSR to key parameters in the sectoral production functions. A simulation of the Soviet education system is linked to a four-sector growth model of the Soviet Union. School graduates enter the labor force by planned allocation to each sector. Capital requirements are determined for each sector and an iterative procedure is used to determine aggregate GNP. Results of the sensitivity analysis show a decisive link between defense spending and growth as well as prediction of growth rates following a nuclear war. Additionally, sensitivity to capital growth and distribution is demonstrated.

A HEURISTIC MODEL FOR EVALUATING SENSITIVITY TO LABOR AND CAPITAL INPUTS, ALLOCATIONS, AND GROWTH RATES IN A FOUR-SECTOR SOVIET ECONOMY FOLLOWING A NUCLEAR ATTACK

I. INTRODUCTION

In the event of a war, the real economic output of a nation will be lowered due to a loss of capital and labor. If the use of nuclear weapons occurs, it can be assumed that the loss of human life and production facilities will be greatly magnified. Economic recovery from such a catastrophe will be greatly influenced by the growth of the labor force. Growth in the labor force is dependent not only upon the net reproduction rate of the population (birth rate - death rate) but also upon the skill levels embodied in the labor force and upon the distribution of labor by skills across the major sectors of the economy. Labor skills depend on the level of education and on-the-job-training. The major sectors of an economy can be grouped into four categories: industrial, agricultural, construction, and transportation and communication.

Major Robert J. Wasilewski, AFIT/GST/79M (Ref 20) investigated the impact of the loss of skilled labor after a nuclear attack and the subsequent economic recovery in the industrial sector of the Soviet Union. It was shown that the different labor skills survival rates have a significant impact on economic recovery. Due to time limitations and in consideration of the fact that Wasilewski's effort was the first of its nature, several limiting assumptions were made. Among these assumptions was that the labor force is divided into three groups based strictly on education level. Secondly, only recovery in the industrial sector was modeled. Of a less important nature, but still significant, was that residual effects of the nuclear blasts were not considered.

Problem Statement

A model which considers the economic recovery of the Soviet Union after a nuclear attack has not been developed to a refined enough stage to be of significant use in targeting strategy planning. The purpose of this research is to develop a model which will be useful in analyzing sensitivity to the key parameters which influence growth in the Soviet economy.

Approach

A model of the Soviet educational system is developed using the Q-GERT simulation language. Length of time in the process and Soviet planning goals are incorporated and this model is linked to a four-sector model for estimating economic growth.

More specifically, length of time in the process refers to the time required to complete a particular phase of education. Three levels of education are considered which roughly equate to elementary school, secondary and college. Allocation of labor to the four economic sectors is made from each education level and according to a hypothetical

Soviet plan.

Utilizing a four-sector break out of the economy permits analysis of possible effects on economic growth of channeling capital and labor into a specific sector. Also, linking particular labor skills to specific economic sectors will lead to an understanding of the extent of economic damage imposed by striking a particular target area.

Finally, residual blast effects are incorporated in the model in order that a more accurate assessment be made of the actual rate of economic growth. Undoubtedly, these residual effects will retard growth, but to what extent is the question that is addressed.

Goal

The goal of this study is to determine the effect on Soviet economic recovery following a nuclear attack utilizing a four-sector economic model while explicitly modeling the production of human capital. Expansion of Wasilewski's central concept to allow for more variable input and the resulting control over the model will permit greater flexibility in sensitivity analysis. This model can then be used to evaluate economic growth after a nuclear attack along with sensitivity to changes in Soviet planning. The next chapter reviews the literature on Soviet growth philosophy.

II. REVIEW OF LITERATURE

This chapter reviews the philosophy of growth in the Soviet planned economy. Findings on the interrelation between the education systems and the labor force are presented. Capital growth projections are given and finally Wasilewski's nuclear damage model is reviewed.

Soviet Growth Philosohpy

In the Soviet Union, the crucial economic decisions - the allocation of output among consumption, investment, and defense and the rates of expansion of different sectors are made administratively (i.e. by central planning), not by the market forces (Ref 11:116). This is what will make the model unique from the perspective we are accustomed to viewing the U.S. economy.

The Soviets develop 5-year plans from which guidance is ascertained for all businesses. The centralized planning system was born during the period of the first 5-year plan, around 1929 - 32 (Ref 15:17). To emphasize the importance of this plan,it is noted that Stalin said this was no longer a plan forecast or plan-guess-timate, this was a compulsory, directive plan with the force of law. Much has changed since then - the Soviet economy has grown much larger and more highly developed. There have been repeated reorganizations of the administrative structure and new techniqes of planning have been devised. None the less, the essential principles of its operation were established by 1932 and remain little changed still today (Ref 15:18).

Education System

Over the past 30 years, economic requirements have played an important role in the development of the Soviet educational system. The rapidly developing postwar economy of the 1950's demanded a skilled labor force that could only be provided by expansion of educational opportunities (Ref 14:1).

Soviet children begin their primary education (grades one through three) at age seven and progress automatically into the incomplete secondary education program (grades four through eight). Graduates of the secondary school are then eligible to enroll in higher education (Ref 14:2). This system is not unlike that in the U.S. as can be seen in Figure 1.

Labor

Educational progress improves the quality of labor by increasing an individual's ability to contribute to production and thereby to increase his earnings (Ref 14:11). Based on this assumption, such noted economists as Abram Bergson and Stanley Cohn have developed weighting schemes to combine individuals with different education levels into an effective labor force. Wasilewski uses this concept by comparing average wages for each education level (Ref 20:63). If L_1 is the labor of the elementary education level, L_2 labor from high school, L_3 labor from the college level and W_1, W_2, W_3 their respective wages then the effective labor can be considered as:

$$L = \frac{W_1}{W_1} L_1 + \frac{W_2}{W_1} L_2 + \frac{W_3}{W_1} L_3 \qquad (1)$$

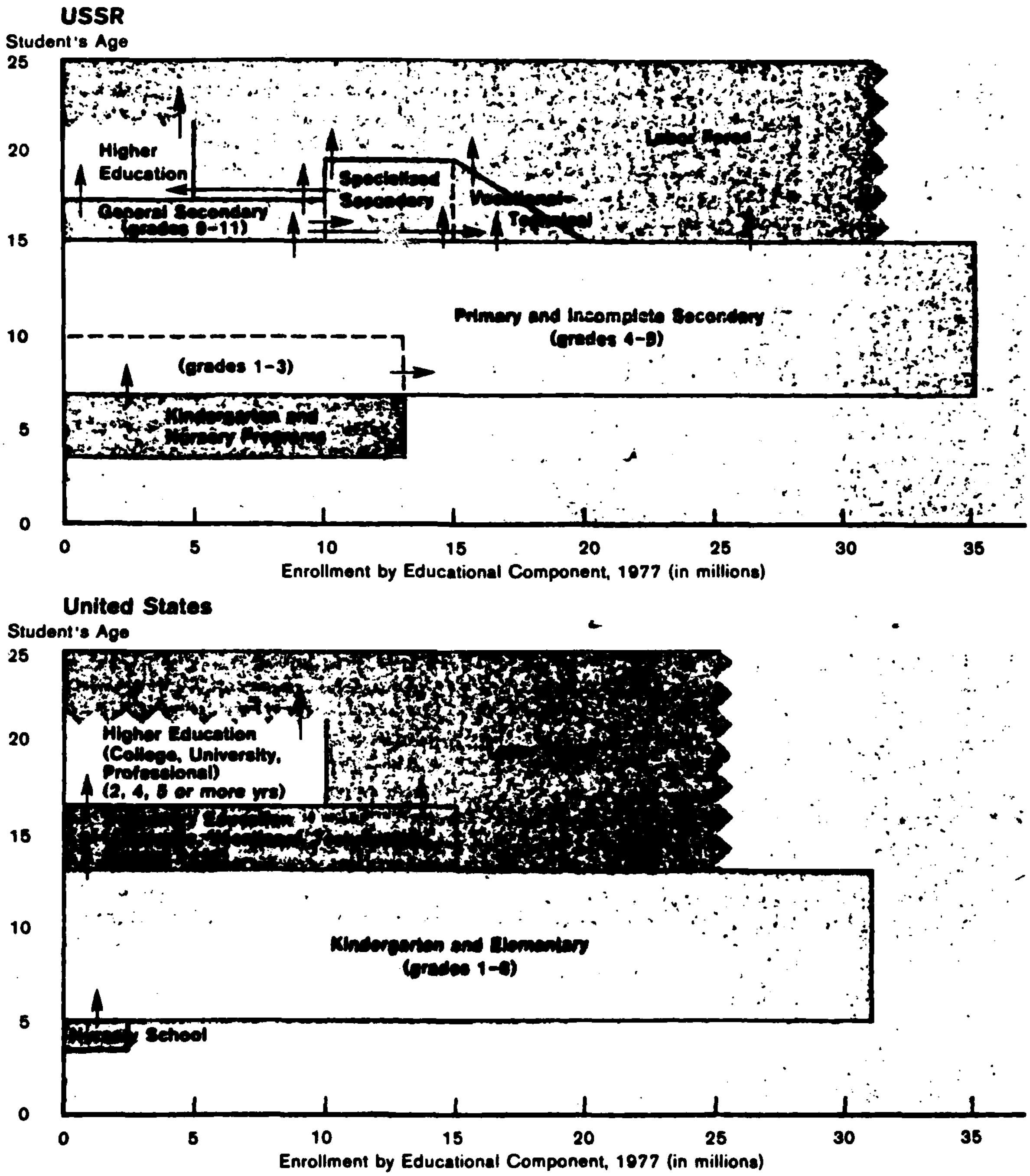

Figure 1. The Structure of Education in the Soviet Union and the United States (Ref 14:3)

Determination of labor staffing is part of the planning process just as much so as the use of capital (Ref 11:194). In direct contrast to a market economy such as in the U.S., the planned economy of the USSR permits some control over the education of individuals and their eventual work place. This is why it is important to consider how many graduates there are from each education level and into what sector of the economy they enter the labor force.

Capital

Increase in the capital stock is equal to gross investment minus depreciation or in other words net investment. The amount of capital in each sector plays a major role along with the labor force in determining output. Capital growth is at about 5% annually according to Desai (Ref 5:409) although,Wasilewski used a 10% per year growth rate (Ref 20:64). To complicate the matter further,growth is assumed by Bergendorff to be 20% per year (Ref 1). All of these growth rates are addressed in this study.

Nuclear Damage

Wasilewski develops and explains a damage model based on targeting the 200 largest cities in the Soviet Union (Ref 20:59). Results indicate a 53% decline in output from the base values prior to the attack, 50.5% loss of capital and 50.2% loss in labor. Based on the 1970 Soviet census, 55.5% of the total urban population live in the 221 largest cities (Ref 13:124). This scenario is based upon attacking an "area" (i.e. a city) rather than a particular target (a missile silo or a factory). Even though nuclear targeting is probably not done this way, for simplicity, it is assumed in this study.

The model developed in this study allows for incorporating various damage results, but Wasilewski's results are used for illustration.

The next chapter discusses the education model that is used to generate the labor force.

III. EDUCATION MODEL

The purpose of this model is to simulate/describe the educational system of the Soviet Union so as to enable determination of labor force effectiveness in each of the four major economic sectors. Labor force effectiveness is determined by a weighting scheme based on level of education as described in Chapter II. The model outputs the number of each type labor according to education level in each of the four sectors: industrial, agriculture, transportation and communication, and construction. From this data the weighting scheme is applied and the data is used as input to a model for predicting growth in the Soviet economy. The ultimate purpose, then, is to demonstrate the influence of education on economic growth.

Since education institutions graduate classes on an annual basis, statistics are gathered yearly. Workers leave the labor force through retirement or death, thus, a 100 year simulation should give rise to somewhat of a steady state (i.e. a fairly stable rate of increase/decrease of labor in each sector each year). This depends on the starting levels which are left as a variable so as to aid in sensitivity analysis.

The Soviet education system consists of three levels much like the U.S. Schoolhouse 1 or education level one (EL_1) is the primary grades (elementary), education level 2 (EL_2) is the secondary (high school) and education level 3

(EL_3) is the higher grades (college). The process flow model (Figure 2) demonstrates the activity paths in the system.

Schoolhouse 1 draws its input from the population or perhaps more significantly from the number in the population having reached age 7. Graduates from each schoolhouse proceed to the next level of education or into the labor force. The labor force consists of four sectors: industrial (I), agriculture (A), transportation and communication (T), and construction (C).

Education can have a very positive effect on the growth of an economy. The population with higher education levels is more apt to be innovative, both in a technical and philosophical sense. These innovations will lead to easier, faster and more efficient means of production. It must be remembered, also, that an individual with a college education could be placed in a position requiring less skill but the opposite does not hold. That is, a high school graduate could hardly be expected to perform very well as a nuclear physicist.

With this background and the results of the model,it will be possible to study the effects of State policy on education, labor force, and ultimately economic growth. This type of analysis may be of particular concern when addressing the issue of targeting strategy say during a nuclear war. If one assumes that the majority of college graduates reside and work in urban areas and these people have a greater impact on economic growth,then it might be one good reason for targeting cities.

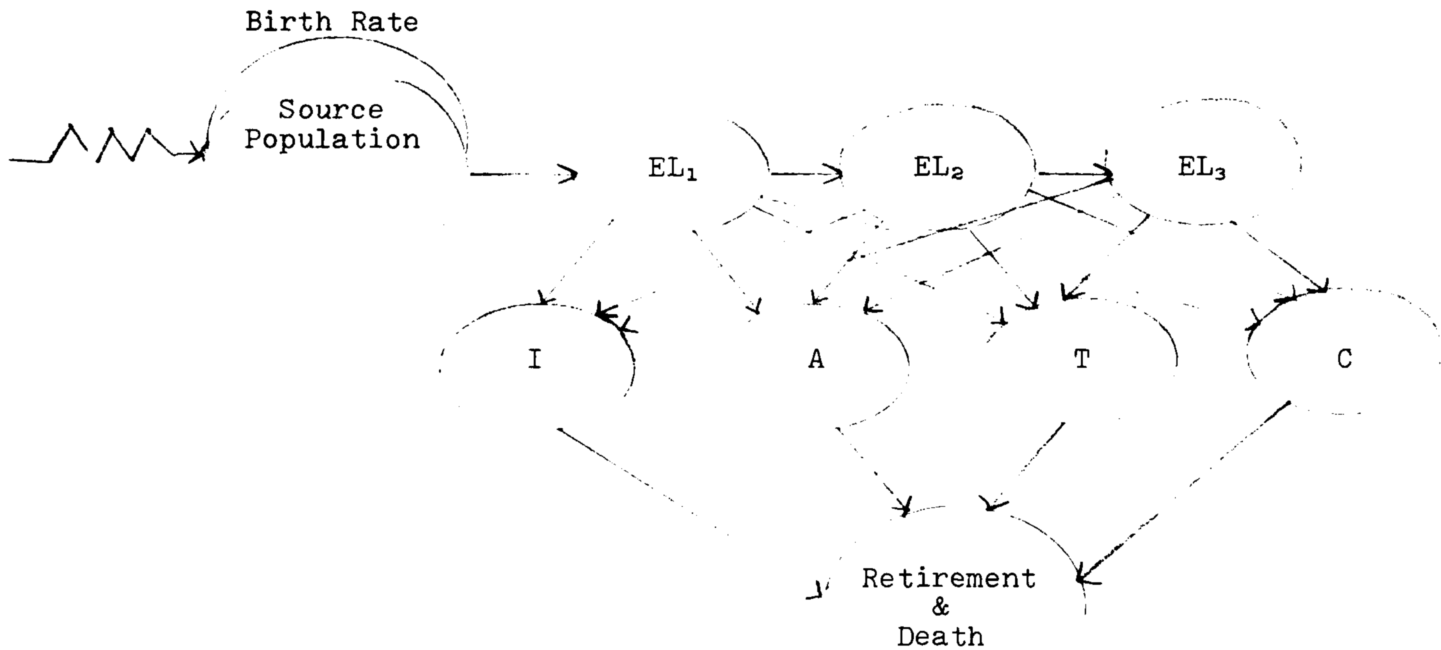

Figure 2. Process Flow

The model is designed to generate a flow into the education institution and then into the labor force. Inflow to education level 1 is through the birth rate and flows from that level forward are based on historical trends. Once the education process is complete, labor force entry is based on a priority basis as determined by the State. Desired levels of entry into each sector were determined somewhat arbitrarily, but quotas were kept realistic in that obviously impossible and impractical levels were not requested. Once the sector with priority 1 is satisfied, attempts are made to satisfy priority 2 and so on for each education level.

Sensitivity analysis can be performed on many different inputs to the education model alone, however, only one aspect was chosen for this study. It is considered that the percentage of high school graduates going on to college will impact the overall labor force structure. Therefore, separate runs of the model were made to determine the sensitivity of the makeup of the labor force to changes in the percentage of college entrants.

The model was run for 100 years with output for the first 25 years being ignored,* since it would take at least 23 years for the first group to graduate from college,

---

* the first year the data is output is actually the 26th year of the simulation

Structure and Variables

A QGERT simulation model of the education system was designed (Ref 16). A structural model along with variable definitions is given in this section. The next section gives a detailed description of the model.

Variable Definition

EL_i	-	education level i = 1,2,3; primary, secondary, and higher respectively
I	-	industrial (Major economic sectors)
A	-	agricultural (Major economic sectors)
T	-	transportation and communication (Major economic sectors)
C	-	construction (Major economic sectors)
L(J)	-	labor (number of workers) in sector J = I,A,T,C
$l_i(J)$	-	amount of labor with educational level i employed in sector J

Required Data

- Population by age
- Level of education by age and employment sector
- Current trends in education specialities (to determine sector of employment)
- Probability of traveling along each path in the system
- A distribution function for the birth rate
- Time in each schoolhouse (a constant)
- Time of service in each sector (which will be a factor of expected years until retirement and the death rate)

Inputs

Population
State Priorities
Initial # in each
Sector & educ. level

Probability of proceeding to next node
(Ed. level or Labor Force)

Birth Rate

Death Rate

Process

Simulate # of persons graduating from each educ. level and where they go

EL_1 - EL_2, I, A, T, C

EL_2 - EL_3, I, A, T, C

EL_3 - I, A, T, C

(see Figure 2)

Outputs

$L(I)^* = l_1(I) + l_2(I) + l_3(I)$

$L(A)^* = l_1(A) + l_2(A) + l_3(A)$

$L(T)^* = l_1(T) + l_2(T) + l_3(T)$

$L(C)^* = l_1(C) + l_2(C) + l_3(C)$

ENVIRONMENT

Figure 3. Structural Model

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* This is the total number of workers in the sector not the effective labor force as described in equation (1) page 5

QGERT Model Description

The QGERT Network[1] used to model this problem is included in Figures 4 - 7 . Appendix A contains the respective computer code listing. The meaning of this network, in relation to the Soviet education system and labor force is as follows. At node 1, one transaction is generated each year. One transaction represents the specific number of people travelling along a given path in the system (ex. number of students entering elementary school this year). Attribute 1 of this transaction is assumed to be the number of births in that year in thousands of people (normally distributed with mean 2200 and standard deviation 100).[2] Seven years later this transaction reaches node 2, where it splits into two transactions. One of these goes to node 3 - this represents those who enter the labor force directly from the 8 years of elementary school. Attribute 1 is changed at node 3 to reflect that this transaction represents 1% of the births of that year.[3] This means that 1% of the elementary school graduates do not enter secondary school (see page 35). Attributes 2,3,4, and 5, assigned at node 3, are the requirements for education level 1 workers by Industry, Transportation/Communication, Construction,

---

1 If Figures 4 - 7 are arranged in quadrant fashion 4|5 over 6|7 the whole network will fit together

2 See page 35 for a more detailed explanation of how these values were derived

3 Attribute values in QGERT are simply storage cells associated with transactions and may be redefined at any time

and Agriculture.[1] The other transaction from node 2 represents those who complete the 8 years of elementary school and go on to enter high school. Attribute 1 is changed at node 5 to 99% of the births. From node 5 (high school entrants), transactions go five ways. Four percent drop out the first year, 3% the second and 3% the third year of high school. These percentages are plausible assumptions based on data given in the CIA report (Ref 14) and are explained further on page 35. Attribute 1 (set of elementary educated population) is changed to reflect this at nodes 6,8, and 10, and the value is stored in a user function[2] at nodes 7,9, and 11. Each year these stored values are added into those entering the labor force directly from education level 1 at node 4. This means that high school dropouts are equivalent to elementary school graduates thus imparting a downward bias to the skill level of the labor force.

The transaction passing from node 5 to node 12 represents the 70% of high school students who graduate and enter the labor force (see page 35), and attribute 1 is adjusted for this. Attributes 2,3,4, and 5 are the requirements for high school students in the four sectors, as done at node 3. The transaction going from 5 to 14 represents those entering college; attribute 1 is decreased to 20%

---

1 The specific numbers and the rationale for choosing them is given on page 41

2 A user function is FORTRAN code which interfaces with QGERT to enable the user to store or manipulate values in a manner not possible with QGERT code

of itself at node 14. Four paths lead from node 14. Three of these represent dropouts; 10% drop out at each year. Transactions going to node 15 represent those dropping out the first year, second year dropouts go to node 17, and third year dropouts to node 19. The attributes are stored in nodes 16, 18, and 20, and are added into the high school graduates entering the labor force each year at node 13. Once agin this reinforces a downward bias in the effective labor force. The transaction going from node 14 to node 21 represents college graduates entering the labor force after 4 years. Seventy percent of those who entered college graduate; attribute 1 is adjusted for this at node 21, and attributes 2,3,4, and 5 represent the requirements for college graduates in each of the four levels as before.

The second main section of the network describes how the entrants into the labor force from each educational level are divided among the four economic sectors. The priority is the same for each education level; Industry gets the first choice, Transportation/Communication second, Construction third, and Agriculture fourth.* Since the procedure is identical for the three education levels, only the network at education level 3 (college) will be described.

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* This priority system is based upon the historical development of the Soviet economy as described by Gregory (Ref 11)

In order to set up the college graduates for assignment to the sectors it is necessary in the QGERT model for the transaction from node 21 (where the college graduates are accumulated) to pass through node 32 (to be described later), to node 22 (which is set up so that a conditional take first branch can be done).[1] If the number of people this transaction represents (contained in attribute 1) is less than or equal to the requirement for industry (in attribute 2), the transaction goes to node 23 where all the "people" are put in attribute 2 (number of education level 3 people assigned to industry) and attributes 3,4, and 5 (representing the number of college graduates assigned to the remaining sectors) are set to zero, and these values are stored in user function six.[2] Otherwise, the transaction goes to node 24, where the number of people required by industry (attribute 2) are subtracted out and the excess left in attribute 1. If the remaining people in this transaction (represented by attribute 1) is less than or equal to the requirement for Transportation/Communication (attribute 3), the transaction goes to node 25; here, the number of people going to T/C is set to the value of attribute 1 (unassigned college educated people), and the

---

1 This branching technique is designed so that the first path in which specified conditions are satisfied is taken

2 This stores the assigned graduates in an array (matrix) which is later added to the existing number of workers in each sector

number going to Construction in user function 6.

If attribute 1 is greater than attribute 3 at node 24, the transaction goes to node 26, where the requirement for Transportation/Communication is subtracted out. If the remainder is not greater than the requirement from Construction, the transaction goes to node 27. At this node, the remaining people are put in Construction, the number for Agriculture set to zero, and the values are stored in user function 6. Finally, if there are college graduates left after the requirements for Industry, Transportation/Communication, and Construction are filled, the transaction goes to node 28. Here, the requirement from Construction is subtracted out, the remainder is placed in attribute 5 - Agriculture - and these values are saved in user function 6. Note that the meaning of attributes 2,3,4, and 5 have changed; where before they were the requirements, they now represent the number of people entering the economic sector.

The third main part of the network describes the labor force itself. The purpose of this section is to add in the new graduates to the existing labor force and establish a cycle for subtracting those leaving the labor force through death or retirement. There are three sections, one for each education level. Again, the section for education level 3 (college graduates) will be described since the other two operate identically. Node 29 is an initialization node with attributes 2,3,4, and 5 representing the number of college graduates assumed to be in each economic sector.* After a .01 year delay (set to insure that this event occurs after the sectoral allocation of the graduates) the transaction is sent to node 30 where the college graduates of the current year are added to the existing education level 3 labor force in each sector.

User function 11 is now called so that the new labor force values can be printed out. At the same point user function 11 increments time by one year before moving to node 55. At node 55, the percent of the labor force that does not die or retire in a year is put in attribute 6 (1 - death/retirement rate which is explained on page 35) for use at node 31 where the population is reduced by the number of deaths and retirees. The transaction then goes back to node 30 where the next year's graduates are added in and the cycle begins again.

A few other things about the network should be noted. First,note the conditional branching (equivalent to a FORTRAN IF statement) at nodes 3,6,8,10,12,15,17,19, and 21. This causes no transactions to proceed beyond these nodes (drops them from the system) until after the 25th year; this is done to give those born in the first year time to complete college, so the rest of the simulation can start with entrants from all education levels. Second, note the branching from node 32 to nodes 29,40, and 51. This brings

* Starting values for each sector were determined from data in the CIA report (Ref 14). See page 36 for values and explanation.

the first transactions to these three nodes on the 26th year (first year used for output), at which time these nodes are used for one time only to place the initial values of the labor force matrix (page 36) in the system. Another thing to note is that the times on the "dropout" activities are .01 years short. This is done to insure that the attributes are stored in user function 2 before they are needed at node 4. The same reason applies to the 0.01 times on activities 26,32, and 37; it insures that the new entrants are stored in user function 6 before they are needed at nodes 30, 42, and 53. Last, note node 58 at the far right. This sink node is used to remove unneeded transactions from the system when they are no longer applicable to the model (i.e. those transactions generated in the previous year).

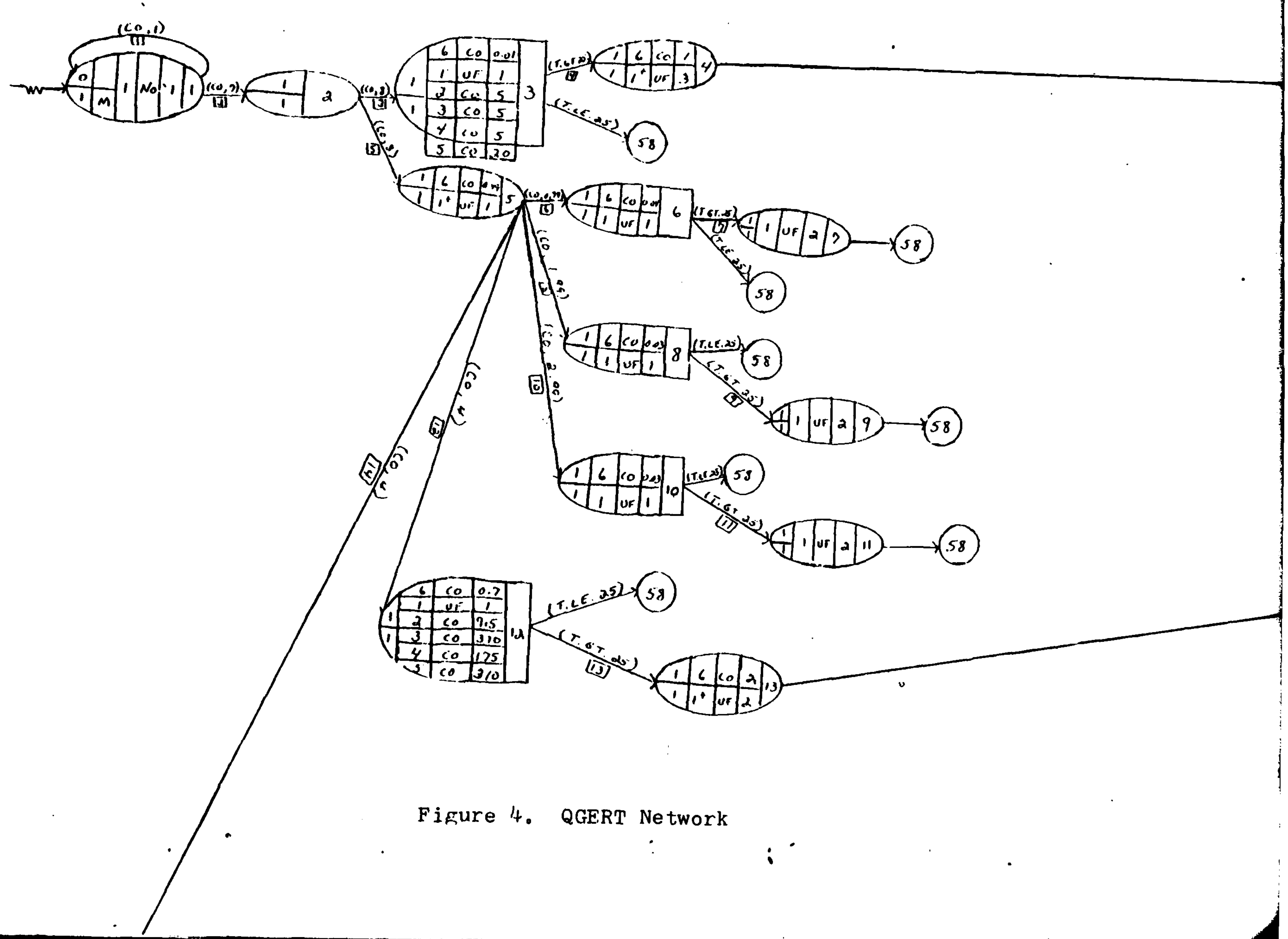


Figure 4. QGERT Network

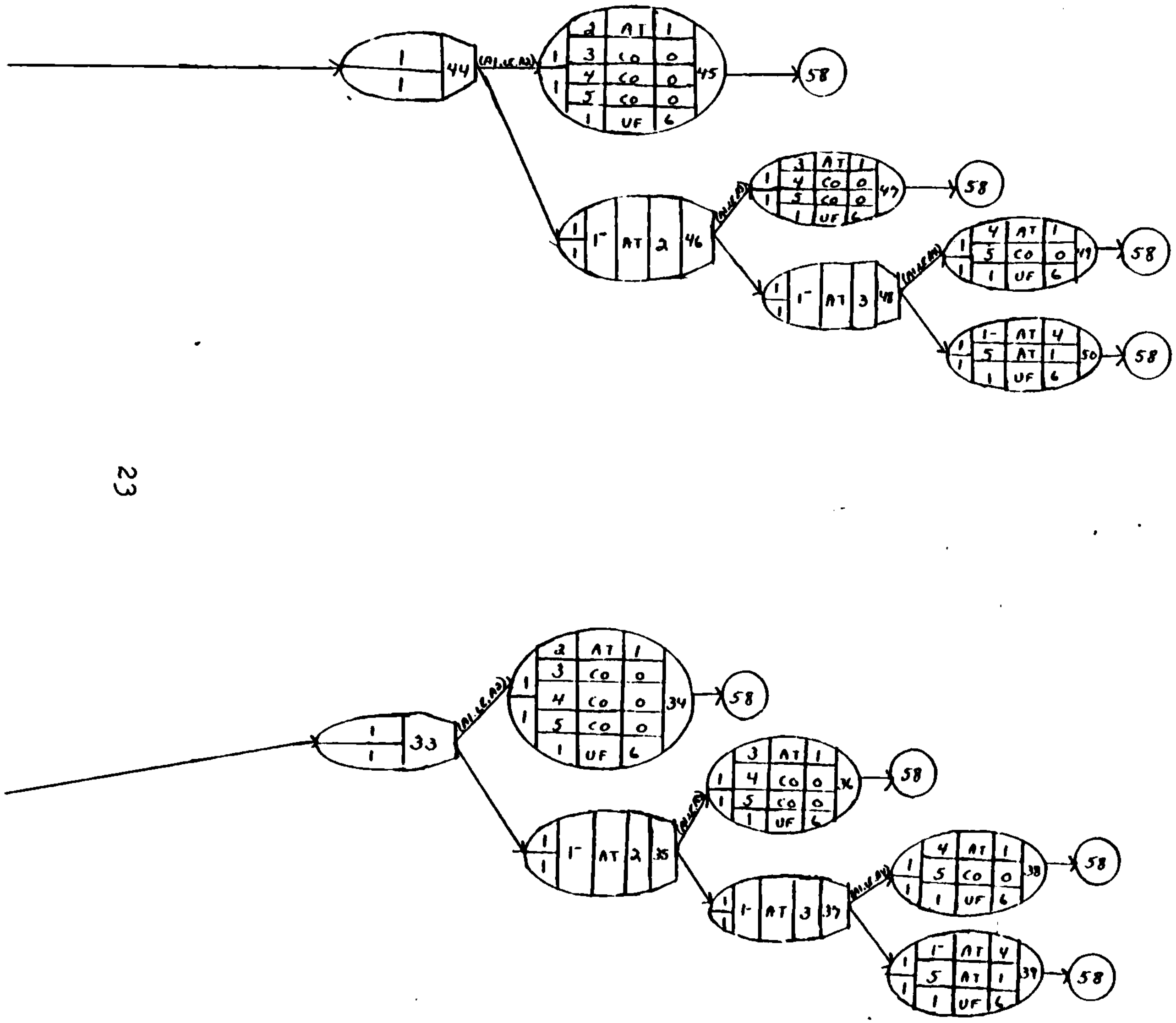


Figure 5. QGERT Network

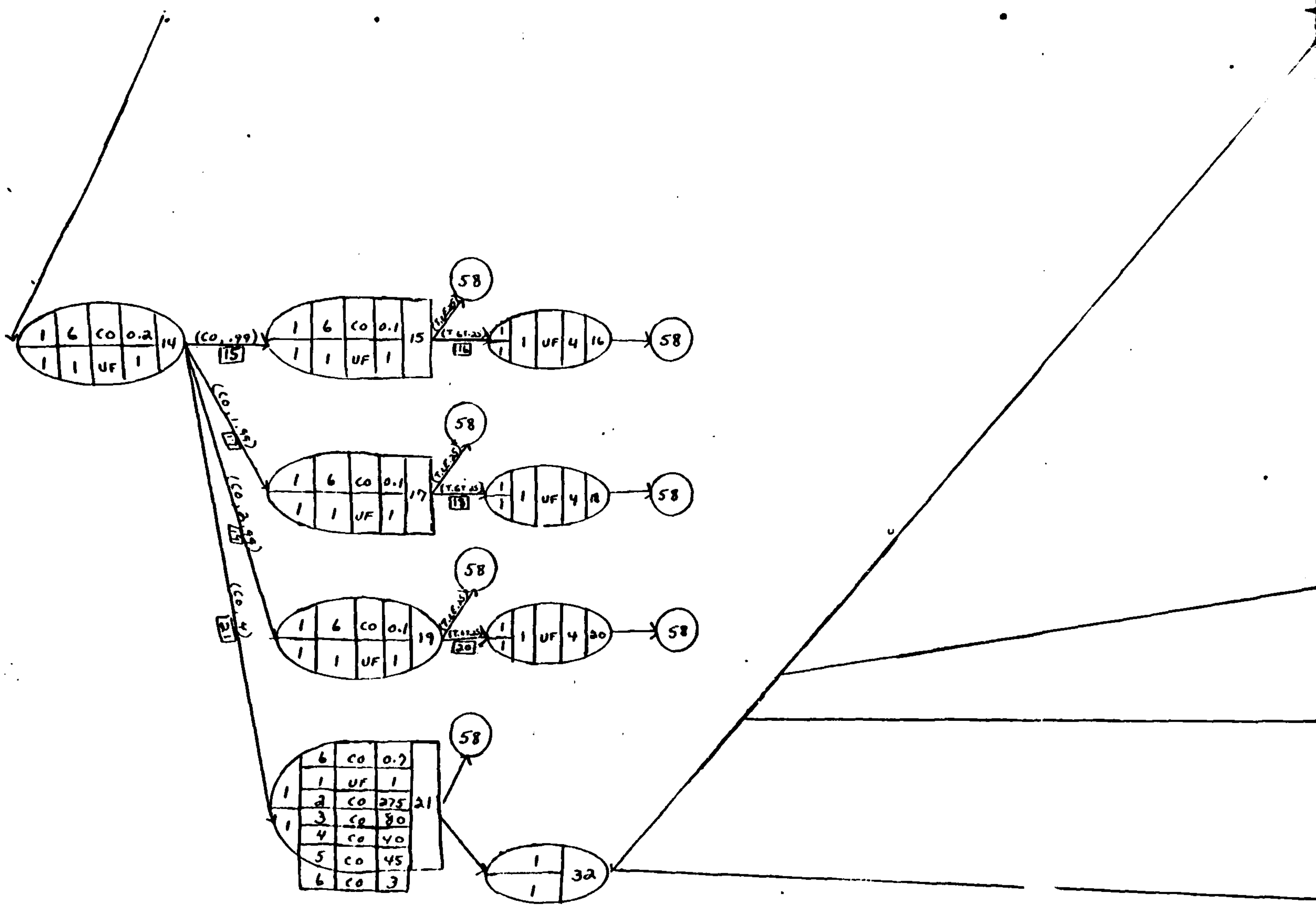


Figure 6. QGERT Network

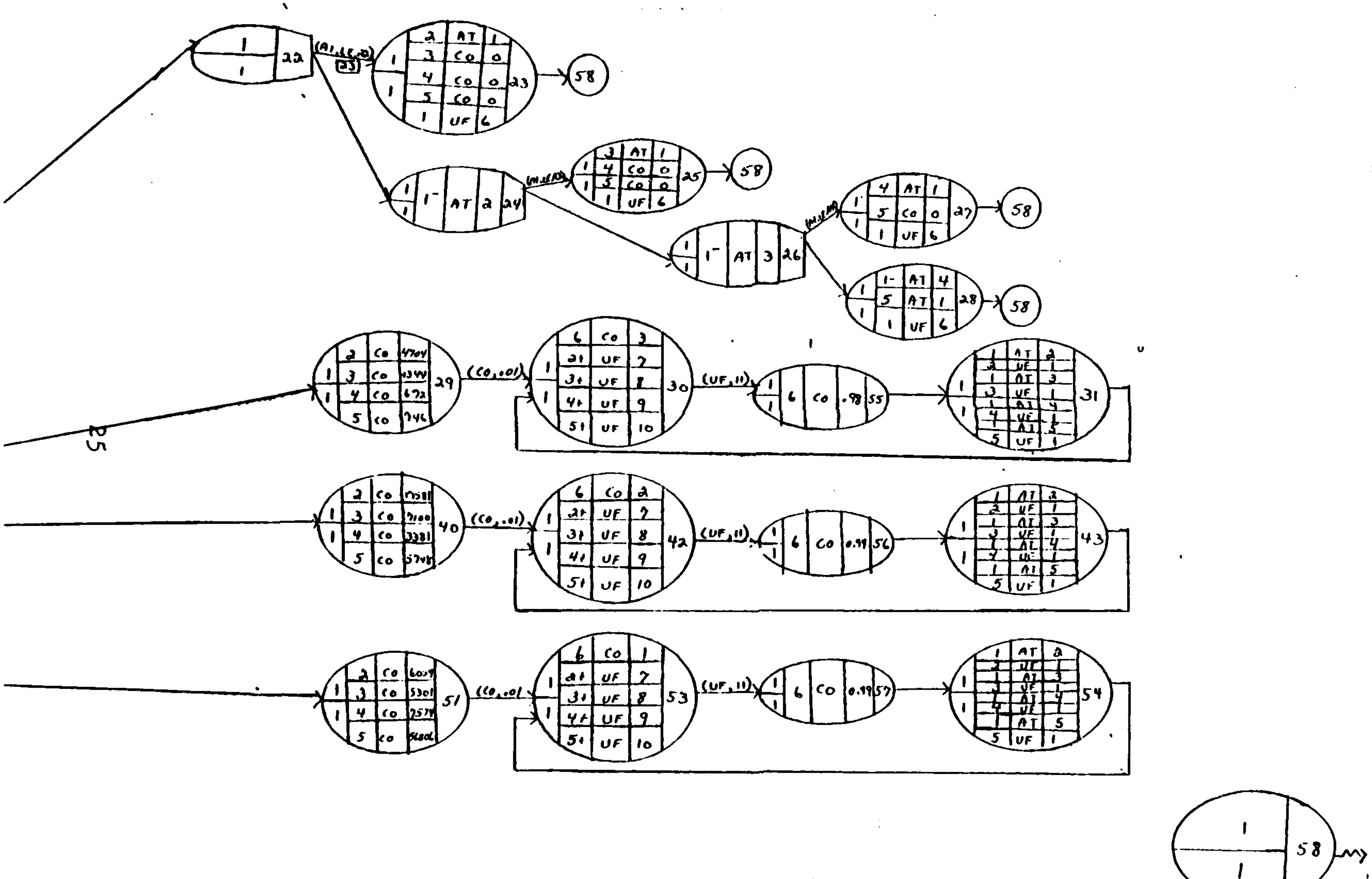
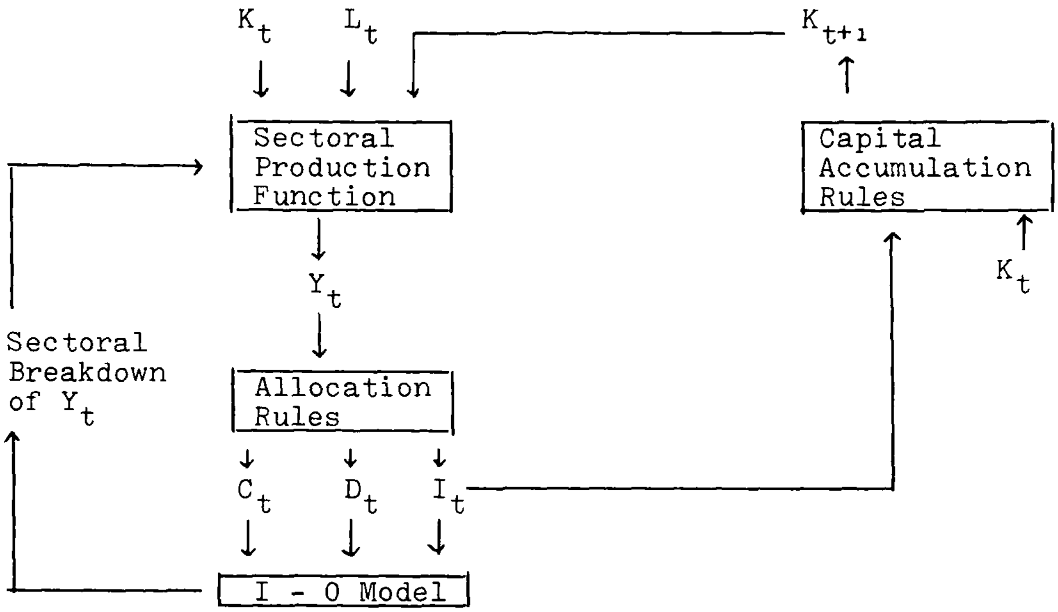


Figure 7. QGERT Network

IV. GROWTH MODEL

A four-sector model of the Soviet economy as designed by Bergendorff and Strangert was programmed to interface with the education model described in Chapter III (Ref 1). The growth model divides the economy into four major sectors: industry, agriculture, construction, and transportation and communication, which represents 94 percent of the output and 94 percent of the capital stock employed in material production. The model is input-output based and uses an iterative procedure for calculating GNP growth. To begin, an allocation rule is used to distribute spending among investment, defense and consumption. Figure 8 illustrates the basic flow of the model.

An assumed level of capital stock is given (ex. $K_o = 100$), and an initial level of Gross National Product is assumed (where $\overline{GNP}_o = \overline{C}_o + \overline{I}_o + \overline{D}_o$). Using an allocation rule, the values of C_o, I_o and D_o are determined. The input-output model decomposes C, I, and D into the provisional outputs of the four sectors. Sectoral production functions are used to determine the amount of capital required to produce the provisional outputs. The required capital is compared to the assumed level of capital stock, and, if $K_R > K_o$, $\overline{GNP}_o$ is reduced downward and we iterate again. Once $K_R = K_o + \Delta$ the iteration stops, the actual capital stock is augmented ($K_1 = K_o + I_o$), and the iteration begins again.



Y = GNP K = Capital L = Effective Labor C = Consumption
D = Defense I = Investment

Figure 8. Generalized Flow of the Disaggregate Growth Model

<u>Allocation Rule</u>

Bergendorff and Strangert propose three possible rules for allocating spending (Ref 1:400). Two have consumption as a residual and the other leaves investment as a residual. Based on general readings on Soviet philosophy,an assumption is made that consumption is viewed as the residual. The choice now is whether investment and defense should get fixed portions or if investment is a residual of defense expenditures. In general it would not seem to be illogical reasoning to assume that the Soviets insure defense spending first and leave investment and consumption as residuals. In addition, empirical data tends to support this approach (Ref 1:396). Thus, the following allocation rule is chosen for this model:

$$D_t = (1 + g)D_{t-1} \tag{2}$$

$$I_t = \alpha(Y_t - D_t) \tag{3}$$

$$C_t = (1- \alpha) (Y_t - D_t) \tag{4}$$

(g - state specified growth rate of defense expenditures;
α - constant share of investment in non-defense GNP)
(Ref 1:401)

Within the Soviet economy g and α are decision variables of the state planning commission (GOSPLAN). Within this model they can be varied.

Sectoral Production Functions

Time series data were used by Bergendorff and Strangert to estimate production functions for each of the sectors. For industry, both a Cobb-Douglas and a CES function with Hicks-neutral technical progress are estimated. Since economic aggregates such as GNP exhibit very regular growth in the Soviet economy,problems with multicollinearity and high variance in parameter estimates make it difficult to discriminate statistically between production functions (Ref 1:398). Therefore, based on programming ease and the note by Bergendorff and Strangert that the Cobb-Douglas production function did not fit the data well, the CES production function was chosen for industry. Only Cobb-Douglas functions were estimated for each of the other sectors. The relevant production functions are listed as follows:

Industry

$$Y_t = A \cdot e^{\lambda t} \quad \delta K^{-\gamma} + (1 - \delta) L^{-\gamma} \quad -1/\gamma \qquad (5)$$

$A = .9763$ $\qquad \delta = .7974$ $\qquad \gamma = .976$

$\lambda = .00451$

Agriculture*

$$Y_t = A \cdot K^{\alpha} L^{1-\alpha} e^{\lambda t} \qquad (6)$$

$A = 1.097$ $\qquad \alpha = .298$ $\qquad \lambda = .005$

Construction

$$Y_t = A \cdot e^{\lambda t} K^{\alpha} L^{\beta} \qquad (7)$$

$A = 1.0$ $\qquad \lambda = .0148$ $\qquad \alpha = .066$

$\beta = 1.0767$

Transportation and Communication

$$Y_t = A \cdot e^{\lambda t} K^{\alpha} L^{1-\alpha} \qquad (8)$$

$A = 1.047$ $\qquad \lambda = .0233$ $\qquad \alpha = .574$

(Ref 1:429)

Disaggregate Iterative Procedure

Figure 9 is a flow chart of the growth model. The code for this model and its interface with the education model is given in Appendix A. The growth model is designed as a subroutine for the education model and is solved in the following way (Ref 1:400). A trial level of GNP (Y_t)

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* The production function for the state farm (Sovholtz) is used to account for all agricultural production. This impacts an unknown bias to agricultural production due to differences in the technology coefficients (A). For instance moving all production from collective farms (Kolkhoz) to state farms could increase output by 22% and moving all output from state farms to private farms could increase output by 100%. However, neither of these moves is assumed to be plausible.

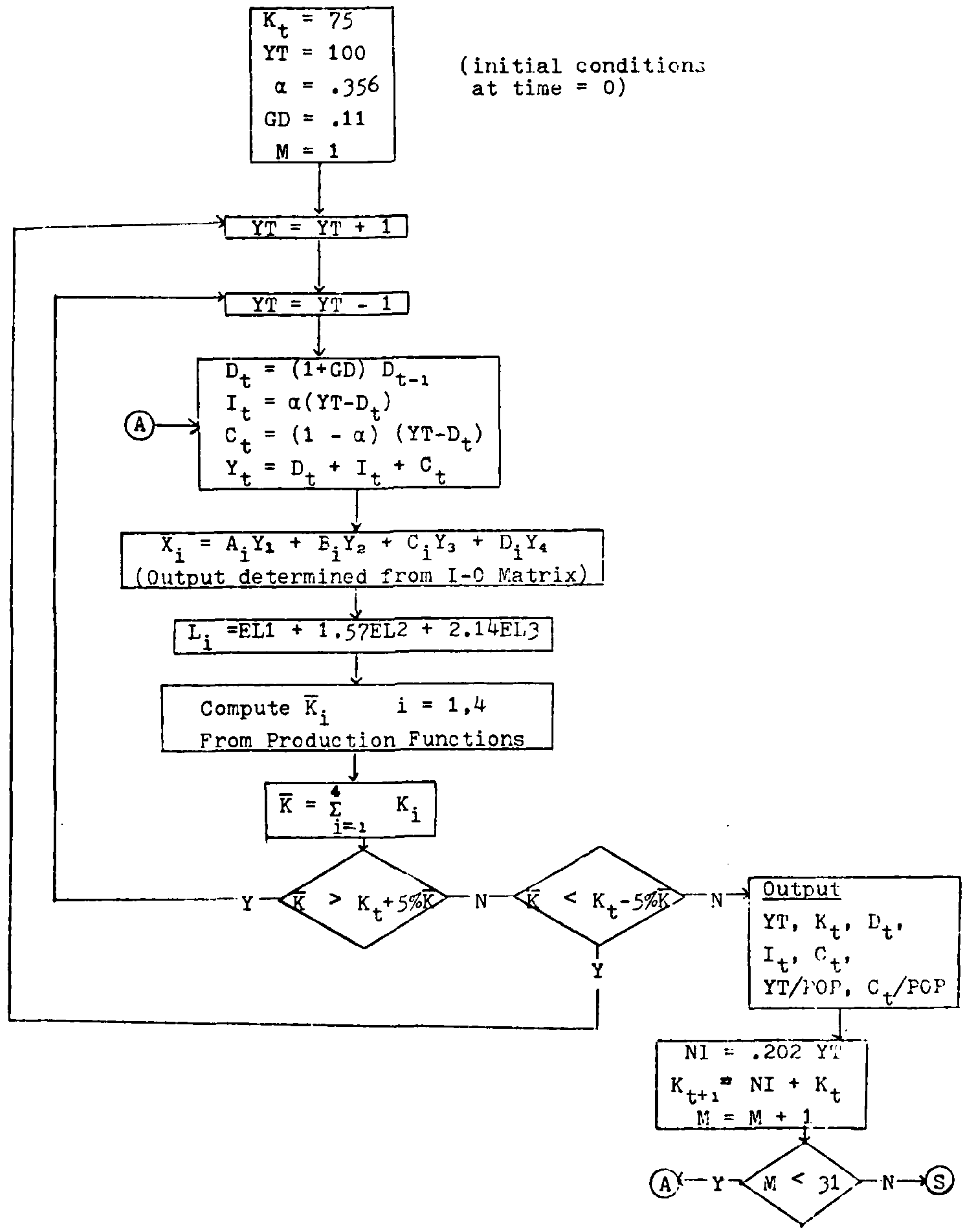

Figure 9. Growth Model

is guessed or derived from earlier iterations. Defense, investment and consumption are determined by the allocation rule. Then the sectoral outputs are computed by using the input-output matrix, the labor, as allocated between the sectors in the education model, is input and an aggregate capital requirement is computed from the production functions. Required capital ($\bar{K}_t$) is now compared with available capital (K_t) as described earlier in the chapter with GNP being adjusted accordingly. Iterations continue until $\bar{K}_t - K_t$ is less than 5 percent of $\bar{K}_t$. Net investment is then determined as a percentage of GNP, capital stock is incremented by net investment and a new iteration begins. The model is run for a 30 year period.

Note: All of these production functions exhibit constant returns to scale (homogeneous of degree one) except for the "construction industry" which exhibits increasing returns to scale (although not by much). This means if all inputs in the four sectors were increasing at the same percentage rate, aggregate output would also be increasing at approximately that rate (approximate because of the construction industry). For example: if $y_1 = f(K_1, L_1)$; $y_2 = f(K_2, L_2)$ are production functions for industries 1 and 2 and are both homogeneous of degree 1 then:

$$Ey_1 = \pi_{k_1} \cdot EK_1 + (1 - \pi_{k_1}) EL_1$$

$$Ey_2 = \pi_{k_2} \cdot EK_2 + (1 - \pi_{k_2}) EL_2$$

where $Ey_1 = \frac{dy_1}{y_1}$; $\pi_{k_1} = \frac{K_1 f_{k_1}}{y_1}$ etc.

Aggregate output is $Y = y_1 + y_2$

so: $EY = \frac{y_1}{Y} Ey_1 + \frac{y_2}{Y} Ey_2$

if $EK_1 = EL_1 = EK_2 = EL_2 = E\gamma$

$\Rightarrow EY = E\gamma$

This result is consistent with the neoclassical steady state growth model. The result approximated this as shown in the next chapter.

V. DATA DESCRIPTION

This chapter describes the data used in the education and growth models. In the growth model the starting values of GNP and capital were set at 100 and 75 respectively. In later runs of the model the value of capital was changed to 638 to reflect 1970 data (Ref 5:409). The GNP value was chosen so that the distribution could be made in percentage terms. According to Campbell (Ref 4:100) consumption accounts for 56 percent, defense 11 percent and investment 33 percent of the final GNP. These are used as the initial values in the model (see code listing - Appendix A).

To determine sectoral output the following balance equation is used:

$$(I^*-A) \underbrace{\begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \end{bmatrix}}_{\vec{Y}} = \underbrace{\begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{bmatrix}}_{\vec{C}} + \underbrace{\begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \end{bmatrix}}_{\vec{D}} + \underbrace{\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}}_{\vec{I}}$$

$$(I^*-A)\vec{Y} = \vec{D} + \vec{I} + \vec{C} \qquad (9)$$

thus $$\vec{Y} = (I^*-A)^{-1}(\vec{D} + \vec{I} + \vec{C}) \qquad (10)$$

Where $\vec{Y}$ = vector of sectoral output

A = input-output (I-O) matrix

I^*= identity matrix

$\vec{D}$ = vector of sectoral demands for national defense

$\vec{I}$ = vector of sectoral demand for gross investment

$\vec{C}$ = vector of sectoral demand for consumption

$\vec{X} = \vec{D} + \vec{I} + \vec{C}$ = vector of sectoral GNP as described above

GNP = $i'\vec{X}$ where i is the unit vector

The I-O matrix A is defined as follows (Ref 1:427):

	Industry	Construction	Agriculture	Trans/Comm
Industry	.4377	.4992	.0986	.2194
Construction	0	0	0	0
Agriculture	0	.0013	.2382	0
Trans/Comm	.0544	0	.0106	0

Each sector of the economy then accounts for a specific share of consumption, investment and defense spending. The composition of sectoral demands is as follows:

$C_1 = .10(i'\vec{C})$ $D_1 = .85(i'\vec{D})$ $I_1 = .32(i'\vec{I})$

$C_2 = 0$ $D_2 = .10(i'\vec{D})$ $I_2 = .60(i'\vec{I})$

$C_3 = .90(i'\vec{C})$ $D_3 = 0$ $I_3 = .03(i'\vec{I})$

$C_4 = 0$ $D_4 = .05(i'\vec{D})$ $I_4 = .05(i'\vec{I})$

Narkhoz used 60% construction, 32% industry and 8% other for the composition of investment (Ref 1:427). In this model,other has been decomposed into 3% agriculture and 5% transportation and communication. Based on U.S. and Swedish data,defense is composed of 90% industry and 10% construction. In this model,5% less is attached to industry and attached to transportation and communication. The assumption that transportation and communication contributes to defense is based on the construction of the Baykal-Amur Mainline (BAM) railroad. The BAM in the southeastern

USSR is approximately 100 miles from the Chinese border (and the TransSiberian Railroad) and it is a plausible assumption that it will have military implications. No specific data was available for the composition of consumption so,with a nuclear scenario in mind,an assumption was made that heavy emphasis on rebuilding consumption would be in agriculture. Thus, consumption was assumed to be composed of 90% agriculture and 10% industry. This assumption would probably not be plausible in nonrecovery situations since a greater percentage of consumption would likely originate in industry.

With agriculture accounting for 90 percent of comsumption expenditures and with only a small amount of investment in agriculture,there is consistency with the choice of the allocation rule which leaves consumption as a residual (Ref 15:132). Construction receives the bulk of investment expenditures in this model (60%). This coincides with Iudaeva's statement (Ref 12:63) that the integrated character of construction is the basis for increasing the effectiveness of capital investments. It is also obvious from the data that industry is the basis for enhancing the USSR's defense potential (Ref 3:105).

Education

Data for input to the education model was derived mainly from the CIA report (Ref 14) with the exception of retirement/death rates which were obtained from Feshbach(Ref 7) and DeWitt (Ref 6). Assumptions as to model design and priority structuring were based on personal conclusions drawn from reading several sources on the educational system and school of thought in the Soviet Union.

Specific data was derived as follows:

Birth rate: growth in school age population was observed over a 10 year period 1970 - 1980. The mean value of the births is 2,200,000 with a standard deviation of about 100,000. (Ref 14:17)

As stated in the CIA report, most people attend secondary school, therefore it was assumed that 1% of EL_1 graduates go directly into the labor force implying 99% proceed to EL_2 (Ref 14). Graduates from EL_2 are approximated to be 10% less than the number admitted (Ref 14:7). The 10% that dropout are distributed as 4% the first year and 3% the second and third years. Approximately 10% of the graduates proceed to EL_3 leaving 70% to enter the labor force. Of the EL_3 entrants it is assumed that 70% graduate leaving 30% that dropout (Ref 14:14). Dropouts are assumed to be 10% each year.

Workers exit the labor force through death or retirement. Feshbach gives the death rate based on 1975 data as 9.3 per 1000 which is approximately 1% per year (Ref 7:116). DeWitt states that EL_3 has a higher rate of attrition because people with higher education are more likely to be lost to the labor force due to political reasons (Ref 6:231). Therefore, the death and retirement rates are given as follows:

EL_1 - .01
EL_2 - .01
EL_3 - .02

Labor

An initial allocation of workers by skill level is assigned to each sector. The starting number in each sector for each education level is given as follows:

Table 1

Initial Sectoral Labor Allocation

Ed. level	Ind.	Agr.	Trans./Comm.	Const.
1	6059	56806	5301	7574
2	17581	5748	7100	3381
3	4704	746	1344	672

These numbers are in thousands of people and are derived from tables in the CIA report (Ref 14). Specialty groups listed in Tables 2 and 3 were sorted into the four sectors with most questionable groups being assigned to industry. The tables illustrate the choices in the first column according to the following code: industry (1), transportation and communication (2), construction (3) and agriculture (4). Percentage of the total enrollment was then computed. Similar data was not available for education level 1,therefore the breakout was assumed to be 75% going to agriculture and 7, 8, and 10 percent going to transportation and communication, industry and construction respectively. These figures are based on the assumption that agricultural labor in any country consists of mostly low skill level workers.

Total values for each education level are found in Table 4. Enrollment percentages were used with the totals

Table 2

USSR: Number of Students Admitted, Enrolled, and Graduated From Specialized Secondary Schools, by Specialty, 1975 (Ref 14:31)

	Specialty Group	Admitted					Enrolled					Graduated				
		Number of Persons				Percent of Part-time	Number of Persons				Percent of Part-time	Number of Persons				Percent of Part-time
		Total	Day	Evening	Corre-spond-ence		Total	Day	Evening	Corre-spond-ence		Total	Day	Evening	Corre-spond-ence	
	Total	**1,403,947**	**896,140**	**152,633**	**355,174**	**36.2**	**4,524,661**	**2,816,725**	**515,815**	**1,192,121**	**37.7**	**1,157,034**	**752,263**	**125,377**	**279,394**	**35.0**
1	Geology and survey of mineral resources	**7,008**	5,465	(x)[1]	1,543	22.0	**24,263**	18,318	(x)	5,945	24.5	**5,740**	4,542	(x)	1,198	20.9
1	Exploration of mineral resources	**14,401**	9,260	2,681	2,520	36.0	**54,462**	33,973	10,804	9,685	37.6	**13,145**	8,365	3,103	1,677	36.4
2	Power engineering	**54,235**	28,796	15,349	10,090	46.9	**194,556**	101,025	53,415	40,116	48.1	**47,744**	24,663	14,913	8,168	48.3
1	Metallurgy	**15,471**	10,011	4,237	1,223	35.3	**51,584**	35,249	12,443	3,892	31.7	**10,867**	6,925	3,138	804	36.3
1	Machine building and instrument making	**160,682**	82,535	54,873	23,274	48.6	**542,397**	277,613	182,231	82,553	48.8	**125,614**	63,053	45,165	17,396	49.8
2	Electrical engineering and electrical instrument-making	**42,459**	26,811	10,568	5,080	36.9	**142,630**	89,528	34,777	18,325	37.2	**33,821**	21,366	8,564	3,891	36.8
2	Radio technology and communications	**41,853**	23,770	5,634	12,449	43.2	**141,731**	77,467	20,443	43,821	45.3	**31,612**	18,352	4,856	8,404	41.9
1	Chemical technology	**22,238**	13,408	6,637	2,193	39.7	**72,575**	45,776	19,025	7,774	36.9	**19,010**	11,841	5,189	1,980	37.7
3	Forestry and technology of wood, cell and paper	**14,198**	8,730	1,447	4,021	38.5	**48,174**	28,905	4,801	14,468	40.0	**10,616**	7,256	975	2,385	31.7
4	Technology of food products	**47,037**	27,765	1,240	18,032	41.0	**164,107**	93,753	4,492	65,862	42.9	**39,483**	24,709	1,044	13,730	37.4
1	Technology of consumer goods	**31,001**	12,963	8,451	9,587	58.2	**108,407**	43,514	28,820	36,073	59.9	**24,785**	11,032	6,088	7,665	55.5
3	Construction	**123,411**	78,184	17,302	27,925	36.6	**435,323**	268,029	64,789	102,505	38.4	**99,772**	63,161	16,312	20,299	36.7
2	Geodesy and cartography	**4,671**	4,161	(x)	510	10.9	**14,097**	12,074	(x)	2,023	14.4	**2,830**	2,458	(x)	372	13.1
2	Hydrology and meteorology	**2,011**	1,411	(x)	600	29.8	**7,206**	4,961	(x)	2,245	31.2	**1,558**	1,136	(x)	422	27.1
4	Agriculture	**193,816**	128,389	(x)	65,427	33.8	**645,756**	407,700	(x)	238,056	36.9	**142,299**	97,493	(x)	44,806	31.5
2	Transportation	**82,005**	48,928	6,714	26,363	40.3	**294,941**	165,733	27,895	101,313	43.8	**60,373**	34,635	5,972	19,766	42.6
1	Economics	**238,092**	115,953	10,031	112,108	51.3	**628,648**	288,667	29,119	310,862	54.1	**208,296**	107,095	5,009	96,192	48.6
1	Law	**1,854**	1,050	30	774	43.4	**4,258**	2,286	104	1,868	46.3	**1,493**	704	61	728	52.8
1	Public health and physical culture	**153,088**	145,886	5,898	1,304	4.7	**430,133**	407,470	16,893	5,770	5.3	**141,991**	137,300	3,146	1,545	3.3
1	Education	**122,343**	94,083	1,059	27,201	23.1	**394,962**	308,905	3,135	82,922	21.8	**109,088**	83,155	952	24,981	23.8
2	Art	**32,013**	28,581	482	2,950	10.7	**124,451**	105,779	2,629	16,043	15.0	**26,897**	23,022	890	2,985	14.4

Table 3

USSR: Number of Students Admitted, Enrolled, and Graduated From Higher Educational Institutions, by Specialty, 1975 (Ref 14:30)

	Specialty Group	Admitted					Enrolled					Graduated				
		Number of Persons				Percent of Part-time	Number of Persons				Percent of Part-time	Number of Persons				Percent of Part-time
		Total	Day	Evening	Corre-spond-ence		Total	Day	Evening	Corre-spond-ence		Total	Day	Evening	Corre-spond-ence	
	Total	**997,737**	**595,863**	**130,125**	**271,749**	**40.3**	**4,853,958**	**2,628,124**	**644,350**	**1,581,484**	**45.9**	**713,389**	**433,303**	**79,717**	**200,369**	**39.3**
1	Geology and prospecting for mineral resources	7,789	5,809	425	1,555	25.4	38,160	26,834	1,990	9,336	29.7	5,904	4,731	226	947	19.9
1	Mining and mineral resources	11,949	8,217	1,970	1,762	31.2	56,045	36,836	8,229	10,980	34 3	8,298	6,335	848	1,115	23.7
2	Power engineering	24,254	14,605	5,239	4,410	39.8	116,498	62,819	25,936	27,743	46.1	14,116	8,832	2,570	2,714	37.4
1	Metallurgy	12,289	7,732	3,364	1,193	37.1	56,149	33,730	15,766	6,653	39.9	7,814	5,364	1,743	707	31.4
1	Machine-building and instrument-making	118,905	65,288	32,653	20,964	45.1	574,043	291,820	160,469	121,754	49.2	73,012	43,640	18,299	11,073	40.2
2	Electronic techniques, electrical instrument-making, and automation	66,023	42,513	16,647	6,863	35.6	329,233	194,447	86,208	48,578	40.9	49,604	33,115	11,103	5,386	33.2
2	Radio engineering and communications	30,606	16,740	6,848	7,018	45.3	149,067	74,277	33,756	41,034	50.2	18,752	11,017	3,866	3,869	41.2
1	Chemical technology	19,341	12,391	4,471	2,479	35.9	98,440	59,696	21,385	17,359	39.4	15,424	10,209	3,073	2,142	33.8
3	Timber engineering and wood, pulp, and paper technology	7,441	5,112	600	1,729	31.3	33,889	21,724	2,966	9,199	35.9	4,673	3,737	210	726	20.0
4	Technology of food products	15,242	8,141	1,636	5,465	46.6	75,895	37,064	7,752	31,079	51.2	10,500	6,258	804	3,438	40.4
1	Technology of consumer goods	12,743	6,744	1,722	4,277	47.1	59,376	28,917	8,406	22,053	51.3	7,605	4,532	929	2,144	40.4
3	Construction	79,816	48,792	15,835	15,189	38.9	377,123	205,096	80,813	91,214	45.6	44,754	28,685	8,313	7,756	35.9
2	Geodesy and cartography	2,612	2,105	13	494	19.4	10,591	7,790	58	2,743	26.4	1,336	1,054	3	279	21.1
2	Hydrology and meterology	1,610	1,135	(x)[2]	475	29.5	8,038	5,503	2	2,533	31.5	1,271	1,012	(x)	259	20.4
4	Agriculture and forestry	83,730	50,730	(x)	33,000	39.4	401,382	218,198	40	183,144	45.6	53,869	36,035	13	17,821	33.1
2	Transportation	29,648	16,341	3,615	9,692	44.9	147,856	70,019	16,646	61,191	52.6	17,452	10,500	1,829	5,123	39.8
1	Economics	121,494	47,045	16,761	57,688	61.3	597,696	198,729	80,275	318,692	66.8	95,567	38,121	11,943	45,503	60.1
1	Law	22,544	7,908	3,599	11,037	64.9	93,174	25,071	15,837	52,266	73.1	13,146	4,140	1,889	7,117	68.5
1	Health and physical culture	64,525	61,258	170	3,097	5.1	351,501	333,699	1,219	16,583	5.1	53,639	50,611	310	2,718	5.6
1	University specialties	72,840	46,976	9,918	15,946	35.5	368,080	214,049	51,184	102,847	41.8	54,613	33,674	6,787	14,152	38.3
1	Specialties in pedagogical and library institutes	184,141	113,894	4,309	65,938	38.1	871,104	452,882	23,146	395,076	48.0	154,697	86,785	4,397	63,515	43.9
2	Art	8,195	6,387	330	1,478	22.1	40,618	28,924	2,267	9,427	28.8	7,343	4,916	562	1,865	33.1

Table 4

USSR: Educational Attainment of the Labor Force (Ref 14:25)

	Thousand Persons							Median Level (Number of Years)
	Total	Higher	Incomplete Higher	Specialized Secondary	General Secondary	Incomplete Secondary	Primary and Less	
1959	99,130	3,271	892	6,641	6,343	25,774	56,209	6.3
1970	115,204	7,468	1,502	12,128	18,364	35,922	39,820	8.4
1971	116,310	7,932	1,552	12,889	19,419	36,758	37,760	8.6
1972	118,516	8,473	1,609	13,610	20,671	37,666	36,487	8.8
1973	120,642	9,014	1,609	14,511	21,924	38,422	35,162	8.9
1974	122,819	9,645	1,609	15,232	23,412	39,330	33,591	9.1
1975	125,054	10,186	1,609	16,043	25,056	40,162	31,998	9.2
1976	127,318	10,727	1,667	16,854	26,935	40,540	30,595	9.4
1977	129,651	11,268	1,667	17,665	29,128	40,767	29,156	9.5
1978	131,940	11,827	1,682	18,344	30,571	41,365	28,151	9.7
1979	134,129	12,428	1,710	19,224	32,044	41,982	26,741	9.8
1980	136,194	13,057	1,728	20,137	33,535	42,594	25,143	10.0
1981	138,136	13,720	1,756	21,093	35,024	43,218	23,325	10.1
1982	139,875	14,384	1,772	22,080	36,532	43,864	21,243	10.1
1983	141,430	15,054	1,795	23,068	38,096	44,512	18,905	10.2
1984	142,836	15,734	1,806	24,060	39,675	45,153	16,408	10.2
1985	144,080	16,533	1,826	25,144	41,375	45,787	13,415	10.3
		EL_3	EL_3	EL_2	EL_2	EL_2	EL_1	

Table 5

USSR: Educational Attainment of the Labor Force in Percentages (Ref 14:27)

	Total	Higher	Incomplete Higher	Specialized Secondary	General Secondary	Incomplete Secondary	Primary and Less
1970	100.00	6.48	1.30	10.53	15.94	31.18	34.57
1971	100.00	6.82	1.33	11.08	16.70	31.60	32.47
1972	100.00	7.15	1.36	11.48	17.44	31.78	30.79
1973	100.00	7.47	1.33	12.03	18.17	31.85	29.15
1974	100.00	7.85	1.31	12.40	19.06	32.03	27.35
1975	100.00	8.15	1.29	12.83	20.04	32.12	25.59
1976	100.00	8.43	1.31	13.24	21.16	31.84	24.03
1977	100.00	8.69	1.29	13.62	22.47	31.44	22.49
1978	100.00	8.96	1.27	13.90	23.17	31.35	21.34
1979	100.00	9.27	1.27	14.33	23.89	31.30	19.94
1980	100.00	9.59	1.27	14.79	24.62	31.27	18.46
1981	100.00	9.93	1.27	15.27	25.35	31.29	16.89
1982	100.00	10.28	1.27	15.79	26.12	31.36	15.19
1983	100.00	10.64	1.27	16.31	26.94	31.47	13.37
1984	100.00	11.02	1.26	16.84	27.78	31.61	11.49
1985	100.00	11.47	1.27	17.45	28.72	31.78	9.31

from Table 4 to calculate the numbers in Table 1. These totals for each education level were then compared with percentages of labor force in each education level to insure that they coincide (Table 5).

Data from the growth model is based on 1970 statistics, therefore as much as possible 1970 data was used for the education model. It was assumed that areas of specialization indicated for 1975 are not significantly different from what they were in 1970.

New requirements for each sector from each education level are calculated as follows:

Table 6

Sectoral Labor Allocation Requirements

Ed. Level	Ind.	Agr.	Trans./Comm.	Const.
1	5	20	5	5
2	915	300	370	175
3	275	45	80	40

These figures were chosen on an assumed average of 2200 graduates per year and keeping required percentages the same as the starting percentages used to compute Table 6.

Priority for assignment is given to Industry, Transportation/Communication, Construction and Agriculture respectively. This implies, for example, if 1500 people flow out of education level 2 into the labor force, they are assigned as follows: 915 to Industry, 370 to Transportation/

Communication, 175 to Construction and 40 to Agriculture. These priorities are what one might expect from a state which is heavily defense oriented and shows little concern for personal consumption items.

VI. SCENARIOS AND RESULTS

Several scenarios were run to test out the sensitivity of the model and in order to establish the "best" base case. Best implies the case that might be assumed to be the most logical based on understanding of the operation of the Soviet economy. These trial cases are discussed first, followed by two possible base cases and respective nuclear scenarios.

Net Investment - Constant 20% Growth

For the case where net investment grows at 20% of GNP each year, Figures 10, 11, and 12 show plots of the results. Defense is assumed to have a constant 11% share of GNP each year. Consumption is determined residually. Figure 10 shows that GNP and capital growth roughly parallel each other. GNP growth during years 18 - 30 indicates a slowing down of that rate so that the rate of capital growth exceeds that of GNP. By comparing Figure 10 and Figure 12, it is clear that $\frac{\dot{K}}{K} > \frac{\dot{L}}{L}$, so in aggregate the economy is acting in accordance with the law of diminishing returns (hence $\frac{\mathring{GNP}}{GNP} < \frac{\mathring{K}}{K}$). Figure 11 shows per capita GNP growing at the same rate as GNP* and per capita consumption growing at a slower rate. Figure 12 shows the effective labor force increasing at a decreasing rate.

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* This implies that the population is fairly constant

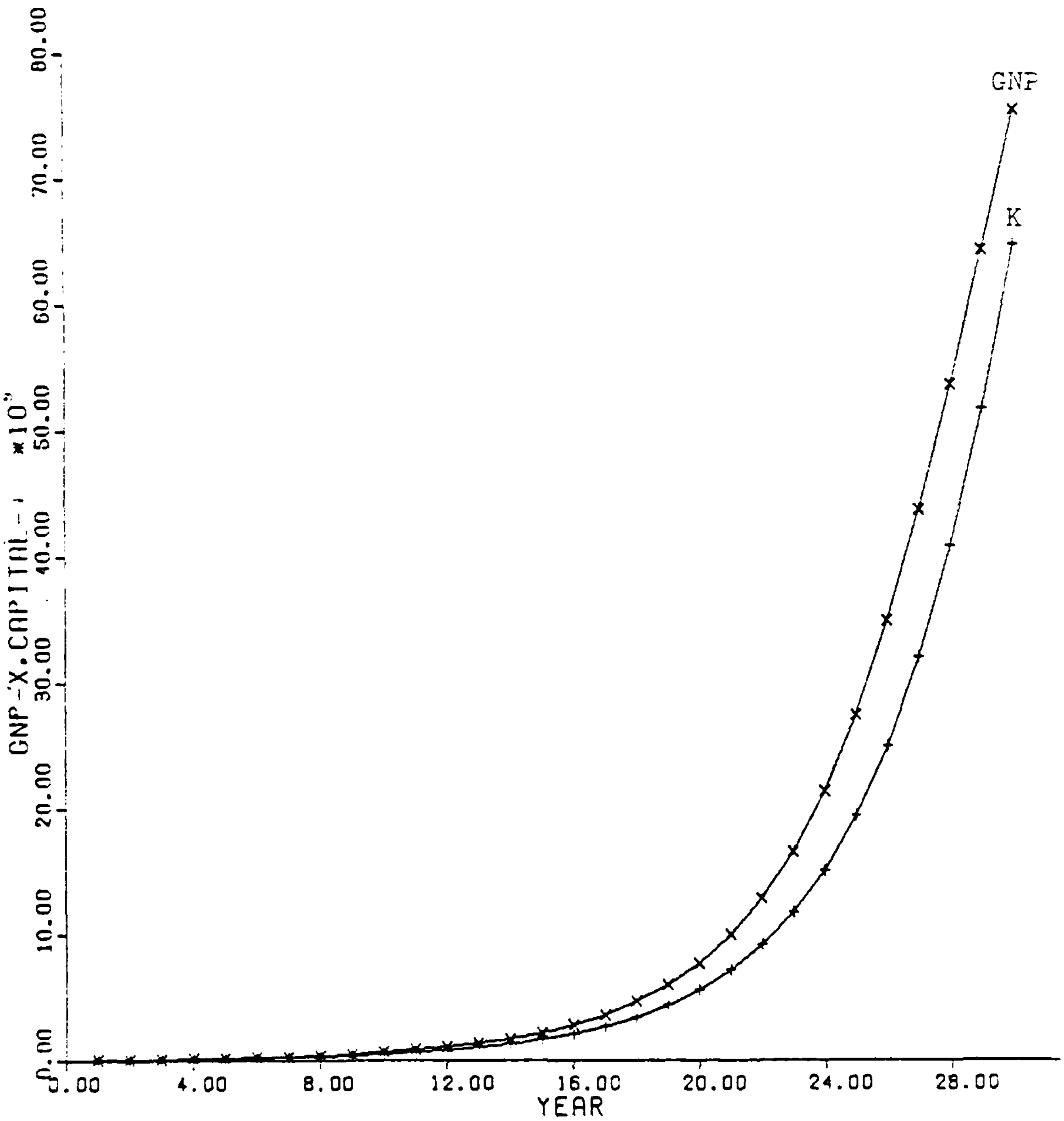

Figure 10. Growth in GNP and Capital Stock (Net Investment - Constant 20% Growth)

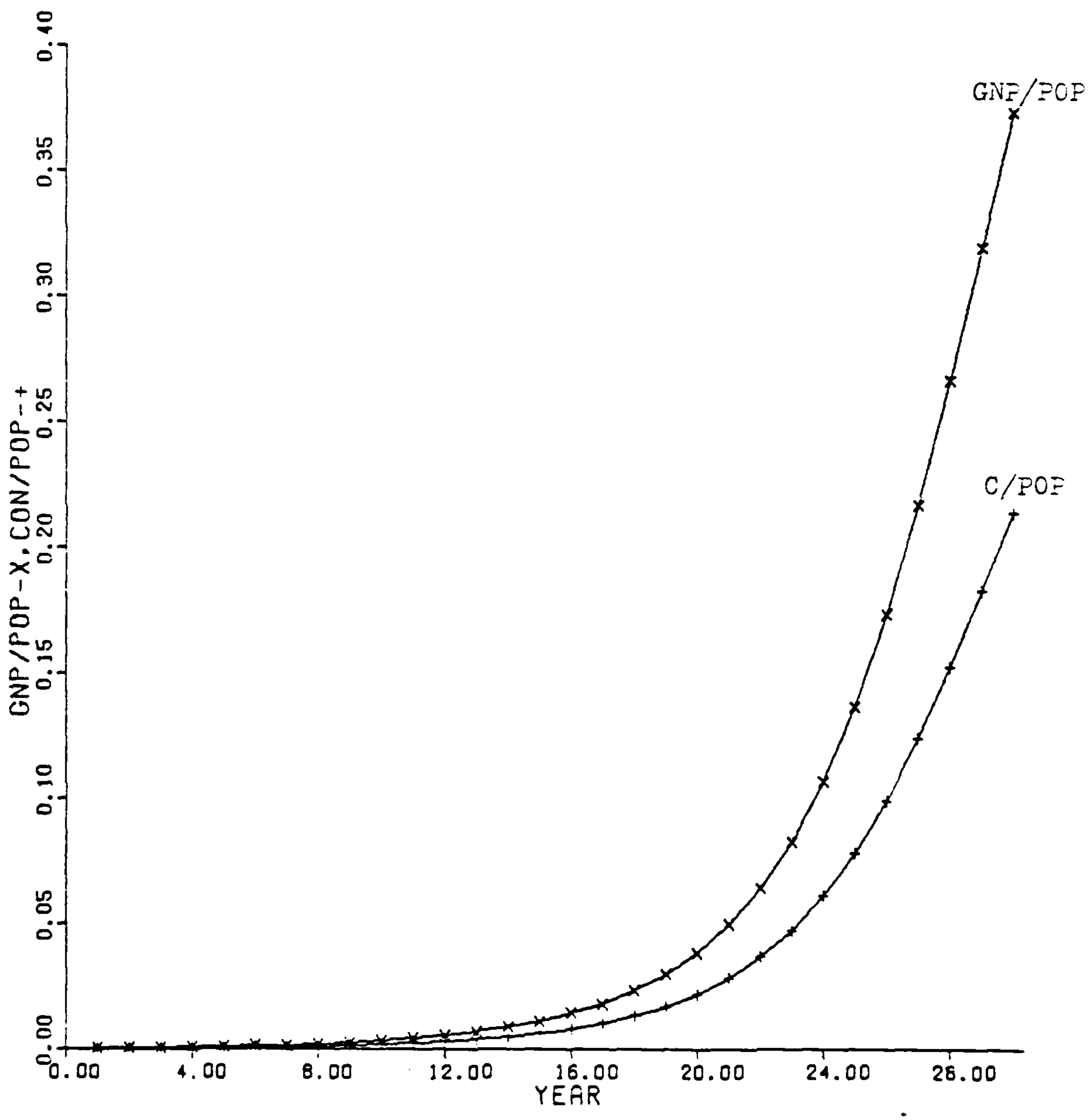

Figure 11. Growth in GNP per Capita and Consumption per Capita (Net Investment - Constant 20% Growth)

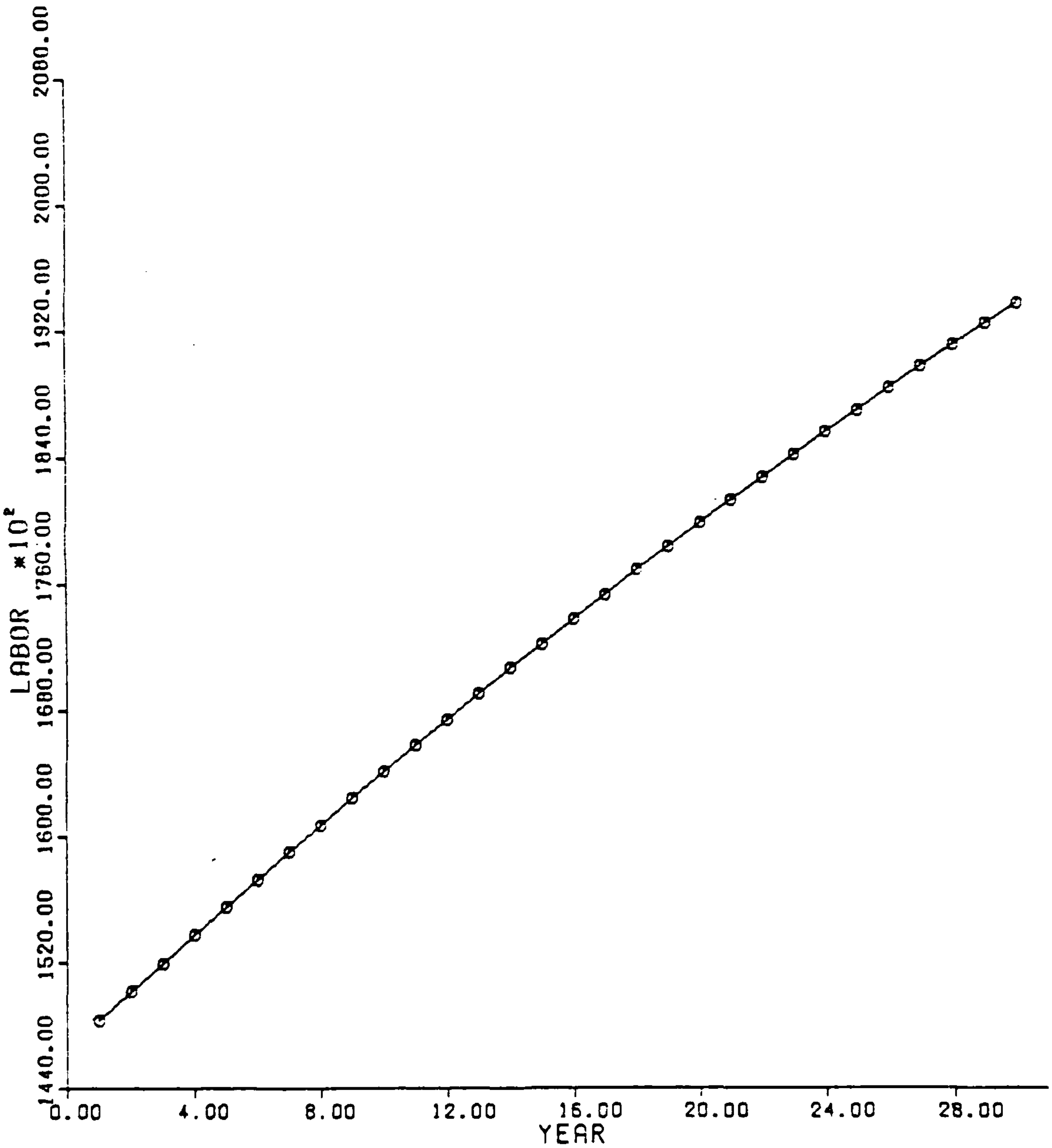

Figure 12. Growth of the Effective Labor Force (Net Investment - Constant 20% Growth)

Net Investment - Decrease after 10 years (Figures 13, 14)

This case leaves growth in net investment at 20% for the first 10 years and then decreases according to the following formula for the next 20 years.

$$g = \text{rate of increase in net investment}$$
$$= .05 + e^{(-1.897 - .035t)} \qquad (11)$$

Where t = year and the rate of decrease is 3.5% per year to a steady state of 5% per year. This is assumed to be close to aggregate Soviet experience. The resultant rate of increase in capital stock is unlikely to be sustainable in the long run. During the 1930's, the USSR had a very rapid accumulation of capital stock,but as the economy has matured the rate of capital accumulation has fallen. As in the previous case, defense receives a constant 11% of GNP each year. Results indicate similar trends as in the first case except at slower rates. The rate of capital accumulation is clearly less than the growth rate of GNP. The labor plot is exactly the same as in Figure 12.

Defense - Constant Increase (Figures 15, 16)

In this case, defense expenditures increase by 10% each year and growth in net investment is at 20% per year for the 30 year simulation. In this model the capital growth rate exceeds that of GNP at the 20 year point as GNP begins to increase at a decreasing rate. The crossover is in part due to noncapital intensive sectors such as agriculture accounting for more of the GNP. Defense spending is down from

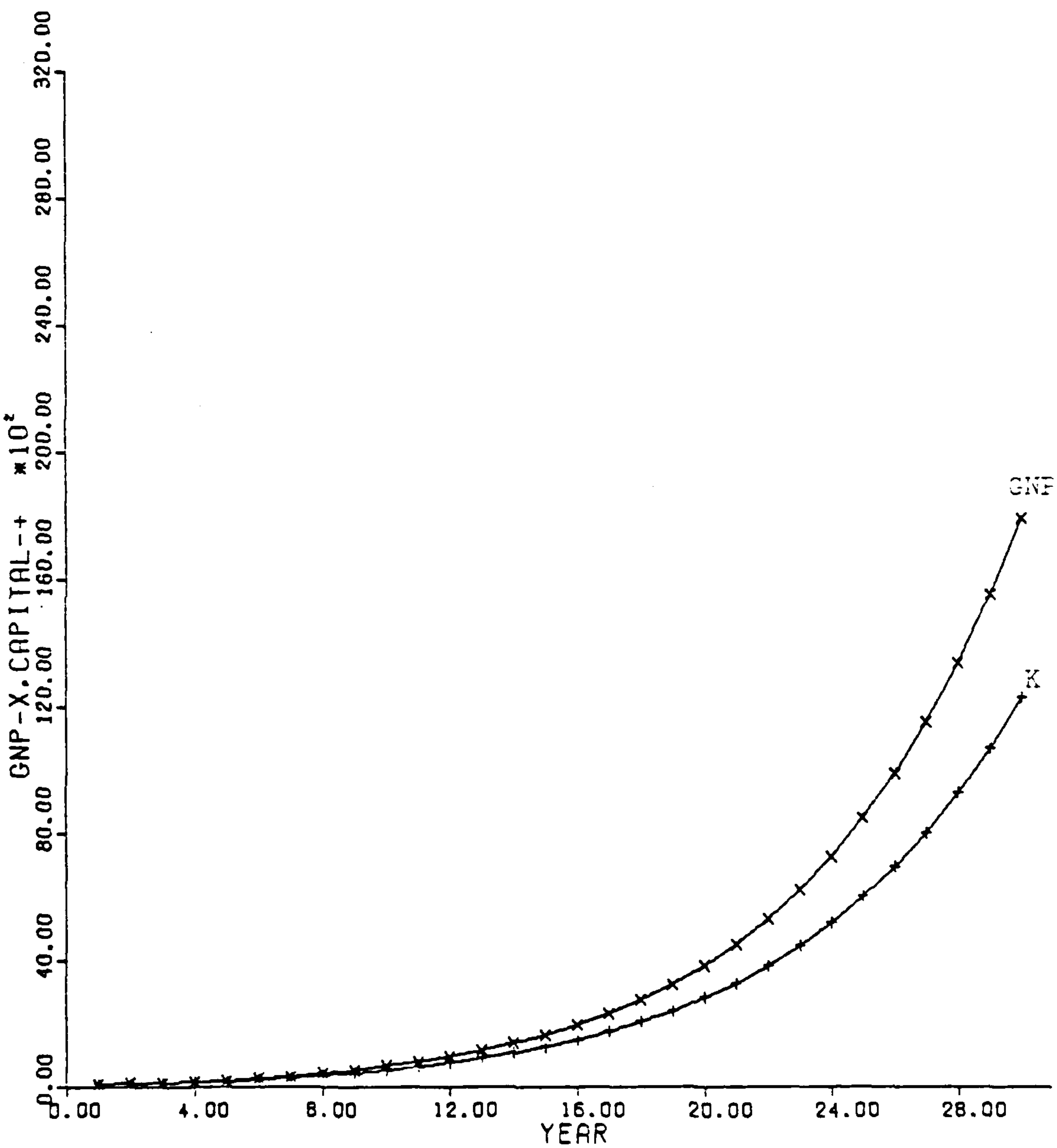

Figure 13. Growth in GNP and Capital Stock (Net Investment - Decrease after 10 years)

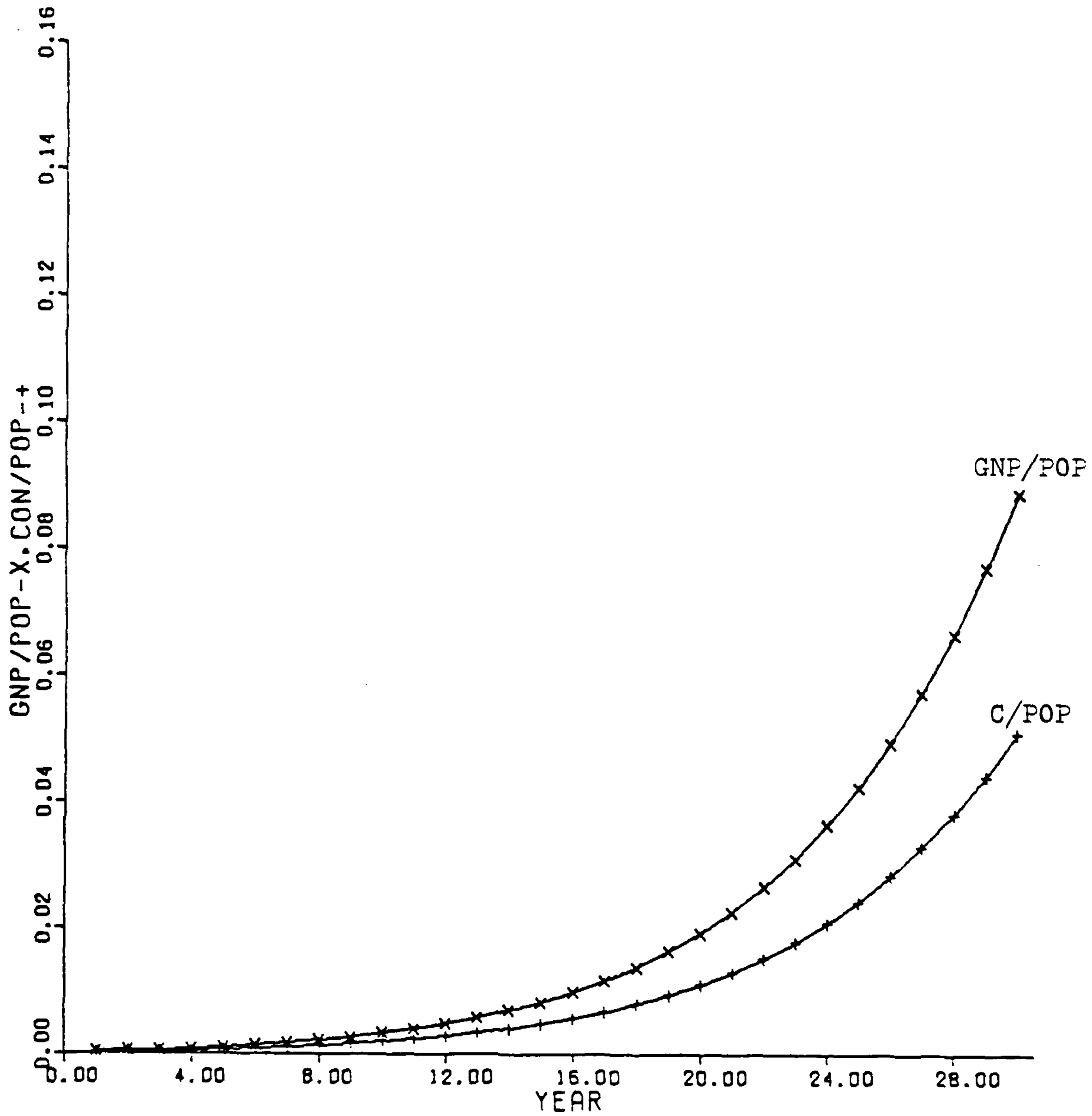

Figure 14. Growth in GNP per Capita and Consumption per Capita (Net Investment - Decrease after 10 years)

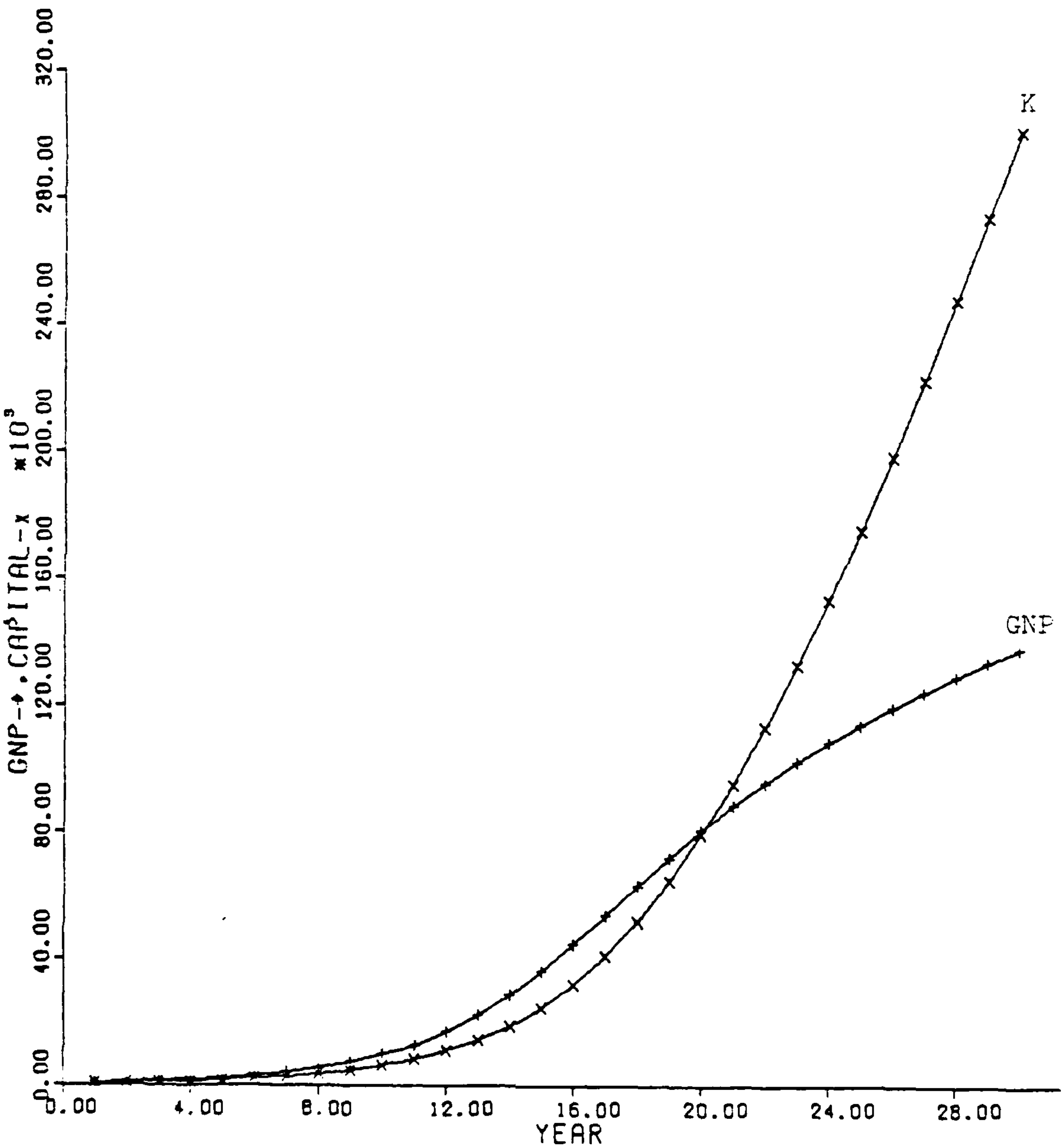

Figure 15. Growth in GNP and Capital Stock (Defense - Constant Increase - 10% per year)

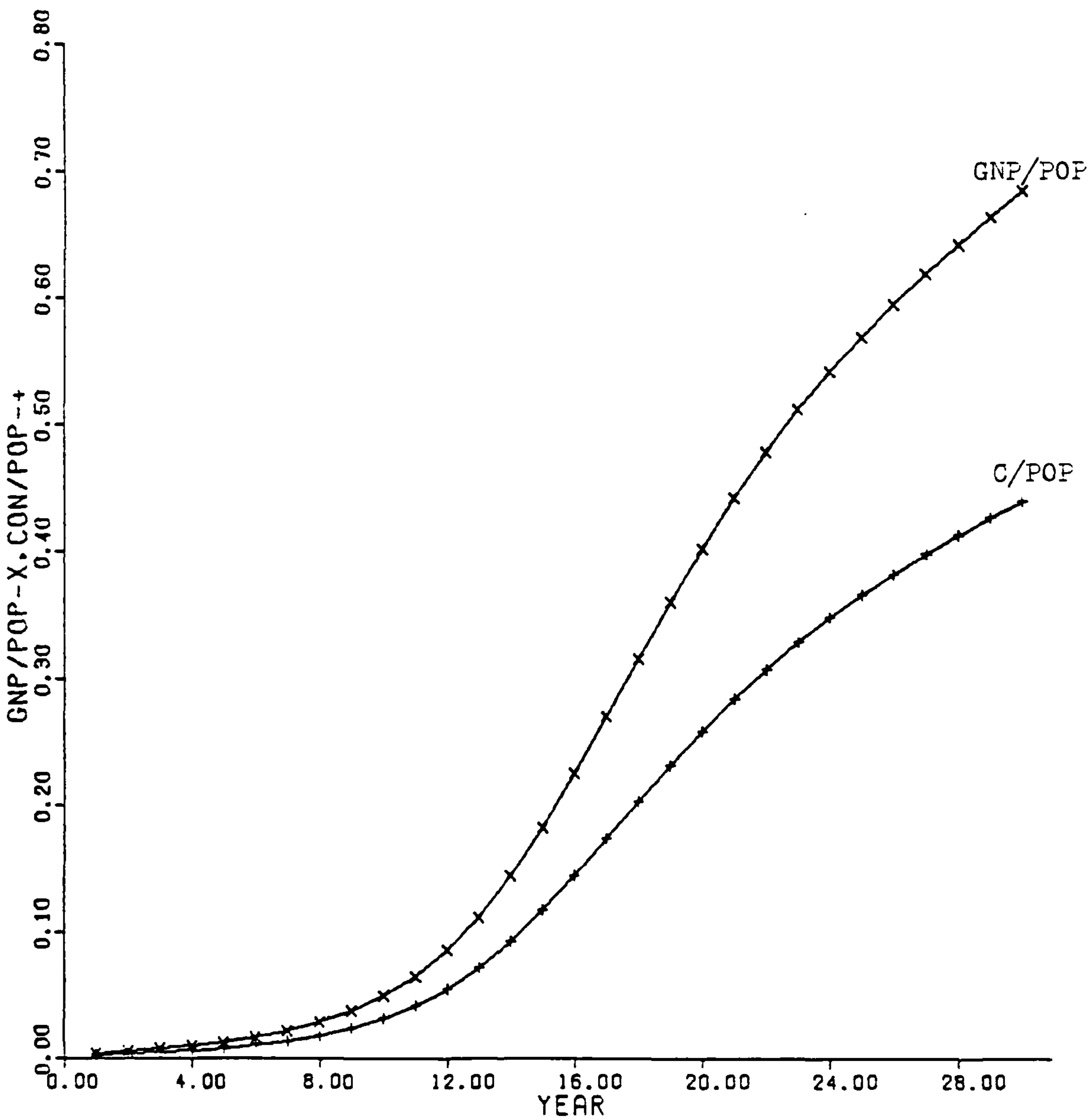

Figure 16. Growth in GNP per Capita and Consumption per Capita (Defense - Constant Increase - 10% per year)

the previous model which implies GNP in industry is down. This reduces capital requirements since industry is the most capital intensive sector. Another factor contributing to this phenomena is that the effective labor force increases at a decreasing rate and by year 20 the slope change has become quite significant.

If the percent rate of change in capital is greater than labor then the rate of increase in per capita income will not be as great as the percent rise in capital. If we assume our aggregate production function to be homogeneous of degree one then this can be proven.* Assume $y = f(K,L)$ is the aggregate production function where K is capital and L is effective labor and differentiation is with respect to time.

$$\dot{y} = f_K\dot{K} + f_L\dot{L} \text{ where } \dot{y} = \frac{dy}{dt},\ \dot{K} = \frac{dK}{dt},\ \dot{L} = \frac{dL}{dt} \tag{12}$$

$$\frac{\dot{y}}{y} = \frac{f_K K}{y}\frac{\dot{K}}{K} + \frac{f_L L}{y}\frac{\dot{L}}{L} \tag{13}$$

$$Ey = \frac{Kf_K}{y}EK + \frac{Lf_L}{y}EL \text{ where } Ey = \frac{\dot{y}}{y},\ EK = \frac{\dot{K}}{K},\ EL = \frac{\dot{L}}{L} \tag{14}$$

define $Z = \frac{y}{L}$ as real per capita income

$$\dot{Z} = \frac{1}{L}\dot{y} - \frac{y}{L^2}\dot{L} \tag{15}$$

$$\frac{\dot{Z}}{Z} = \frac{1}{L}\frac{\dot{y}}{Z} - \frac{y}{L^2}\frac{\dot{L}}{Z} = \frac{1}{L}\frac{L}{y}\dot{y} - \frac{y}{L^2}\frac{L}{y}\dot{L} \tag{16}$$

$$\frac{\dot{Z}}{Z} = \frac{\dot{y}}{y} - \frac{\dot{L}}{L} \tag{17}$$

$$EZ = Ey - EL \tag{18}$$

---

* The construction industry in the four-sector model is homogeneous of degree greater than one but it is fairly close (see page 29). The other three sectors have production functions that are homogeneous of degree 1.

Substituting Ey from equation (14)

$$EZ = \frac{Kf_K}{y} EK + \frac{Lf_L}{y} EL - EL \qquad (19)$$

If $y = f(K,L)$ is homogeneous of degree 1 then by Euler's Theorem:

$$y = Kf_K + Lf_L \text{ is a true statement} \qquad (20)$$

so, $y - Kf_K = Lf_L$

From equation (19):

$$EZ = \frac{Kf_K}{y} EK + \frac{(y-Kf_K)}{y} EL - EL \qquad (21)$$

$$EZ = \frac{Kf_K}{y} EK - \frac{Kf_K}{y} EL \qquad (22)$$

$$EZ = \frac{Kf_K}{y} (EK - EL) \qquad (23)$$

if $EK = EL \Rightarrow EZ = 0$

if $EK > EL \Rightarrow EZ > 0$

In this model $EK > EL$ and $\frac{Kf_K}{y}$ is a positive fraction[1] so $EZ < EK$ or the percent rise in per capita income over time is not as great as the percent increase in capital over time.[2]

<u>Defense Constant Share</u> (Figures 17, 18)

This case allots a constant 11 percent of GNP to defense each year as well as the net investment decreasing

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[1] If $y = AK^{\alpha}L^{1-\alpha}$ then $\frac{Kf_K}{y} = \alpha$ and from Chapter V. all the α values are positive fractions.

[2] This can be seen by comparing plots in figures 15 and 16.

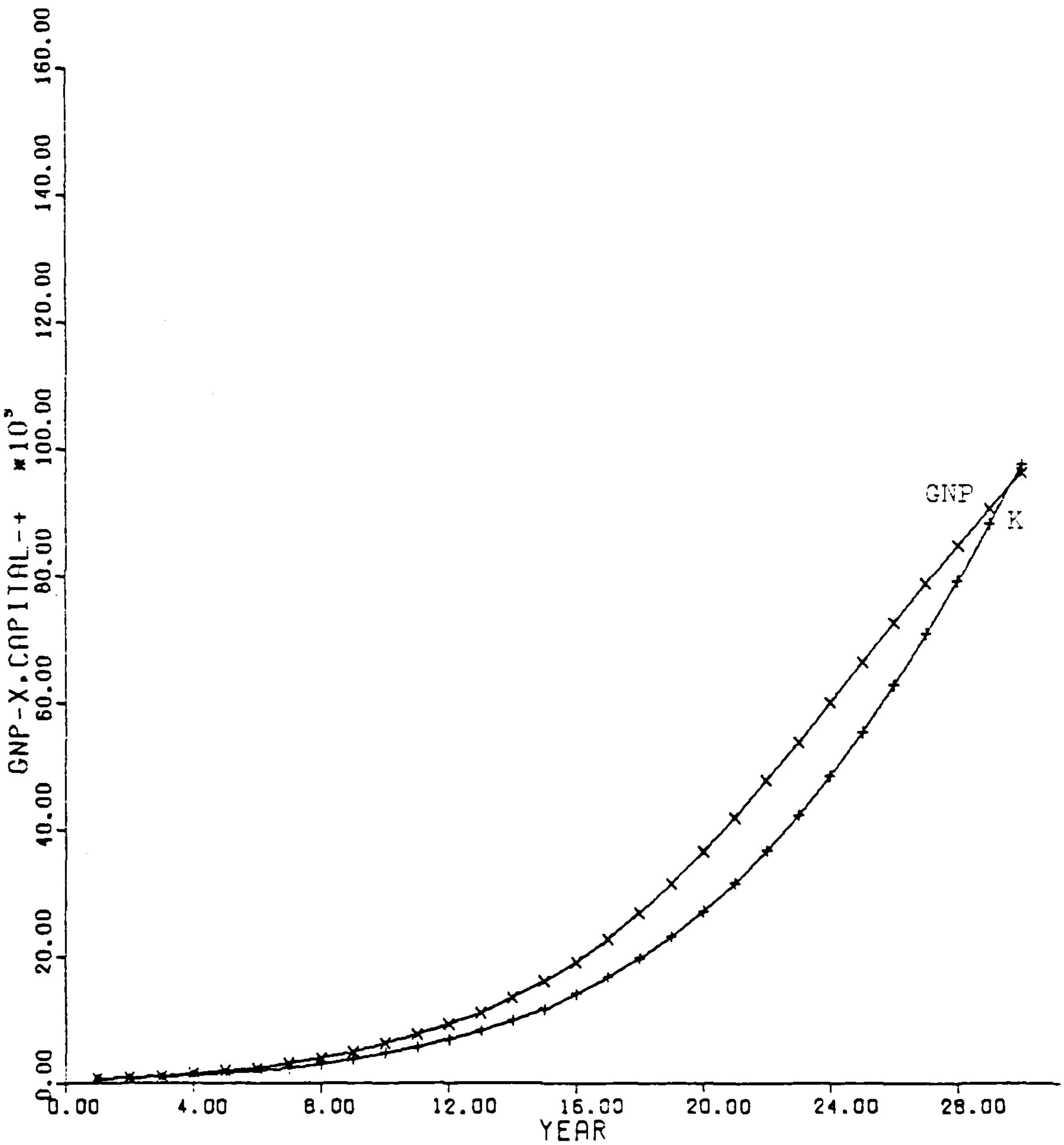

Figure 17. Growth in GNP and Capital Stock
(Defense Constant Share - 11% of GNP)

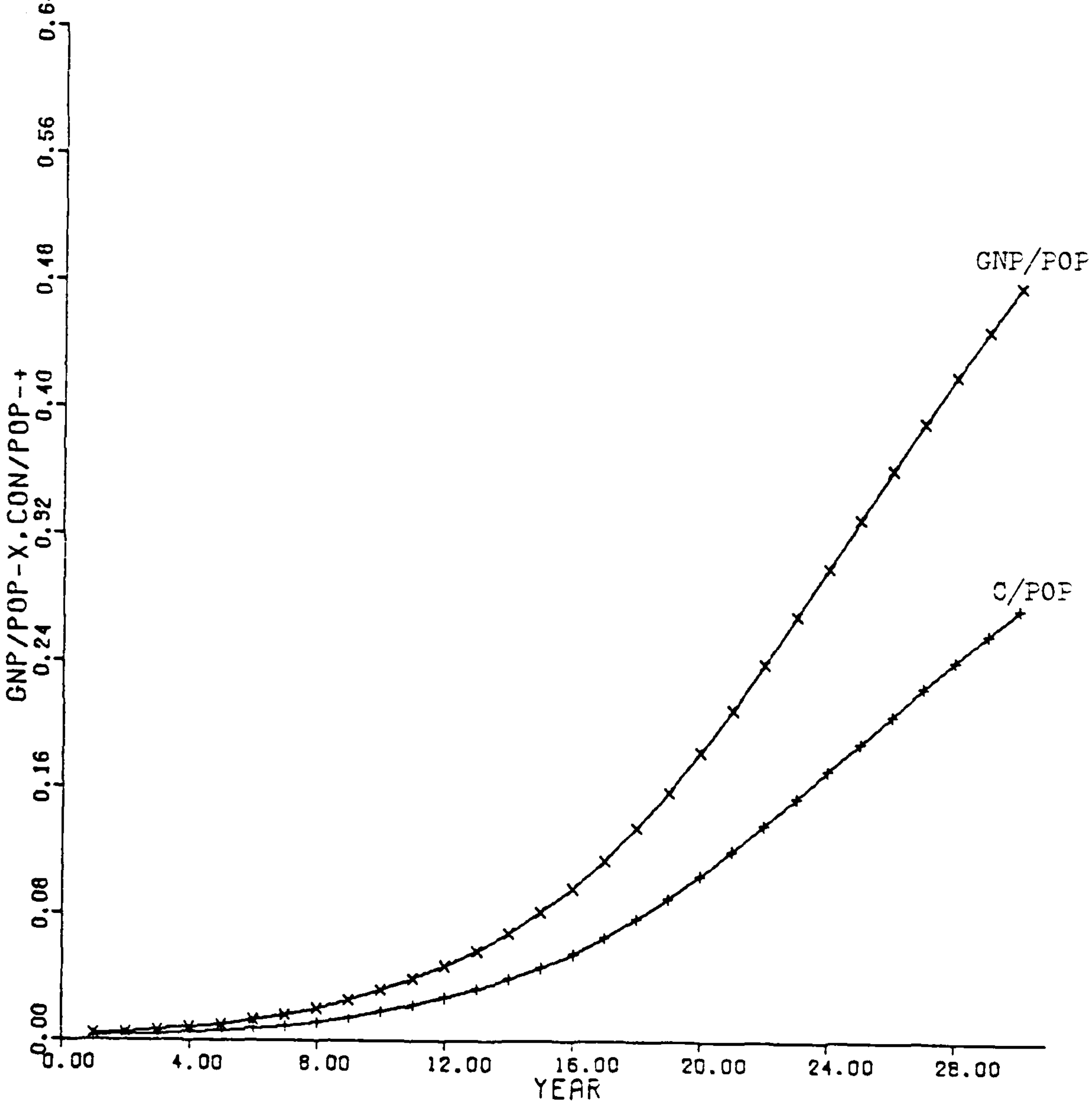

Figure 18. Growth in GNP per Capita and Consumption per Capita (Defense Constant Share - 11% of GNP)

after 10 years model which was explained with equation (11). Figure 17 shows the crossover of GNP and capital at year 30 indicating a better utilization of capital than in the previous model. Per capita consumption does not reach as high a level in this model, but the rate of increase does not begin to decline in the 30 years as it does in the previous case (Figure 16).

These results were assumed to be from the most reasonable combination of inputs and therefore this is used as the base case in the nuclear scenario. For comparison purposes constant net investment growth rates of 10 percent and 5 percent cases were run and the results are included in Appendix B. As previously mentioned (page 7) arguments for either of these cases might also be brought forward and substantiate their use as the base case. To demonstrate the implications, the 5 percent capital growth rate nuclear scenario results are also given in Appendix B.

Nuclear Scenario - No Change in Death Rate (Figures B-1, B-2, B-3; Appendix B)

The nuclear scenario is as described in Chapter III., that is, new starting values for capital and labor are assumed. Capital is reduced 50.5% from the base case. Reduction in actual manpower is 50.2% for industry, transportation and communication, and construction and 10% for agriculture. Since the scenario assumes bombing of cities it is assumed that the labor loss in the rural agricultural areas would be much less.

Results indicate that capital recovers in 5 years, effective labor 23 years and GNP 5 years.

<u>Nuclear Scenario - Increased Death Rate</u>

In order to capture the effects of residual nuclear radiation, the death rate for education levels 2 and 3 was increased by .5%. Since most education level 1 labor is in the agriculture sector its death rate was only increased by .2%. Research conducted by the Cancer Research Institute and Japanese medical teams on survivors of Hiroshima and Nagasaki indicate higher levels of cancer. However, there were no more abnormalities among the offspring of the survivors than among the general population (Ref 19:98). This would seem to indicate that a death rate increase for much longer than the 30 years simulation of this model would not be justified.

Results (Figures B-4, B-5, B-6) indicate that capital recovers in 5 years, effective labor 29 years, and GNP 5 years. Thus, the increased death rate (as small as it is) has no significant impact on economic recovery. As in the previous case, the capital recovery rate appears to be quite short. During World War II the Soviet Union used capital taken from Germany and it seems reasonable to assume that similar use of European capital is possible. Effective labor recovery is constrained by the education model (i.e. the time required for an individual to get through the education system).

The constant net investment growth rate of 5% case results (Figures B-9, B-10, B-11) indicate that capital recovers in 13 years, effective labor 29 years, and GNP 12 years.

VII. VERIFICATION AND VALIDATION

Verification is the process of assuring that the model does what it is expected/designed to do. This can often be checked simply by comparing hand calculation results with those of the computer model.

> Validation is the process of bringing to an acceptable level the user's confidence that any inference about a system derived from the simulation is correct. It is impossible to prove that any simulator is a correct or "true" model of the real system. Fortunately, we are seldom concerned with validating the insights we have gained or will gain from the simulation. Thus, it is the operational utility of the model and not the truth of its structure that usually concerns us.
> (Ref 17:29)

With those explanations in mind,a few words about the specific model of this research effort will be given.

Education Model

If 2200 births were generated in a year we might expect that on the average:

2200 enter primary school (EL_1) which implies (.01) (2200) = 22 enter the labor force with primary education (LF_1) leaving 2178 (2200 - 22) to enter secondary education (EL_2) which implies (.70) (2178) = 1525 enter LF_2 and (.10) (2178) = 218 drop out of EL_2 and are added to LF_1. This leaves (.20) (2178) = 435 entering college (EL_3). Of the 435 entrants (.30) (435) = 131 drop out and are added to LF_2 and (.70) (435) = 304 graduate and enter LF_3.

Thus, the total entering the labor force at each education level is:

EL_1 - 240
EL_2 - 1656
EL_3 - 304

Results of the simulation show gains in each sector total to the following for each education level:

$EL_1 = 30 + 30 + 50 + 129 = 239$
$EL_2 = 600 + 325 + 300 + 432 = 1657$
$EL_3 = 250 + 56 = 306$

Since the population birth rate is generated from a normal distribution by random numbers the actual results are quite in line with the expected results. It is also easily verified that priority is given to the sectors in the order and amounts as specified in Chapter V. Thus, it can be concluded that the education model is doing what it was designed to do.

From Table 5 (p. 40) it can be determined that in 1970 the educational attainment of the labor force in percentages was:

Higher (3)	Secondary (2)	Primary (1)
6.48	27.77	65.75

Results of the model show similar percentages: 6.52, 29.75, and 63.73 respectively. From this we can conclude that the model is valid in that it generates data which is fairly consistent with actual 1970 statistics.

Growth Model

Since the growth model is a straight-forward Fortran program, verification was made by performing one iteration by hand calculations. These results are simple enough and do not warrant illustration here. Checks were also made to verify that the sum of all defense, investment, and consumption expenditures totaled to the GNP figure and that the difference between required and available capital was less than five percent of the required capital. It is thus concluded that the model is verifiable.

Validation of the model lies in the "economic sense" of the results as indicated in Chapter VI. That is, the model is based on plausible assumptions and it produces results which are economically defensible. Additionally, it can be noted that GNP and capital growth rates closely parallel each other which agrees with Desai's statistics[1] (Ref 5:409) and results of SOVMOD I (Ref 10:113).[2]

Validity of this model for use as a predictor of economic recovery in the Soviet Union following a nuclear attack lies ultimately in the economic and historical base of the underlying assumptions. If the assumptions are accepted as valid and the data as plausible, and since there are no historical statistics with which this model can be compared, then overall validity of the model must be accepted.

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[1] These are actual historical values of GNP and capital stock

[2] SOVMOD is the most comprehensive econometric model of the Soviet Union available

VIII. CONCLUSION

It is important that the reader not take the absolute values of the results as reality. What is most important is the relationship between the parameters of the model. For example, whether capital recovery takes 5 years or 13 years is not as important as the fact that the difference occurs as a direct result of the investment formula. It is obvious that effective labor recovery is contingent on parameters in the education model such as dropout rates and percentages allowed to proceed to the next education level. Thus it is important that the interrelationships between parameters in the model be examined to determine how these relationships effect recovery. Another real value of this model lies in the simplicity of being able to change much of the data in order to do sensitivity analysis.

Limitations

This study is based on many assumptions which directly affect the results. Some assumptions were made because of data limitations. For example, the damage model data is necessarily restricted by the fact that the study was kept unclassified. Most assumptions were made in order to reduce a complex problem to one simple enough to enable examination of interrelationships between key variables in the economic growth model. One such assumption is limiting the economy to four sectors. The many assumptions are explicitly stated throughout the report and are written in the model so they are easily changed. The reader should examine these assumptions in order to assess their impact on the results.

Recommendations for Future Study

The following is a list of recommendations for future study which would enhance the validity of the model.

A. The present model permits free exchange of capital between the sectors. This implies that a tractor used in agriculture could be melted down and made into a drill press, instantaneaously and without loss of value. In reality the assumption of free substitutability of capital yields a too optimistic prediction of Soviet economic recovery. It is conceivable that following a nuclear attack, machinery, for example, may be left intact but no source of fuel will exist. Until fuel can be obtained, substantial delays would result in rebuilding the industry needed for recovery of the economy.

B. An improved nuclear damage model could be developed by considering bombing of specific targets such as communication and transportation centers.

C. The finding of data sources to eliminate some of the assumptions would enhance the model. For example, if actual Soviet planning desires were known for the sectoral requirements of college-educated labor, a more accurate estimate of effective labor could be made.

Such data requirements would probably necessitate upgrading the study to a classified document.

D. A more refined education model to include a breakout of secondary schools by type (vocational, technical, etc.) along with an accounting for on-the-job training would have an impact on the effective labor.

E. An additional loop could be added in the QGERT model to account for college graduates that enter the labor force as academic instructors. This would result in fewer highly skilled workers available for the producing sectors. Also, if a shortage of instructors existed, then a delay in turning out high skill labor would result. Similarly, government bureaucrats and other administrative (nonproductive) personnel could be considered separately.

F. The assumption of a steady state in the education system prior to the nuclear attack may not be valid following the attack. It is possible that since people will have to go where they are needed most (such as growing food and building shelters) no one will be in school until basic economic recovery is attained. This may reduce the effective labor force for many years.

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APPENDIX A

Computer Code

QGERT CODE - EDUCATION MODEL

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VAS,56,6,CO,0.99*
VAS,43,1,AT,2,2,UF,1,1,AT,3,3,UF,1,1,AT,4,4,UF,1,1,AT,5,5,UF,1*
VAS,45,2,AT,1,3,CO,0.,4,CO,0.,5,CO,0.,1,UF,6*
```

```
VAS,46,1-,AT,2*
VAS,47,3,AT,1,4,CO,0.,5,CO,0.,1,UF,6*
VAS,48,1-,AT,3*
VAS,49,[illegible],AT,1,5.CO,[illegible].,1,UF,6*
VAS,50,1-,[illegible]
[illegible]
VAS,51,6,CO,1,2-,UF,7,3+,UF,[illegible],4+,UF,[illegible],[illegible]+,UF,10
VAS,57,6,CO,1.99*
VAS,54,1,AT,2,2,UF,1,1,AT,3,3,UF,1,1,AT,4,4,UF,1,1,AT,5,5,UF,1*
ACT,1,1,CO,1.,1*
ACT,1,2,CO,7.,2*
ACT,2,3,CO,8.,3*
ACT,3,4,,,4,,,T.GT.25*
ACT,3,58,(9)T.LE.25*
ACT,2,5,CO,8.,5*
ACT,5,6,CO,0.99,6*
ACT,6,7,,,7,,,T.GT.25*
ACT,6,58,(9)T.LE.25*
ACT,5,8,CO,1.99,8*
ACT,8,9,,,9,,,T.GT.25*
ACT,8,58,(9)T.LE.25*
ACT,5,10,CO,2.99,10*
ACT,10,11,,,11,,,T.GT.25*
ACT,10,58,(9)T.LE.25*
ACT,5,12,CO,4,12*
ACT,12,13,,,13,,,T.GT.25*
ACT,12,58,(9)T.LE.25*
ACT,5,14,CO,4.,14*
ACT,14,15,CO,0.99,15*
ACT,15,16,,,16,,,T.GT.25*
ACT,15,58,(9)T.LE.25*
ACT,14,17,CO,1.99,17*
ACT,17,18,,,18,,,T.GT.25*
ACT,17,58,(9)T.LE.25*
ACT,14,19,CO,2.99,19*
ACT,19,20,,,20,,,T.GT.25*
ACT,19,58,(9)T.LE.25*
ACT,14,21,CO,4.,21*
ACT,21,32,,,22,,,T.GT.25*
ACT,32,22*
ACT,32,29*
ACT,32,40*
ACT,32,51*
ACT,21,58,(9)T.LE.25*
ACT,22,23,,,23,,,A1.LE.A2*
ACT,22,24*
ACT,24,25,,,24,,,A1.LE.A3*
ACT,24,26*
ACT,26,27,,,25,,,A1.LE.A4
ACT,26,28*
ACT,29,30,CO,0.01,26*
ACT,35,31*
ACT,31,3[illegible]*
ACT,13,37*
ACT,33,34,,,28,,,A1.LE.A2*
ACT,33,35*
ACT,35,36,,,29,,,A1.LE.A3*
ACT,35,37*
ACT,37,38,,,30,,,A1.LE.A4*
ACT,37,39*
```

```
ACT,40,42,CC,0.01,32*
ACT,41,56,UF,11*
ACT,53,47,UF,11*
ACT,39,55,UF,11*
ACT,53,43*
ACT,43,42*
ACT,4,44*
ACT,44,45,,,34,,,A1.LE.A2*
ACT,44,46*
ACT,46,47,,,35,,,A1.LE.A3*
ACT,45,48*
ACT,47,49,,,36,,,A1.LE.A4*
ACT,43,50*
ACT,51,53,CC,0.01,37*
ACT,57,54*
ACT,54,53*
FIN*
```

```
      FUNCTION UF(IFN)
      COMMON/QVAR/ NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),NPUN,
     *NPUNS,NTC(500),PARAM(100,4),TBEG,TNOW
      DIMENSION A2EL(3),A3EL(3),A4EL(3),A5EL(3)
      COMMON/SVAR/ SUMA,SUMB
      GO TO (1,2,3,4,5,6,7,8,9,10,11),IFN
    1 AF=GATRB(5)
      UF=GATRB(1)*AF
      RETURN
    2 SUMA=SUMA+GATRB(1)
      UF=2
      RETURN
    3 UF=SUMA
      SUMA=0.0
      RETURN
    4 SUMB=SUMB+GATRB(1)
      UF=4
      RETURN
    5 UF=SUMB
      SUMB=0.0
      RETURN
    6 IA6=GATRB(6)
      A2EL(IA6)=GATRB(2)
      A3EL(IA6)=GATRB(3)
      A4EL(IA6)=GATRB(4)
      A5EL(IA6)=GATRB(5)
      RETURN
    7 IA6=GATRB(6)
      UF=A2EL(IA6)
      RETURN
    8 IA6=GATRB(6)
      UF=A3EL(IA6)
      RETURN
    9 IA6=GATRB(6)
      UF=A4EL(IA6)
      RETURN
   10 IA6=GATRB(6)
      UF=A5EL(IA6)
      RETURN
   11 UF=1
      CALL US
      RETURN
      END
```

```
      SUBROUTINE UI
      COMMON/QVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     *NPUN,NPUNS,NTC(500),PARAM(100,4),TBEG,TNOW
      COMMON/SVAR/ SUMA,SUMB
      SUMA=0.0
      SUMB=0.0
      RETURN
      END
```

```
      SUBROUTINE US
      COMMON/SCOM1/ [illegible]
     1[illegible]
      [illegible] D(5,[illegible]),GI([illegible]),C([illegible]),Y([illegible]),CAP([illegible]),FTL(5),TL(5,5,[illegible])
      DIMENSION T([illegible]),PCY(40),PCC([illegible]),EL(40),GNP(40),DEF(40)
      INTEGER A,B,BC,BD,E,F
      M=TNOW-25
      A=GATRB(1)
      B=GATRB(2)
      BC=GATRB(3)
      BD=GATRB(4)
      E=GATRB(5)
      F=TNOW
C THESE ARE THE LABOR VALUES FOR EACH SECTOR BY EDUCATION
C LEVEL.  OBTAINED FROM THE OGERT MODEL.
      TL(1,A,M)=B
      TL(2,A,M)=BC
      TL(3,A,M)=BD
      TL(4,A,M)=E
      IF(F.EQ.26.AND.A.EQ.3)PRINT 110
  110 FORMAT(9X,"ED. LEVEL",7X,"INDUSTRY",5X,"TRANS/COMM",3X,
     1"CONSTRUCTION",4X,"AGRICULTURE",11X,"YEAR",//)
      PRINT 100,A,B,BC,BD,E,F
  100 FORMAT(3X,6I15)
      IF(F.EQ.100.AND.A.EQ.1)GO TO 85
      GO TO 99
C INITIAL VALUES------YEAR(M),POPULATION(POP),GNP(YT),
C CAPITAL(CAP),GROWTH IN DEFENSE(GD),DEFENSE(DEF),PERCENTAGE
C GNP ALLOCATED TO INVESTMENT(INVEST),CONSUMPTION(CNSMP)
C 2---INDUSTRY
C 3---CONSTRUCTION
C 4---AGRICULTURE
C 5---TRANSPORTATION AND COMMUNICATION
   55 M=1
      IN=1
      POP=195000.
      DEF(1)=11.
      YT=3[illegible]
      CAP(1)=636.
      GD=.1[illegible]
      P=.[illegible]
   1[illegible] DEF(M)=.11*YT
      INVEST=P*(YT-DEF(M))
      CNSMP=(1-P)*(YT-DEF(M))
      D(M,2)=.85*DEF(M)
      D(M,3)=.10*DEF(M)
      D(M,4)=0.
      D(M,5)=.05*DEF(M)
      GI(2)=.32*INVEST
      GI(3)=.60*INVEST
      GI(4)=.03*INVEST
      GI(5)=.05*INVEST
      C(2)=.10*CNSMP
      C(3)=0.
      C(4)=.90*CNSMP
      C(5)=0.
      DO 5 K=2,5
```

```
C GNP IN SECTOR K
      Y(K)=GT(K)+C(K)-D(M,K)
    8 CONTINUE
      [illegible]
C OUTPUT LEVELS FOR EACH SECTOR AS DETERMINED FROM THE I-O
C TABLE(X1-INDUSTRY,X2-CONSTRUCTION,X3-AGRICULTURE,X4-TSC)
      X1=1.7 1*Y(2)+.0696*Y(3)+.2109*Y(4)-.3922*Y(5)
      X2=Y(2)
      X3=.0017*Y(3)+1.313*Y(4)
      X4=. 957*Y(2)+.0473*Y(3)+.0246*Y(4)+.9794*Y(5)
      DO 5 I=1,4
C EFFECTIVE LABOR INEACH SECTOR
      FTL(I)=TL(I,1,M)+1.57*TL(I,2,M)+2.14*TL(I,3,M)
    5 CONTINUE
C REQUIRED CAPITAL FOR EACH SECTOR COMPUTED FROM RESPECTIVE
C PRODUCTION FUNCTIONS
      C1=((X1/(.9763*2.7**(.00451*M)))**.976-(.2126)*FTL(1)**(-.976))/.7
     1974
      C2=(X4/(1.147*FTL(2)**.426*2.7**(.0233*M)))**1.742
      C3=(X2/(FTL(3)**.334*2.7**(.0149*M)))**15.15
      C4=(X3/(1.097*FTL(4)**.702*2.7**(.005*M)))**3.356
C TOTAL REQUIRED CAPITAL AND COMPARISON TO AVAILABLE CAPITAL
      CC=C1+C2+C3+C4
      AA=CAP(M)+(.05*CC)
      AAA=CAP(M)-(.05*CC)
      IF(CC.GT.AA)YT=YT-1
      IF(CC.LT.AAA)YT=YT+1
      IF(CC.GT.AA.OR.CC.LT.AAA)GO TO 10
C POPULATION COUNT
      POP=(POP*22.0)-.01*(POP+2200)
C TOTAL CONSUMPTION
      CON=C(2)+C(3)+C(4)+C(5)
      PCY(M)=YT/POP
      PCC(M)=CON/POP
      GNP(M)=YT
C TOTAL EFFECTIVE LABOR
      EL(M)=FTL(1)+FTL(2)+FTL(3)+FTL(4)
      PRINT 310
  310 FORMAT(//,2X,"YEAR",10X,"GNP",9X,"CAPITAL(A)",4X,"CAPITAL(R)")
      PRINT 31 ,M,YT,CAP(M),CC
  31  FORMAT(3X,I2,2X,3F14.2,/)
      PRINT 410
  410 FORMAT(9X,"GNP/POP",7X,"CON/POP",10X,"LABOR")
      PRINT 400,PCY(M),PCC(M),EL(M)
  400 FORMAT(3X,2F14.3,2X,F14.2,/)
      DO 11 K=2,5
      IF(K.EQ.2)PRINT 210
  210 FORMAT(11X,"DEFENSE",6X,"INVESTMENT",4X,"CONSUMPTION")
      PRINT 200,D(M,K),GI(K),C(K)
  2.  FORMAT(3X,3F14.2)
   11 CONTINUE
      T(M)=M
      M=M+1
C CALCULATION OF GROWTH IN NET INVESTMENT(TNI)
      IF(M.LE.10)TNI=.202*YT
      IF(M.GT.10)TNI=(.25+2.7**(-1.387-.035*M))*YT
      IN=1
```

```
      N=M-1
      CAP(N)=TNI+CAP(N)
      IF(M.LT.31)GO TO 1
      CALL PLOTS(0.,0.,9)
      CALL PLOT(0.,1.,3)
      CALL SCALE(GNP,3.,30,1)
      CALL SCALE(T,8.,30,1)
      CALL AXIS(0.,0.,15HGNP-X,CAPITAL-+,15,8.,90.,GNP(31),GNP(32))
      CALL AXIS(0.,0.,4HYEAR,-4,8.,0.,T(31),T(32))
      CALL LINE(T,GNP,30,1,1,4)
      CAP(32)=GNP(32)
      CAP(31)=GNP(31)
      CALL LINE(T,CAP,30,1,1,3)
      CALL PLOTE(N)
      CALL PLOT(0.,1.,3)
      CALL SCALE(PCY,3.,30,1)
      CALL SCALE(T,8.,30,1)
      CALL AXIS(0.,0.,19HGNP/POP-X,CON/POP-+,19,8.,90.,PCY(31),PCY(32))
      CALL AXIS(0.,0.,4HYEAR,-4,8.,0.,T(31),T(32))
      CALL LINE(T,PCY,30,1,1,4)
      PCC(31)=PCY(31)
      PCC(32)=PCY(32)
      CALL LINE(T,PCC,30,1,1,3)
      CALL PLOTE(N)
      CALL PLOT(0.,1.,3)
      CALL SCALE(EL,8.,30,1)
      CALL SCALE(T,8.,30,1)
      CALL AXIS(0.,0.,5HLABOR,5,8.,90.,EL(31),EL(32))
      CALL AXIS(0.,0.,4HYEAR,-4,8.,0.,T(31),T(32))
      CALL LINE(T,EL,30,1,1,1)
      CALL PLOTE(N)
   99 CONTINUE
      RETURN
      END
```

APPENDIX B

Results

Base Case Results (See Figures 17 & 18)

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
1	770.0	638.00	607.74

GNP/POP	CON/POP	LABOR
.00392421	.00224492	148294.27

DEFENSE	INVESTMENT	CONSUMPTION
72.00	77.75	44.13
8.47	145.00	0.00
0.00	7.29	397.20
4.24	12.15	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
2	965.00	793.54	756.39

GNP/POP	CON/POP	LABOR
.00491769	.00281352	150129.42

DEFENSE	INVESTMENT	CONSUMPTION
90.32	37.92	55.37
10.63	133.50	0.00
0.00	9.13	498.31
5.31	15.30	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
3	1216.00	999.67	942.68

GNP/POP	CON/POP	LABOR
.00618365	.00354422	151939.17

DEFENSE	INVESTMENT	CONSUMPTION
113.70	123.2	69.70
13.39	231.10	0.00
0.00	11.55	627.27
6.69	19.25	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
4	1531.00	1234.30	1175.69

GNP/POP	CON/POP	LABOR
.00777714	.00435735	153748.93

DEFENSE	INVESTMENT	CONSUMPTION
143.15	155.2	67.75
16.84	291.0	0.00
0.00	14.57	789.76
8.42	24.23	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
5	1935.0	1547.57	1471.48

GNP/POP	CON/POP	LABOR
.00961892	.00552782	156521.73

DEFENSE	INVESTMENT	CONSUMPTION
166.92	195.15	110.91
21.29	357.8	0.00
0.00	18.39	998.16
10.64	30.57	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
6	2447.00	1934.44	1342.55

GNP/POP	CON/POP	LABOR
.01240396	.00710947	157274.13

DEFENSE	INVESTMENT	CONSUMPTION
228.79	248.10	140.25
26.92	455.72	0.00
0.00	23.25	1262.27
13.46	38.75	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
7	3133.00	2429.73	2314.09

GNP/POP	CON/POP	LABOR
.01571291	.00907591	159034.10

DEFENSE	INVESTMENT	CONSUMPTION
290.13	314.55	177.85
34.13	539.8	0.00
0.00	29.40	1570.06
17.07	49.15	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
8	3941.00	3055.54	2910.19

GNP/POP	CON/POP	LABOR
.01993564	.01142543	160759.25

DEFENSE	INVESTMENT	CONSUMPTION
368.43	399.35	225.98
43.35	708.91	0.00
0.00	37.40	2032.94
21.69	62.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
9	5015.0	3851.62	3569.25

GNP/POP	CON/POP	LABOR
.02534801	.01452947	162473.99

DEFENSE	INVESTMENT	CONSUMPTION
469.00	509.46	287.50

55.15	933.40	0.00
00.0	47.57	2587.47
27.59	79.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
10	6395.0.	4854.85	4634.43

GNP/POP	CON/POP	LABOR
.03225421	.01958402	164161.33

DEFENSE	INVESTMENT	CONSUMPTION
597.93	548.32	366.54
70.34	1215.60	0.00
0.00	60.73	3298.82
35.17	101.30	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
11	7749..	5947.53	5570.32

GNP/POP	CON/POP	LABOR
.03908078	.0223935	165829.55

DEFENSE	INVESTMENT	CONSUMPTION
724.53	735.57	444.14
85.24	1473.00	0.00
0.00	73.55	3997.28
42.62	122.75	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
12	9362.00	7310.83	6678.05

GNP/POP	CON/POP	LABOR
.04716924	.02703552	157476.94

DEFENSE	INVESTMENT	CONSUMPTION
875.35	949.12	536.59
102.93	1779.5	0.00
0.00	98.99	4829.33
51.49	149.3	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
13	11275.00	8384.25	7985.10

GNP/POP	CON/POP	LABOR
.05675239	.03272820	159113.20

DEFENSE	INVESTMENT	CONSUMPTION
1054.21	1143.04	646.24
124.03	2143.20	0.00
0.00	107.15	5816.14
62.01	178.60	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
14	13535.0	[illegible]	9524.91

GNP/POP	CON/POP	LABOR

.05816753	.03911338	170717.50

DEFENSE	INVESTMENT	CONSUMPTION
1261.62	1372.15	775.83
148.92	2572.81	0.00
0.00	128.64	6952.46
74.45	214.40	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
15	15130.0	11898.85	11332.40

GNP/POP	CON/POP	LABOR
.08133605	.04561957	172279.13

DEFENSE	INVESTMENT	CONSUMPTION
1513.77	1641.29	927.95
178.09	3077.4	0.00
0.00	153.87	8351.51
89.04	256.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
16	19284.0	14118.97	13446.70

GNP/POP	CON/POP	LABOR
.09678865	.05547539	173841.48

DEFENSE	INVESTMENT	CONSUMPTION
1803.05	1974.99	1105.28
212.12	3555.4	0.00
0.00	133.27	9947.54
106.06	315.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
17	22857.00	13715.83	15911.53

GNP/POP	CON/POP	LABOR
.11461518	.06539284	175392.56

DEFENSE	INVESTMENT	CONSUMPTION
2137.13	2317.44	1310.37
251.47	4375.2	0.00
0.00	217.25	11790.65
125.71	362.1	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
18	25935.0	19705.32	18769.12

GNP/POP	CON/POP	LABOR
.13493975	.07774217	176920.81

DEFENSE	INVESTMENT	CONSUMPTION
2516.42	2777.98	1543.31
296.23	5127.47	0.00
0.00	256.22	13894.26
148.14	426.70	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
19	31522.00	27157.30	22064.52

GNP/POP	CON/POP	LABOR
.15777604	.13043092	175419.81

DEFENSE	INVESTMENT	CONSUMPTION
2947.31	3135.8	18[illegible]6.71
346.74	5932.27	0.00
0.00	293.51	16259.43
173.37	499.35	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
20	36595.00	27137.28	25841.31

GNP/POP	CON/POP	LABOR
.18301279	.10439989	179901.40

DEFENSE	INVESTMENT	CONSUMPTION
3421.67	3710.33	2097.48
472.55	5955.40	0.00
0.00	347.52	18877.31
211.27	579.70	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
21	42037.00	31542.62	30136.66

GNP/POP	CON/POP	LABOR
.21132943	.12035241	181366.01

DEFENSE	INVESTMENT	CONSUMPTION
3936.17	4258.11	2412.83
463.17	9102.8	0.00
0.00	410.1	21715.48
231.53	555.97	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
22	47945.00	35724.65	34376.38

GNP/POP	CON/POP	LABOR
.23933673	.13717924	182915.50

DEFENSE	INVESTMENT	CONSUMPTION
482.86	4957.8	2748.02
527.40	9114.97	0.00
0.00	455.7	20732.14
263.74	759.5	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
23	54037.00	42335.80	40379.48

GNP/POP	CON/POP	LABOR
.20951229	.15447351	185249.58

DEFENSE	INVESTMENT	CONSUMPTION
5112.45	5478.72	3057.18

594.41	1 272.5	0.00
[illegible]	513.57	21874.66
297.2	956.[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
24	6 268.[illegible]	49553.55	46347.36

GNP/POP	CON/POP	LABOR
.3 133[illegible]56	.1720774[illegible]	165567.11

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]635.06	5197.4	3454.32
682.95	11457.[illegible]	0.00
0.00	572.85	31168.39
331.47	954.77	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
25	66544.[illegible]	55517.19	52874.15

GNP/POP	CON/POP	LABOR
.33132266	.18990283	187071.23

DEFENSE	INVESTMENT	CONSUMPTION
5221.86	57[illegible]6.55	3814.04
731.96	125[illegible]9.8[illegible]	0.00
0.00	532.49	34326.32
365.99	1[illegible]34.15	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
26	72780.[illegible]	62939.45	59942.69

GNP/POP	CON/POP	LABOR
.35216603	.2[illegible]7[illegible]21[illegible]	1854[illegible].52

DEFENSE	INVESTMENT	CONSUMPTION
5814.93	73[illegible]5.89	4171.46
8[illegible]0.58	13835.4[illegible]	0.00
0.00	631.77	375[illegible]3.13
4[illegible]0.29	1152.95	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
27	78925.[illegible]	7[illegible]9 4.35	67528.65

GNP/POP	CON/POP	LABOR
.3[illegible]231353	.22435842	189819.54

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]379.56	5021.92	4523.72
868.19	15[illegible]3.6	0.00
0.00	75[illegible].19	40713.56
434.09	125[illegible].3[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
28	84905.	7[illegible]3[illegible]1.57	75562.93

GNP/POP	CON/POP	LABOR
.[illegible]2188[illegible]	.2[illegible]13[illegible]352	191192.13

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]942.45	3512.48	[illegible]258.75
931.41	151[illegible]8.4	0.00
0.00	9[illegible].42	43518.58
467.2[illegible]	13[illegible]5.7[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
29	91797.[illegible]	[illegible]9339.77	84132.43

GNP/POP	CON/POP	LABOR
.45[illegible]57941	.2582541[illegible]	192533.76

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]489.52	32[illegible]5.75	5204.12
996.77	1725[illegible].8	0.00
0.00	853.7	46837.09
499.38	147[illegible].4	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
30	95483.[illegible]	[illegible]775[illegible].93	93066.93

GNP/POP	CON/POP	LABOR
.4[illegible]84[illegible]944	.2742[illegible]516	193857.12

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]021.15	3732.98	5530.12
1051.31	193[illegible]1.4[illegible]	0.00
0.00	917.[illegible]	49770.18
530.65	1529.45	0.00

Nuclear Scenario - No Change in Death Rate

YEAR	GNP	CAPITAL (A)	CAPITAL (R)
1	375.[illegible]	31[illegible].[illegible]	302.30

GNP/POP	CON/POP	LABOR
.00356529	.00218104	102705.64

DEFENSE	INVESTMENT	CONSUMPTION
35.16	33.05	21.55
4.14	71.40	0.00
0.00	3.57	193.96
2.07	5.95	0.00

YEAR	GNP	CAPITAL (A)	CAPITAL (R)
2	470.00	391.95	373.38

GNP/POP	CON/POP	LABOR
.00470001	.00259386	105066.96

DEFENSE	INVESTMENT	CONSUMPTION
43.95	47.35	26.94
5.17	93.80	0.00
0.00	4.44	242.45
2.59	7.45	0.00

YEAR	GNP	CAPITAL (A)	CAPITAL (R)
3	589.00	496.89	464.01

GNP/POP	CON/POP	LABOR
.00582143	.00333561	107401.86

DEFENSE	INVESTMENT	CONSUMPTION
55.07	59.52	33.76
6.48	111.5[illegible]	0.00
0.00	5.59	303.83
3.24	9.30	0.00

YEAR	GNP	CAPITAL (A)	CAPITAL (R)
4	739.00	605.67	577.26

GNP/POP	CON/POP	LABOR
.00722074	.00413854	109731.10

DEFENSE	INVESTMENT	CONSUMPTION
69.10	74.89	42.36
8.13	110.4	0.00
0.00	7.02	381.21
4.05	11.71	0.00

YEAR	GNP	CAPITAL (A)	CAPITAL (R)
5	931.00	755.15	719.29

GNP/POP	CON/POP	LABOR
.00859529	.0051557[illegible]	112012.94

DEFENSE	INVESTMENT	CONSUMPTION
87.05	94.39	53.36
10.24	136.4[illegible]	0.00
[illegible]	9.82	480.25
5.12	14.7[illegible]	0.00

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A HEURISTIC MODEL FOR EVALUATING SENSITIVITY TO LABOR AND CAPIT--ETC(U)

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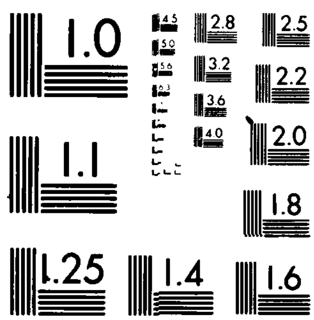

MICROCOPY RESOLUTION TEST CHART
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YEAR	GNP	CAPITAL(A)	CAPITAL(R)
6	1174.[illegible]	9[illegible]3.21	898.51

GNP/POP	CON/POP	LABOR
.01121925	.00643[illegible]42	11[illegible]263.10

DEFENSE	INVESTMENT	CONSUMPTION
1[illegible]9.77	1[illegible]8.72	67.29
12.91	222.6[illegible]	0.00
[illegible]	11.17	6[illegible]5.60
6.46	18.57	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
7	14[illegible]3.0[illegible]	118[illegible].36	1124.33

GNP/POP	CON/POP	LABOR
.014[illegible]2.55	.[illegible]8[illegible]3503	116523.98

DEFENSE	INVESTMENT	CONSUMPTION
136.66	17[illegible].[illegible]8	65.00
16.31	231.4	0.00
0.00	14.07	765.00
8.16	23.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
8	1877.[illegible]	147[illegible].92	1469.60

GNP/POP	CON/POP	LABOR
.01755954	.01006443	118742.04

DEFENSE	INVESTMENT	CONSUMPTION
175.50	19[illegible].[illegible]9	117.58
2[illegible].65	356.4[illegible]	0.00
0.00	17.32	958.24
10.32	29.[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
9	2380.00	18[illegible]9.08	1770.82

GNP/POP	CON/POP	LABOR
.02203652	.01253045	120944.41

DEFENSE	INVESTMENT	CONSUMPTION
222.57	2[illegible]1.2[illegible]	136.41
26.18	4[illegible]2.4[illegible]	0.00
0.00	22.52	1227.71
13.[illegible]9	37.7[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
10	3025.[illegible]	23[illegible].6[illegible]	2228.49

GNP/POP	CON/POP	LABOR
.02772673	.0153919[illegible]	1231[illegible]7.25

DEFENSE	INVESTMENT	CONSUMPTION
2[illegible]2.6[illegible]	3[illegible]6.53	173.38
33.29	5[illegible]4.9[illegible]	0.00
0.00	29.7[illegible]	15[illegible].43
16.6[illegible]	47.9	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
11	3658.[illegible]	23[illegible]4.67	2672.28

GNP/POP	CON/POP	LABOR
.0331979[illegible]	.019[illegible]27[illegible]	125244.26

DEFENSE	INVESTMENT	CONSUMPTION
342.12	37[illegible].83	219.66
47.24	535.4[illegible]	0.00
0.00	34.7[illegible]	1686.96
20.12	57.9[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
12	4410.[illegible]	3373.82	3194.24

GNP/POP	CON/POP	LABOR
.03963559	.0227175[illegible]	127363.56

DEFENSE	INVESTMENT	CONSUMPTION
412.34	447.54	252.76
48.51	838.2	0.00
0.00	41.91	2274.87
24.26	59.35	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
13	5315.[illegible]	40[illegible].77	3811.63

GNP/POP	CON/POP	LABOR
.04723625	.02707393	129456.50

DEFENSE	INVESTMENT	CONSUMPTION
496.11	537.92	314.12
58.37	1018.6[illegible]	0.00
0.00	57.43	2737.07
29.18	34.0[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
14	6365.[illegible]	4731.6[illegible]	4535.09

GNP/POP	CON/POP	LABOR
.05613682	.03217538	131520.31

DEFENSE	INVESTMENT	CONSUMPTION
595.13	645.12	364.82
70.02	12[illegible]9.5[illegible]	0.00
0.00	5[illegible].48	3283.35
35.01	1[illegible].8	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
15	7616.[illegible]	567[illegible].[illegible]	5385.13

GNP/POP	CON/POP	LABOR
.06555721	.0391[illegible]	133521.47

DEFENSE	INVESTMENT	CONSUMPTION
712.1[illegible]	7[illegible]2.15	435.52
83.78	1447.[illegible]	0.00
0.00	72.35	3928.67
41.89	12[illegible].67	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
16	9090.[illegible]	55[illegible].39	6379.9[illegible]

GNP/POP	CON/POP	LABOR
.[illegible]872743	.[illegible]451234[illegible]	13[illegible]529.06

DEFENSE	INVESTMENT	CONSUMPTION
8[illegible]9.92	9[illegible]1.6	521.[illegible]0
99.99	17[illegible].[illegible]	0.00
[illegible]	[illegible]5.4	[illegible]689.02
5[illegible].0[illegible]	1[illegible]4.[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
17	1[illegible]820.[illegible]	[illegible]917.79	7541.86

GNP/POP	CON/POP	LABOR
.[illegible]9288752	.[illegible]3[illegible]3941	137519.67

DEFENSE	INVESTMENT	CONSUMPTION
1011.67	1[illegible]35.95	620.16
119.[illegible]2	2[illegible]6.8[illegible]	0.00
[illegible].00	1[illegible]2.8[illegible]	5581.43
59.51	1[illegible]1.4	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
18	12840.[illegible]	9379.15	8894.84

GNP/POP	CON/POP	LABOR
.1[illegible]927834	.[illegible]523739[illegible]	139475.46

DEFENSE	INVESTMENT	CONSUMPTION
12[illegible].54	13[illegible]1.75	735.94
141.24	24[illegible].8[illegible]	0.00
[illegible].0[illegible]	122.[illegible]	6523.44
7[illegible].62	2[illegible]3.4	0.[illegible]0

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
19	15185.0[illegible]	1[illegible]9[illegible]5.[illegible]	10464.99

GNP/POP	CON/POP	LABOR
.1[illegible]814223	.[illegible]73[illegible]460	1414[illegible]5.14

DEFENSE	INVESTMENT	CONSUMPTION
1419.8[illegible]	1579.52	67[illegible].34
167.[illegible]4	2[illegible]5.5[illegible]	0.00
[illegible].0[illegible]	1[illegible].33	7833.09
83.52	2[illegible].5[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
20	17894.[illegible]	125[illegible].53	1228[illegible].41

GNP/POP	CON/POP	LABOR
.1[illegible]974794	.[illegible]85[illegible]2953	1[illegible]331[illegible].13

DEFENSE	INVESTMENT	CONSUMPTION
1673.[illegible]9	1914.[illegible]	1[illegible]25.61
196.83	34[illegible]1.4	0.00
[illegible]	1[illegible].[illegible]	9233.51
9[illegible].42	2[illegible]3.[illegible]	0.[illegible]

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
21	2[illegible]955.[illegible]	151[illegible]7.45	14384.54

GNP/POP	CON/POP	LABOR
.1[illegible]420[illegible]36	.[illegible]49[illegible]8197	145167.01

DEFENSE	INVESTMENT	CONSUMPTION
19[illegible]3.03	2128.6[illegible]	12[illegible]3.35
231.95	3931.2[illegible]	0.00
0.00	129.55	1[illegible]830.14
115.47	332.5	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
22	24511.[illegible]	17538.[illegible]	16798.70

GNP/POP	CON/POP	LABOR
.2[illegible]181899	.1131745[illegible]	147351.62

DEFENSE	INVESTMENT	CONSUMPTION
2291.78	2435.12	14[illegible]4.87
269.62	4659.5	0.00
0.00	232.99	12643.85
134.81	3[illegible]8.3[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
23	28447.00	20537.83	19560.18

GNP/POP	CON/POP	LABOR
.23238372	.13319305	148891.83

DEFENSE	INVESTMENT	CONSUMPTION
2659.79	2834.15	1630.47
312.92	5[illegible]17.80	0.00
0.00	2[illegible].39	14674.21
156.46	45[illegible].65	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
24	32790.00	23875.87	22701.83

GNP/POP	CON/POP	LABOR
.26579[illegible]65	.1523[illegible]4[illegible]5[illegible]	150712.35

DEFENSE	INVESTMENT	CONSUMPTION
3065.87	3324.49	1879.39
36[illegible].69	5233.4[illegible]	0.00
0.00	3[illegible]1.67	16914.52
18[illegible].35	519.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
25	375[illegible]5.[illegible]	27555.67	26253.16

GNP/POP	CON/POP	LABOR
.3[illegible]17[illegible]33	.17232256	152512.18

DEFENSE	INVESTMENT	CONSUMPTION
35[illegible]6.72	38[illegible]2.5[illegible]	2169.64
412.55	7129.[illegible]	0.00
[illegible].0	355.4[illegible]	193[illegible]6.73
2[illegible]6.23	594.17	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
26	42533.[illegible]	71[illegible]9.[illegible]	30237.72

GNP/POP	CON/POP	LABOR
.339593[illegible]3	.1943411[illegible]	15428[illegible].90

DEFENSE	INVESTMENT	CONSUMPTION
3976.84	4312.32	2437.82
467.86	8035.5[illegible]	0.00
0.00	4[illegible]4.23	21940.39
233.93	5[illegible]3.9[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
27	4[illegible]8[illegible]1..	754[illegible]3.73	34670.35

GNP/POP	CON/POP	LABOR
.37865433	.21714415	156035.21

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]469.39	[illegible]8[illegible]5.4	2739.76
525.81	9037.0[illegible]	0.00
0.00	454.35	24657.86
262.91	[illegible]7.25	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
28	53234.0[illegible]	41537.9[illegible]	39560.10

GNP/POP	CON/POP	LABOR
.4[illegible]287254	.240[illegible]8[illegible]99	157791.38

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]977.35	5337.12	3051.16
565.57	1[illegible]119.5[illegible]	0.00
0.00	515.98	27460.44
292.79	8[illegible]3.3[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
29	58744.0[illegible]	471[illegible]1.20	44906.31

GNP/POP	CON/POP	LABOR
.45895223	.263[illegible]5306	159503.45

DEFENSE	INVESTMENT	CONSUMPTION
[illegible]492.56	5975.8[illegible]	3366.97
6[illegible]6.18	11137.2[illegible]	0.00
0.00	553.36	33302.74
323.09	9[illegible]7.5[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
3[illegible]	64267.[illegible]	53234.23	5[illegible]699.68

GNP/POP	CON/POP	LABOR
.49860375	.2557[illegible]373	161202.54

DEFENSE	INVESTMENT	CONSUMPTION
5006.95	6515.8[illegible]	3683.53
7[illegible]6.94	12217.2	0.00
0.00	51[illegible].35	33[illegible]1.75
3[illegible]3.47	1718.1	0.00

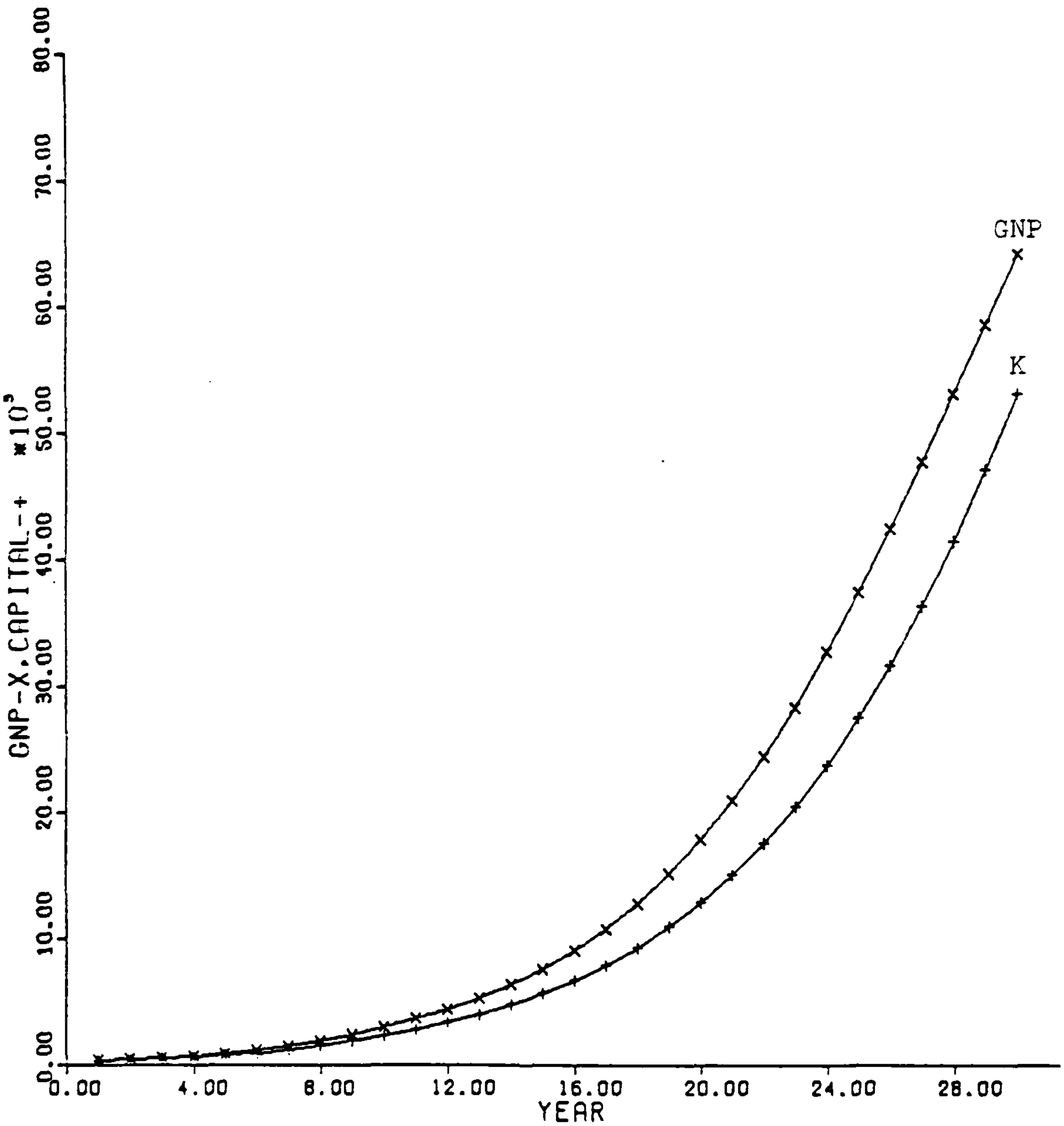

Figure B-1. Growth in GNP and Capital Stock (Nuclear Scenario - No Change in Death Rate)

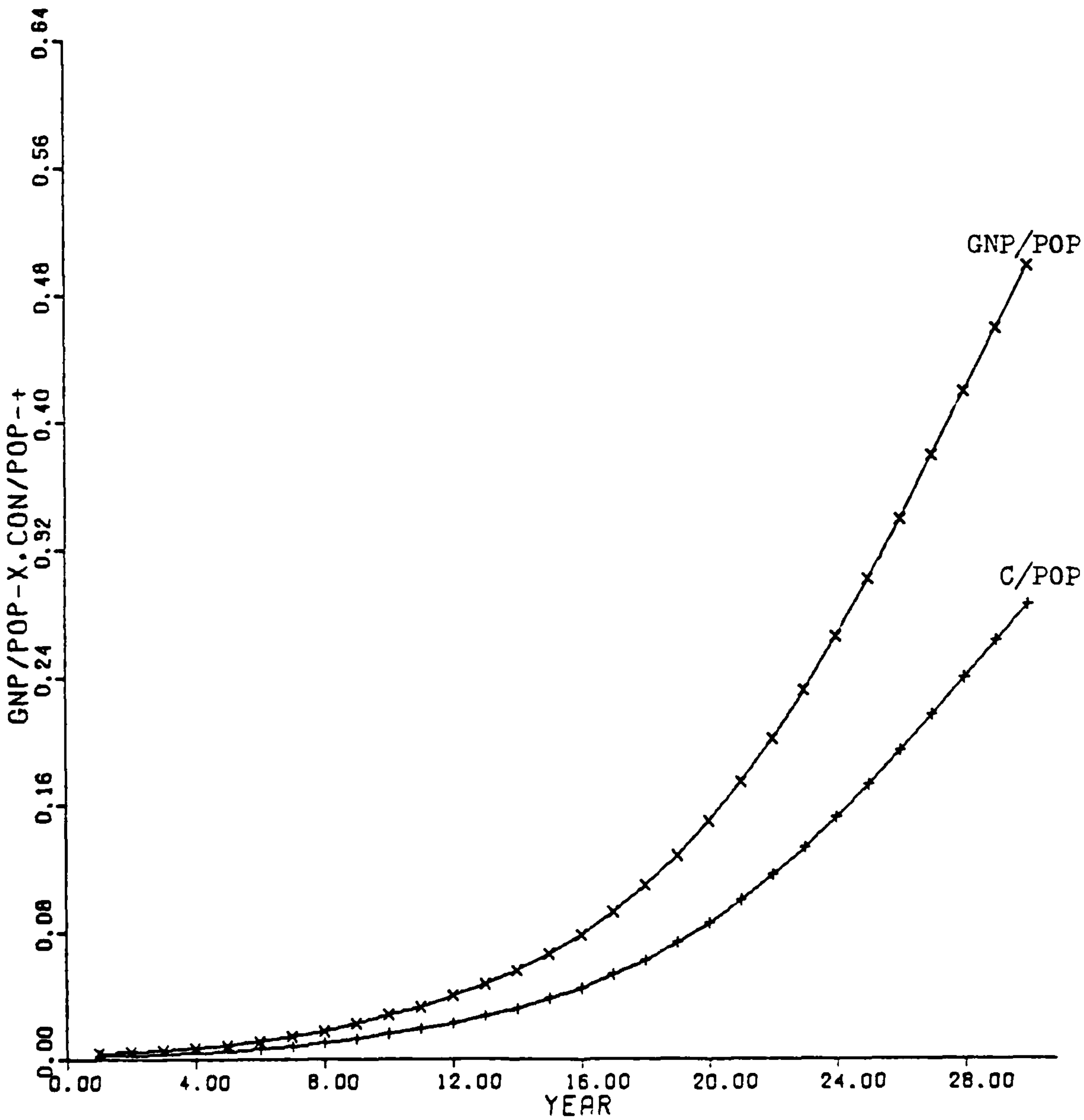

Figure B-2. Growth in GNP per Capita and Consumption per Capita (Nuclear Scenario - No Change in Death Rate)

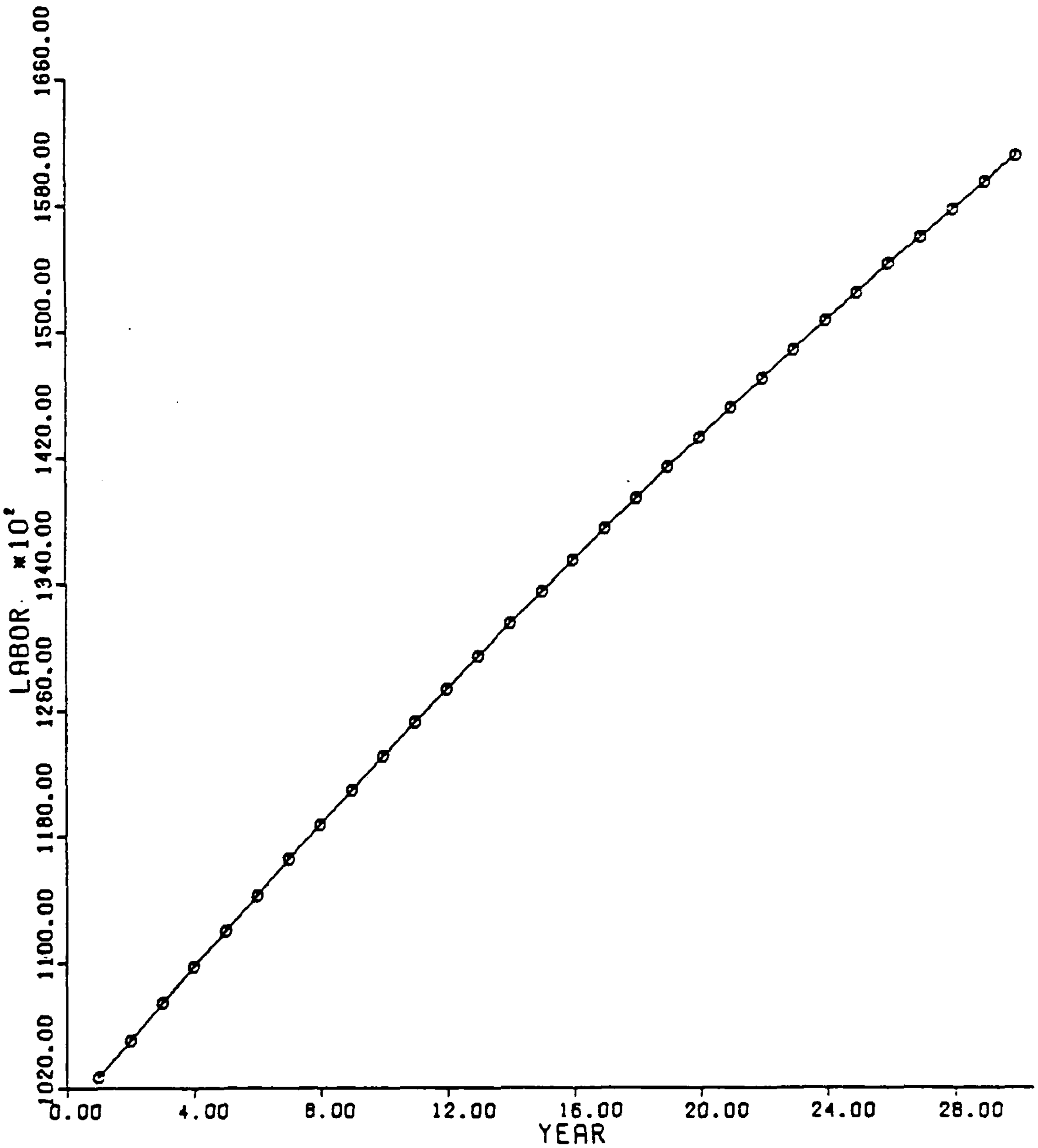

Figure B-3. Growth in Effective Labor
(Nuclear Scenario - No Change in Death Rate)

Nuclear Scenario - Increased Death Rate

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
1	376.00	316.0(	362.30

GNP/POP	CON/POP	LABOR
.00382460	.00219211	102708.64

DEFENSE	INVESTMENT	CONSUMPTION
35.16	38.98	21.55
4.14	71.40	0.10
0.00	3.57	193.96
2.07	5.95	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
2	470.00	391.95	373.38

GNP/POP	CON/POP	LABOR
.00474732	.00272997	104737.74

DEFENSE	INVESTMENT	CONSUMPTION
43.95	47.35	26.94
5.17	98.50	0.00
0.00	4.44	242.45
2.59	7.4	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
3	589.00	486.09	464.01

GNP/POP	CON/POP	LABOR
.0059486J	.00348657	106731.31

DEFENSE	INVESTMENT	CONSUMPTION
55.07	59.52	33.76
6.48	111.55	0.00
0.00	5.58	303.83
3.24	9.30	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
4	739.00	605.87	577.28

GNP/POP	CON/POP	LABOR
.00736372	.00422059	108713.76

DEFENSE	INVESTMENT	CONSUMPTION
69.10	74.83	42.36
8.13	140.40	0.00
0.00	7.02	381.21
4.06	11.70	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
5	931.[illegible]	[illegible].15	719.30

GNP/POP	CON/POP	LABOR
.0[illegible]921613	.[illegible]528272	11[illegible]642.98

DEFENSE	INVESTMENT	CONSUMPTION
87.05	[illegible]4.[illegible]	53.36
1[illegible].24	1[illegible]6.4[illegible]	0.00
0.00	[illegible].82	480.25
5.12	14.7[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
6	1174.0[illegible]	943.21	898.52

GNP/POP	CON/POP	LABOR
.01154713	.0055183[illegible]	112539.67

DEFENSE	INVESTMENT	CONSUMPTION
109.77	113.72	67.29
12.91	222.5[illegible]	0.00
0.00	11.13	605.60
6.46	18.5[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
7	1463.00	11[illegible].36	1124.36

GNP/POP	CON/POP	LABOR
.01449485	.0083078[illegible]	114422.81

DEFENSE	INVESTMENT	CONSUMPTION
138.66	15[illegible].[illegible]8	85.00
16.31	231.40	0.00
0.00	14.07	765.00
8.16	23.45	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
8	1877.00	1479.92	1409.65

GNP/POP	CON/POP	LABOR
.01823312	.0104525[illegible]	116268.56

DEFENSE	INVESTMENT	CONSUMPTION
175.50	19[illegible].[illegible]8	107.58
20.65	356.4[illegible]	0.00
0.00	17.82	968.24
10.32	29.7[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
9	2380.0[illegible]	1859.[illegible]8	1770.91

GNP/POP	CON/POP	LABOR
.02298[illegible]21	.01317134	118084.78

DEFENSE	INVESTMENT	CONSUMPTION
222.53	241.2[illegible]	135.41
26.18	452.4[illegible]	0.00

[illegible]	[illegible]	1227.71
13.[illegible]	[illegible]	[illegible]

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
10	3025.[illegible]	23[illegible].84	2228.64

GNP/POP	CON/POP	LABOR
.0290360[illegible]	.0155423[illegible]	119867.18

DEFENSE	INVESTMENT	CONSUMPTION
282.84	3[illegible]6.55	173.38
33.22	57[illegible].9[illegible]	0.00
[illegible]	[illegible].74	1560.43
16.64	[illegible]7.9	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
11	3658.[illegible]	28[illegible]4.67	2672.51

GNP/POP	CON/POP	LABOR
.03490953	.0[illegible]20[illegible]0875	121611.19

DEFENSE	INVESTMENT	CONSUMPTION
342.02	3[illegible].8[illegible]	219.66
40.24	535.4[illegible]	0.00
[illegible]	[illegible]4.7[illegible]	1866.96
20.12	[illegible]7.95	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
12	4410.0[illegible]	3353.82	3194.59

GNP/POP	CON/POP	LABOR
.04184841	.023[illegible]8583	123326.81

DEFENSE	INVESTMENT	CONSUMPTION
412.34	4[illegible]7.[illegible]	252.76
48.51	[illegible].2[illegible]	0.00
0.00	[illegible]1.91	2274.87
24.25	[illegible]9.35	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
13	53[illegible].[illegible]	4[illegible].77	[illegible]810.40

GNP/POP	CON/POP	LABOR
.05005348	.0285[illegible]855	125020.88

DEFENSE	INVESTMENT	CONSUMPTION
495.92	537.5[illegible]	3[illegible]4.00
58.34	1[illegible]9.[illegible]	0.00
0.00	[illegible]0.4[illegible]	2736.04
29.17	[illegible]4.[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
14	6353.[illegible]	4751.35	4535.24

GNP/POP	CON/POP	LABOR

.5972173	.342771	124673.43

DEFENSE	INVESTMENT	CONSUMPTION
594.94	6.5.12	364.70
69.93	1219.6	0.00
0.00	[illegible].48	3282.32
35.00	1[illegible].8[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
15	7613.0[illegible]	5553.48	5384.44

GNP/POP	CON/POP	LABOR
.07107448	.04073775	126265.90

DEFENSE	INVESTMENT	CONSUMPTION
711.82	7[illegible]1.84	436.35
83.74	1417.27	0.00
0.00	[illegible]2.35	3927.12
41.87	12[illegible].6[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
16	9085.0[illegible]	5597.41	6378.81

GNP/POP	CON/POP	LABOR
.08438490	.04836603	129851.24

DEFENSE	INVESTMENT	CONSUMPTION
849.54	923.95	520.77
99.95	1726.37	0.00
0.00	36.34	4686.96
49.97	1[illegible]3.9[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
17	10811.0[illegible]	7915.26	7539.59

GNP/POP	CON/POP	LABOR
.09989356	.05725499	131417.32

DEFENSE	INVESTMENT	CONSUMPTION
1010.83	1096.07	619.64
118.92	2055.01	0.00
0.00	1[illegible]2.75	5576.79
59.46	1[illegible]1.25	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
18	12825.0[illegible]	9335.46	8891.21

GNP/POP	CON/POP	LABOR
.11791063	.06759155	132953.72

DEFENSE	INVESTMENT	CONSUMPTION
1199.14	1310.16	735.08
141.08	243[illegible].8[illegible]	0.00
0.00	121.39	6615.70
70.54	2[illegible]3.13	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
19	15153.[illegible]	1[illegible]957.42	1[illegible]461.72

GNP/POP	CON/POP	LABOR
.13672263	.[illegible]79[illegible]1[illegible]35	134[illegible]49.31

DEFENSE	INVESTMENT	CONSUMPTION
1417.74	15[illegible]7.28	869.08
166.79	29[illegible]2.4[illegible]	0.00
0.00	1[illegible]4.12	7821.74
83.40	2[illegible]9.2[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
20	17855.00	12991.14	12278.17

GNP/POP	CON/POP	LABOR
.10256686	.[illegible]9317587	135919.50

DEFENSE	INVESTMENT	CONSUMPTION
1669.44	181[illegible].2[illegible]	1023.38
196.41	3394.2[illegible]	0.00
1.00	159.71	9210.39
98.2[illegible]	232.85	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
21	20929.00	15391.29	14373.00

GNP/POP	CON/POP	LABOR
.18965804	.108[illegible]344[illegible]	137360.56

DEFENSE	INVESTMENT	CONSUMPTION
1956.86	2121.92	1199.57
230.22	39[illegible]8.5[illegible]	0.00
0.00	198.93	10796.10
115.11	331.55	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
22	244[illegible]2.0[illegible]	1[illegible]51[illegible].88	16779.25

GNP/POP	CON/POP	LABOR
.22[illegible]10956	.12515799	138778.26

DEFENSE	INVESTMENT	CONSUMPTION
2261.59	24[illegible]3.92	1398.63
268.42	4539.5[illegible]	0.00
0.00	2[illegible]1.93	12587.63
134.21	3[illegible]5.5[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
23	28271.0[illegible]	2[illegible]5[illegible]4.75	19528.49

GNP/POP	CON/POP	LABOR
.25385431	.145[illegible]9917	140174.54

DEFENSE	INVESTMENT	CONSUMPTION
2643.34	2[illegible]5.2[illegible]	1620.36

311.98	5374.27	0.00
0.00	238.72	14563.43
155.49	467.87	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
24	32515.[illegible]	23793.41	22651.41

GNP/POP	CON/POP	LABOR
.29066669	.16659852	141545.99

DEFENSE	INVESTMENT	CONSUMPTION
3040.15	3235.6[illegible]	1863.63
357.67	6131.2	0.00
0.00	309.05	16772.67
178.83	515.1[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
25	37089.[illegible]	27483.93	26172.66

GNP/POP	CON/POP	LABOR
.33011263	.18928734	142895.04

DEFENSE	INVESTMENT	CONSUMPTION
3467.82	3753.32	2125.79
407.98	7039.69	0.00
0.00	352.53	19132.14
203.99	537.55	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
26	41927.[illegible]	31517.85	30113.36

GNP/POP	CON/POP	LABOR
.37158033	.21237498	144209.70

DEFENSE	INVESTMENT	CONSUMPTION
3920.17	4257.83	2403.09
461.20	7970.41	0.00
0.00	398.52	21627.79
230.60	654.21	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
27	46952.[illegible]	35205.27	34483.13

GNP/POP	CON/POP	LABOR
.41437217	.23750155	145512.09

DEFENSE	INVESTMENT	CONSUMPTION
4398.01	4757.32	2691.10
516.47	8925.57	0.00
0.00	446.29	24219.91
258.24	743.81	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
28	52037.[illegible]	412[illegible].25	39286.22

GNP/POP CON/POP LABOR

.4578125	.252794[illegible]	14685[illegible].21

DEFENSE	INVESTMENT	CONSUMPTION
4870.13	523[illegible].35	2985.42
572.96	99[illegible]1.3[illegible]	0.00
0.00	435.39	26668.77
286.46	925.1[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
29	57247.00	467[illegible]1.60	44517.33

GNP/POP	CON/POP	LABOR
.50112707	.287225[illegible]	148057.23

DEFENSE	INVESTMENT	CONSUMPTION
5352.59	59[illegible]4.15	3281.17
629.72	10832.8[illegible]	0.00
0.00	5[illegible]4.14	29530.52
314.86	9[illegible]6.9[illegible]	0.00

YEAR	GNP	CAPITAL(A)	CAPITAL(R)
30	62378.00	52659.61	50162.20

GNP/POP	CON/POP	LABOR
.54381401	.3115924[illegible]	149295.27

DEFENSE	INVESTMENT	CONSUMPTION
5831.60	5323.52	3574.80
686.07	11955.60	0.00
0.00	532.83	32173.19
343.04	959.05	0.00

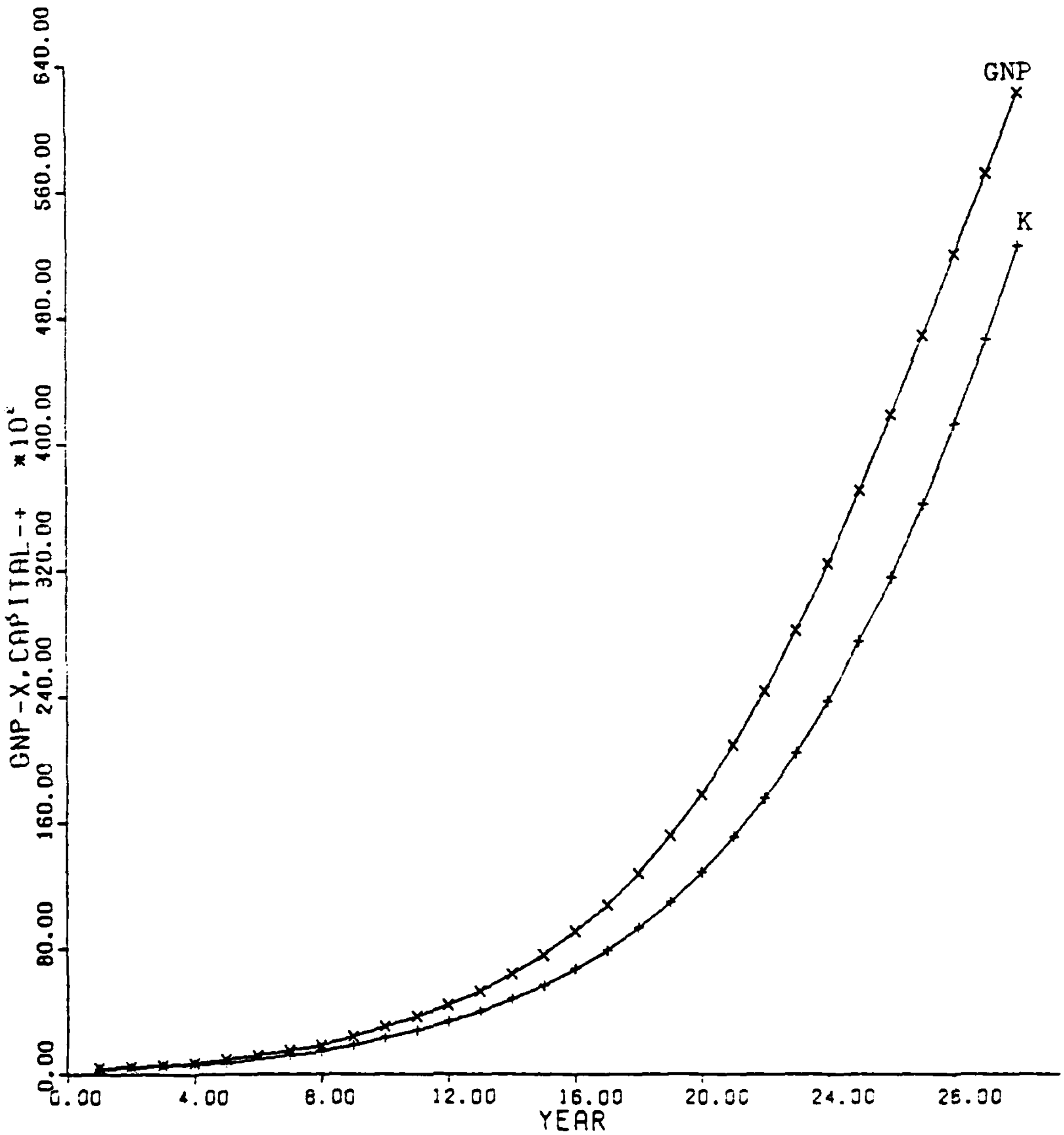

Figure B-4. Growth in GNP and Capital Stock (Nuclear Scenario - Increased Death Rate)

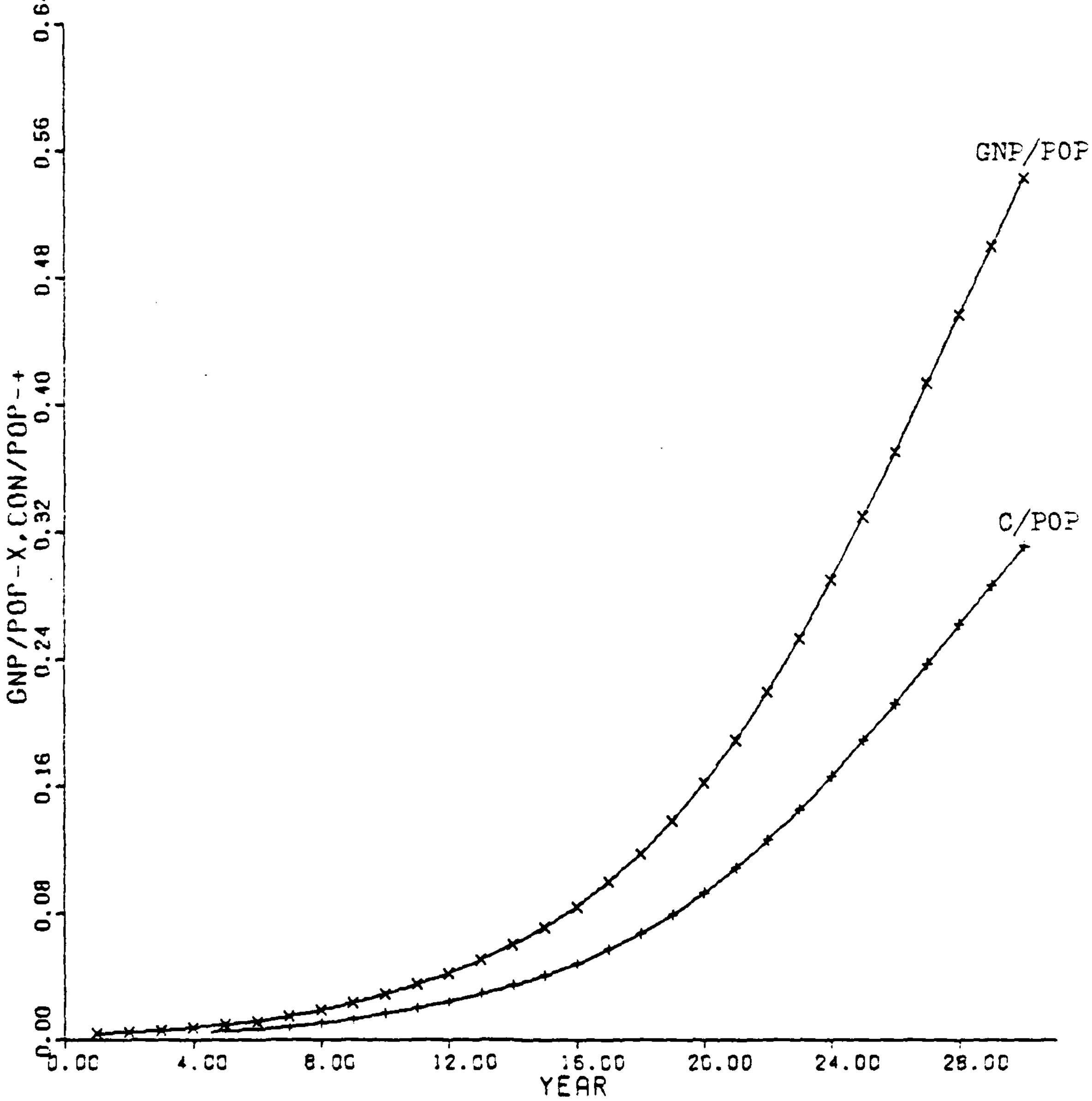

Figure B-5. Growth in GNP per Capita and Consumption per Capita (Nuclear Scenario - Increased Death Rate)

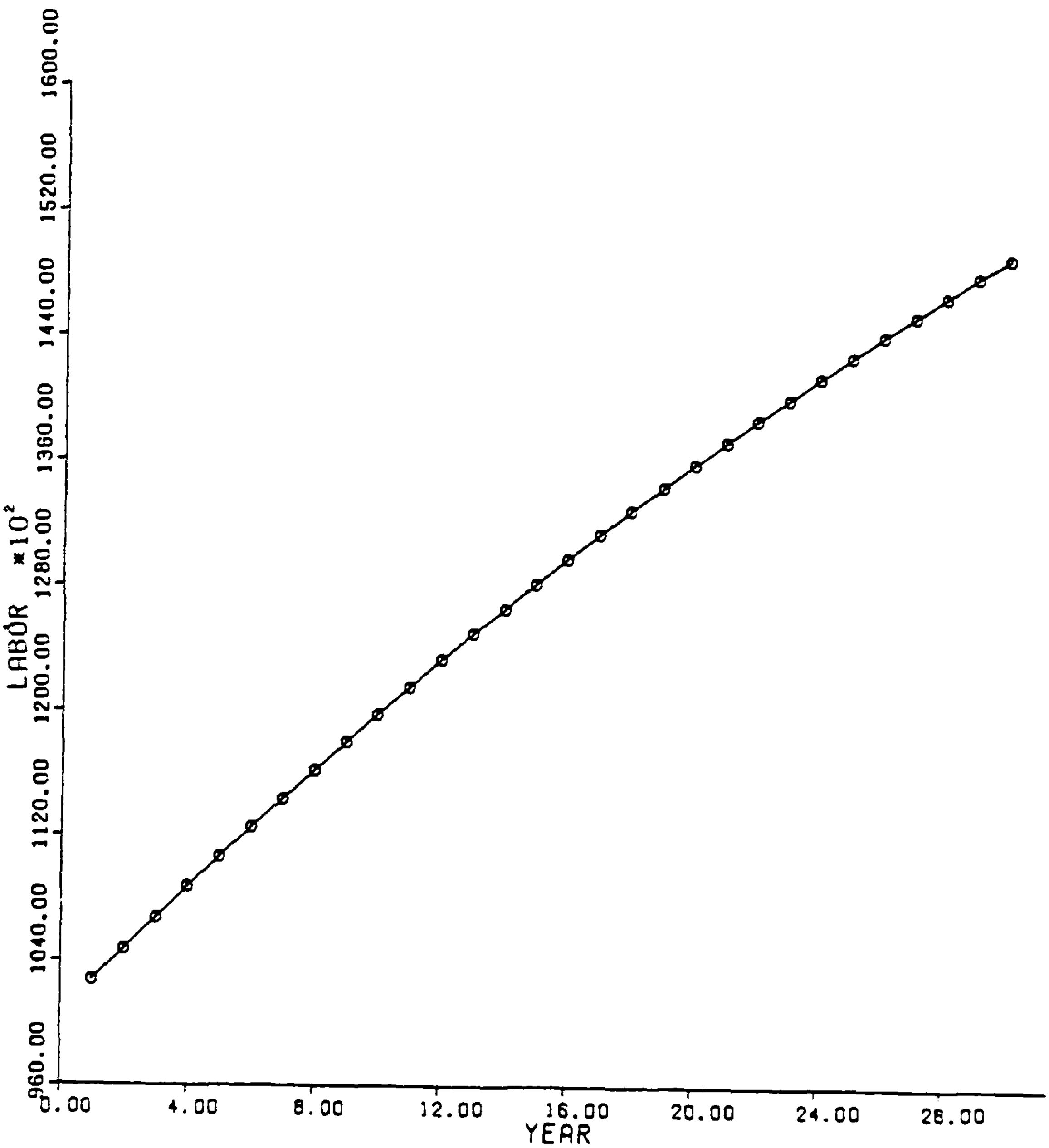

Figure B-6. Growth in Effective Labor
(Nuclear Scenario - Increased Death Rate)

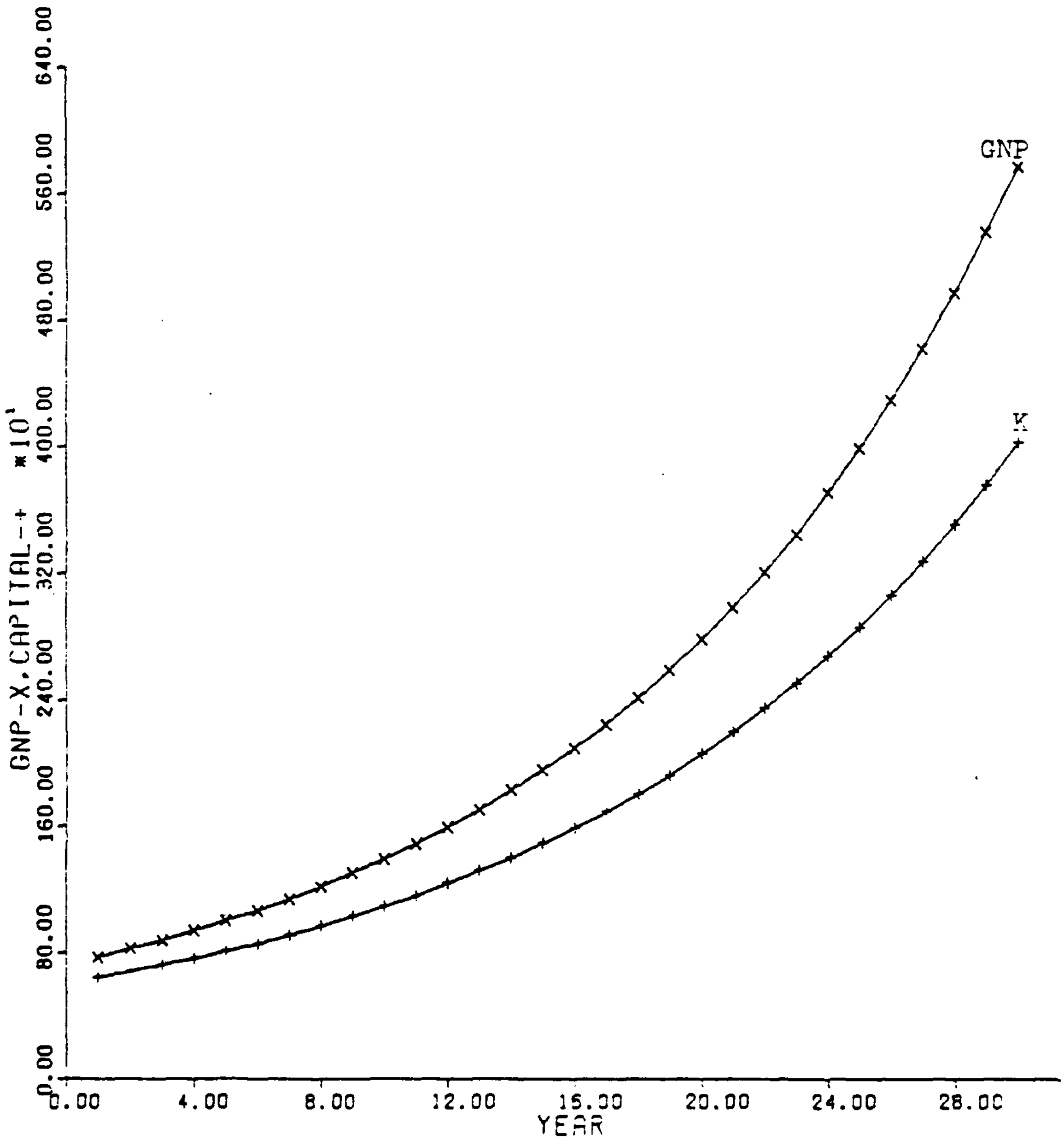

Figure B-7. Growth in GNP and Capital Stock
(5% Growth in Net Investment - Base Case)

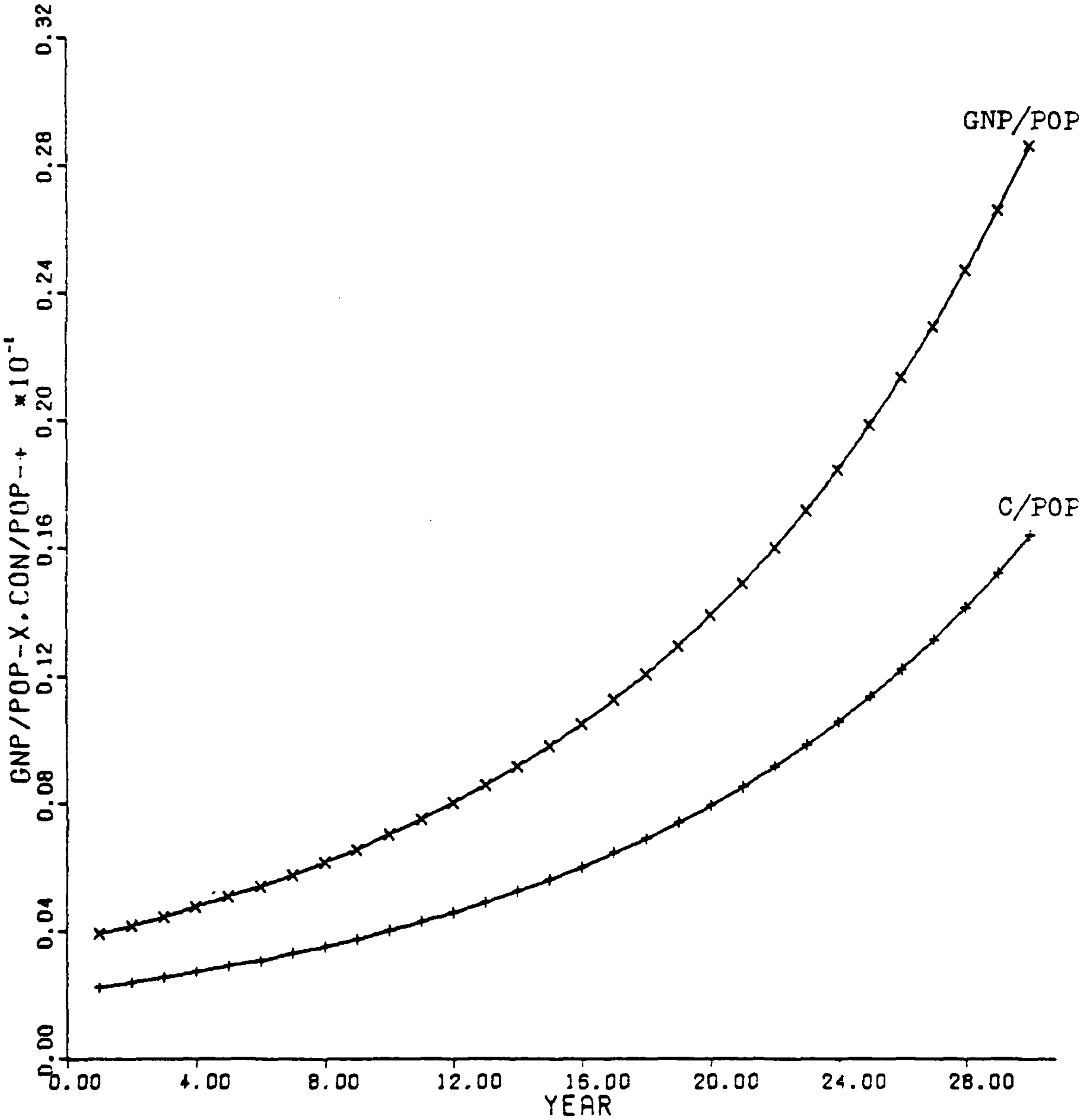

Figure B-8. Growth in GNP per Capita and Consumption per Capita (5% Growth in Net Investment - Base Case)

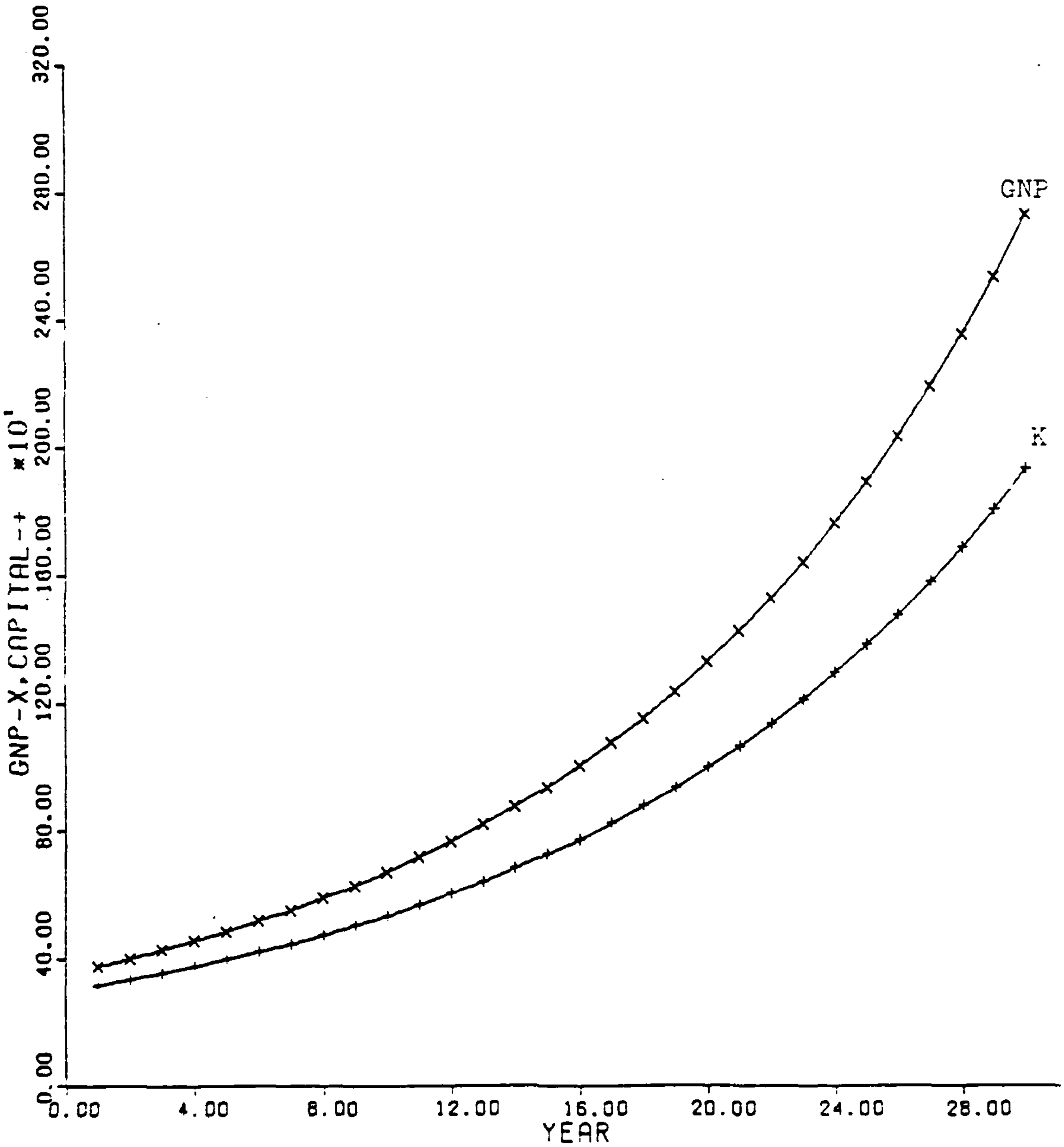

Figure B-9. Growth in GNP and Capital Stock
(5% Growth in Net Investment - Nuclear Scenario)

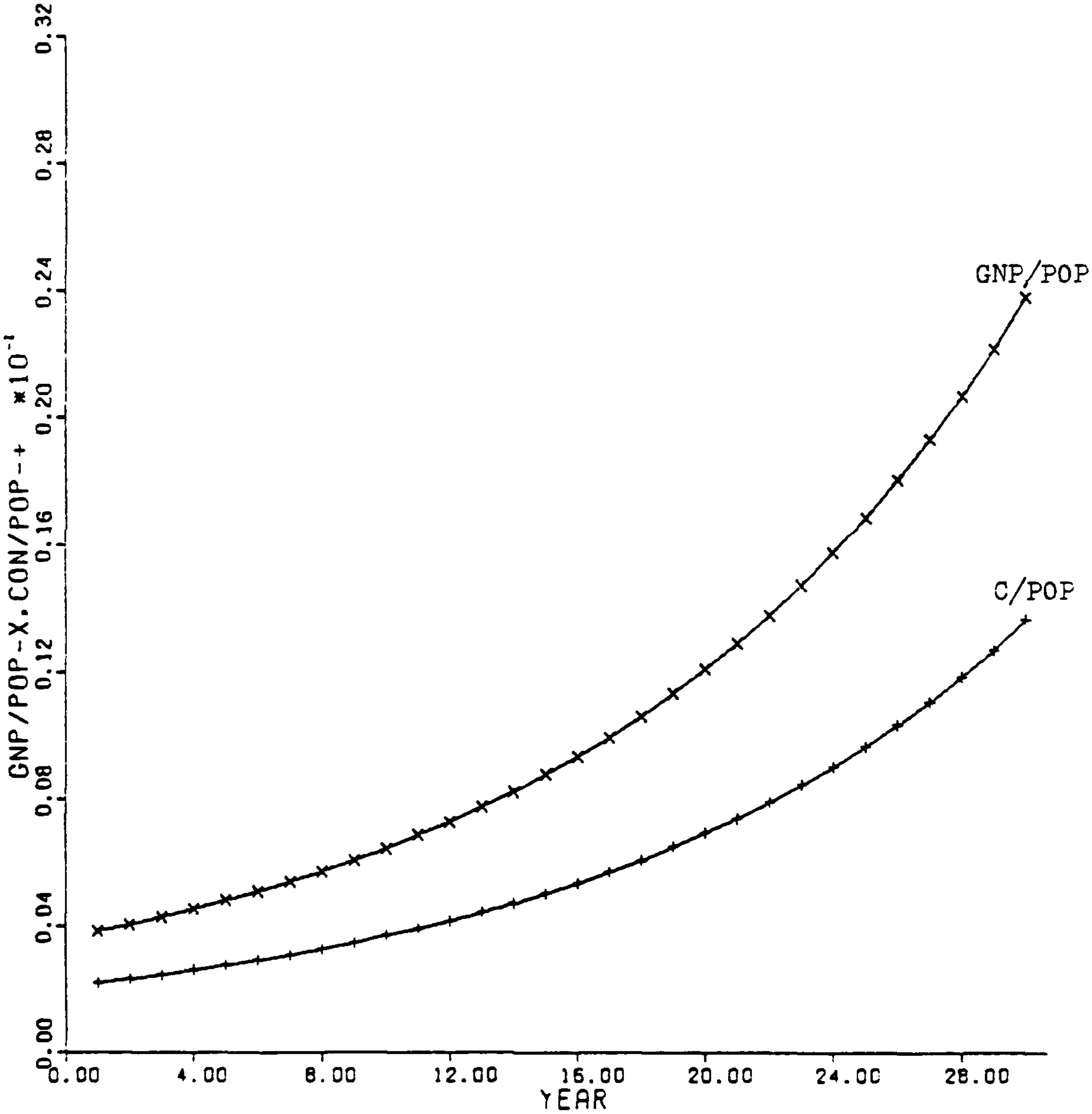

Figure B-10. Growth in GNP per Capita and Consumption per Capita (5% Growth in Net Investment - Nuclear Scenario)

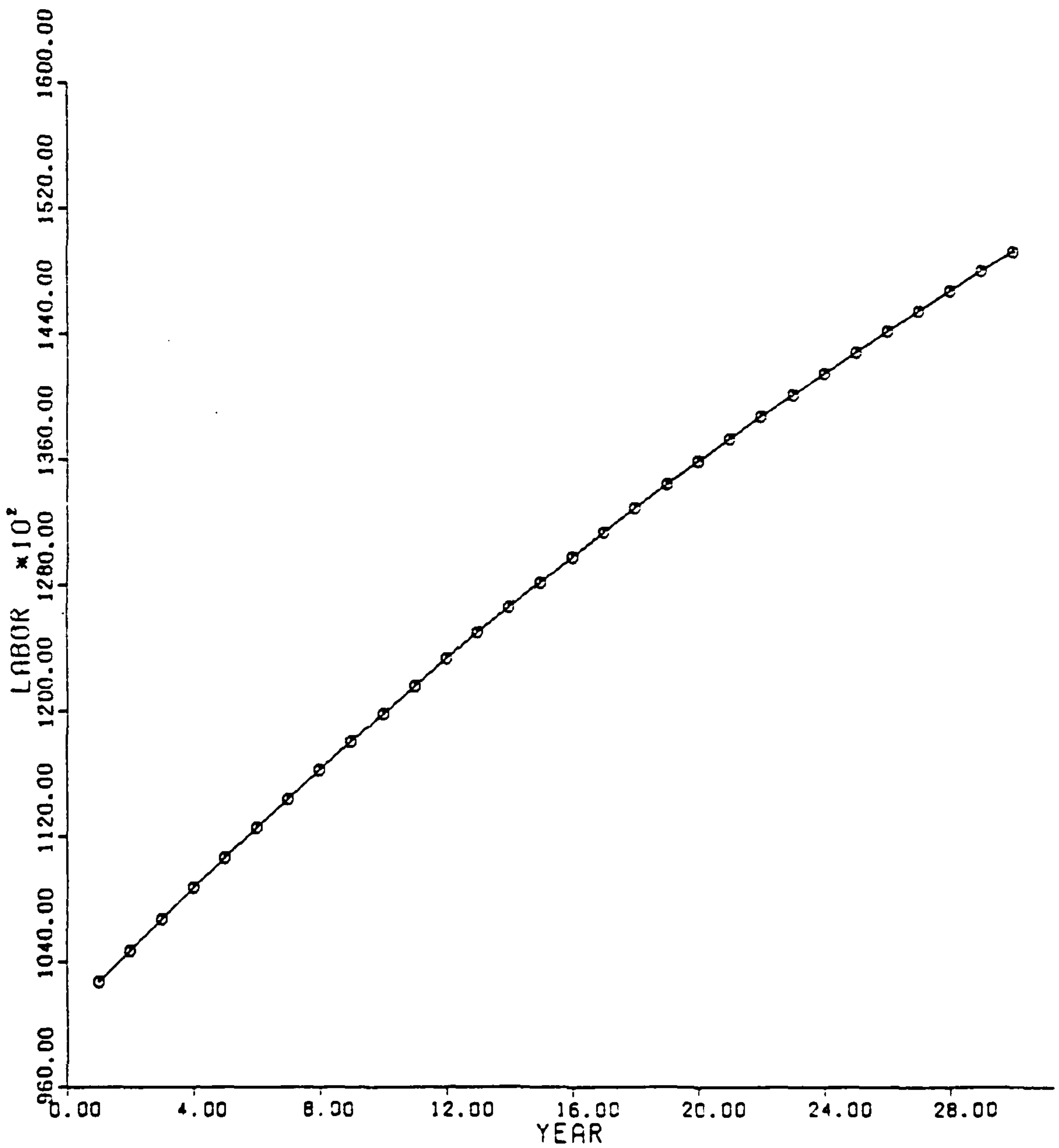

Figure B-11. Growth in Effective Labor (5% Growth in Net Investment - Nuclear Scenario)

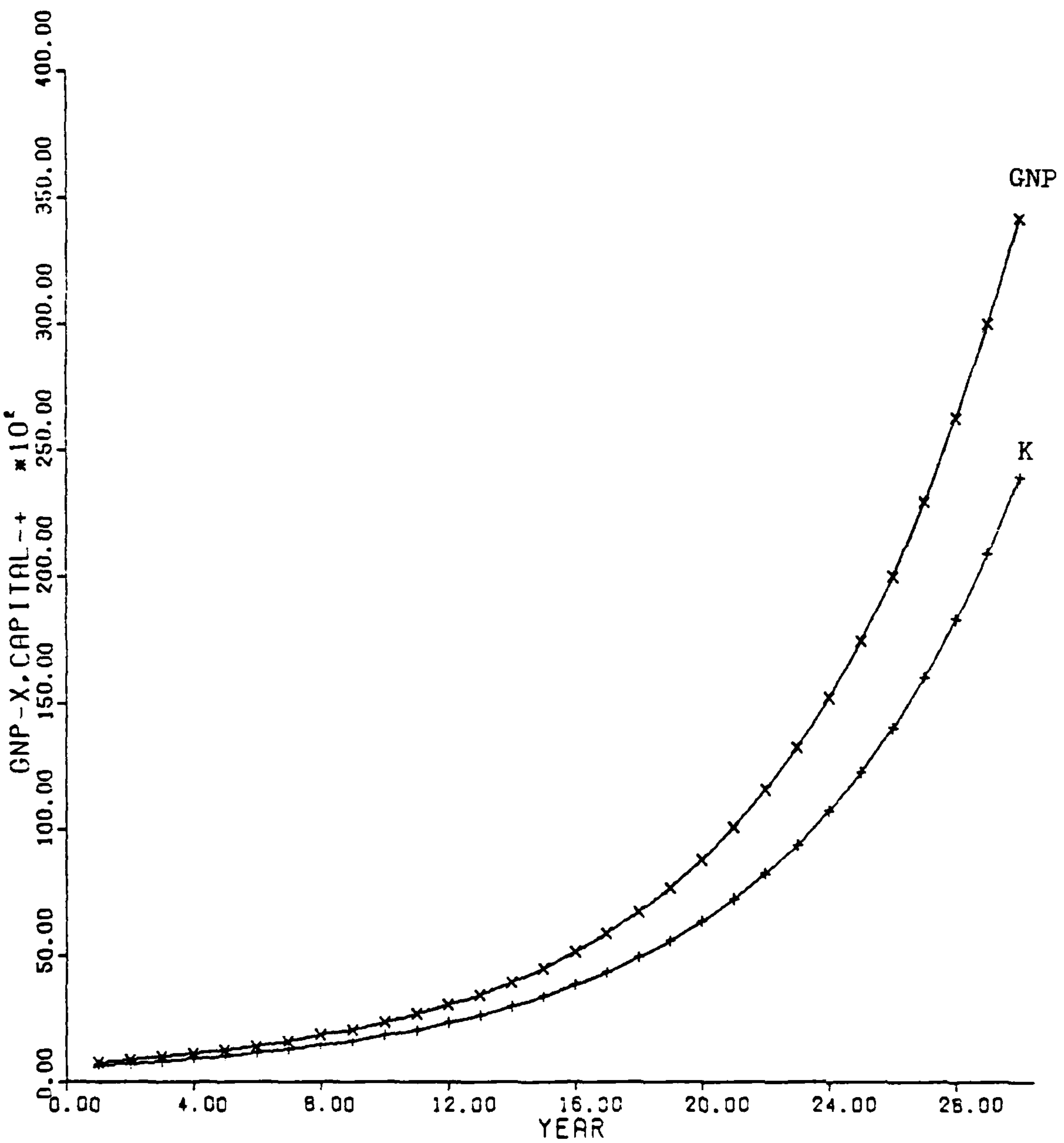

Figure B-12. Growth in GNP and Capital Stock (10% Growth in Net Investment - Base Case)

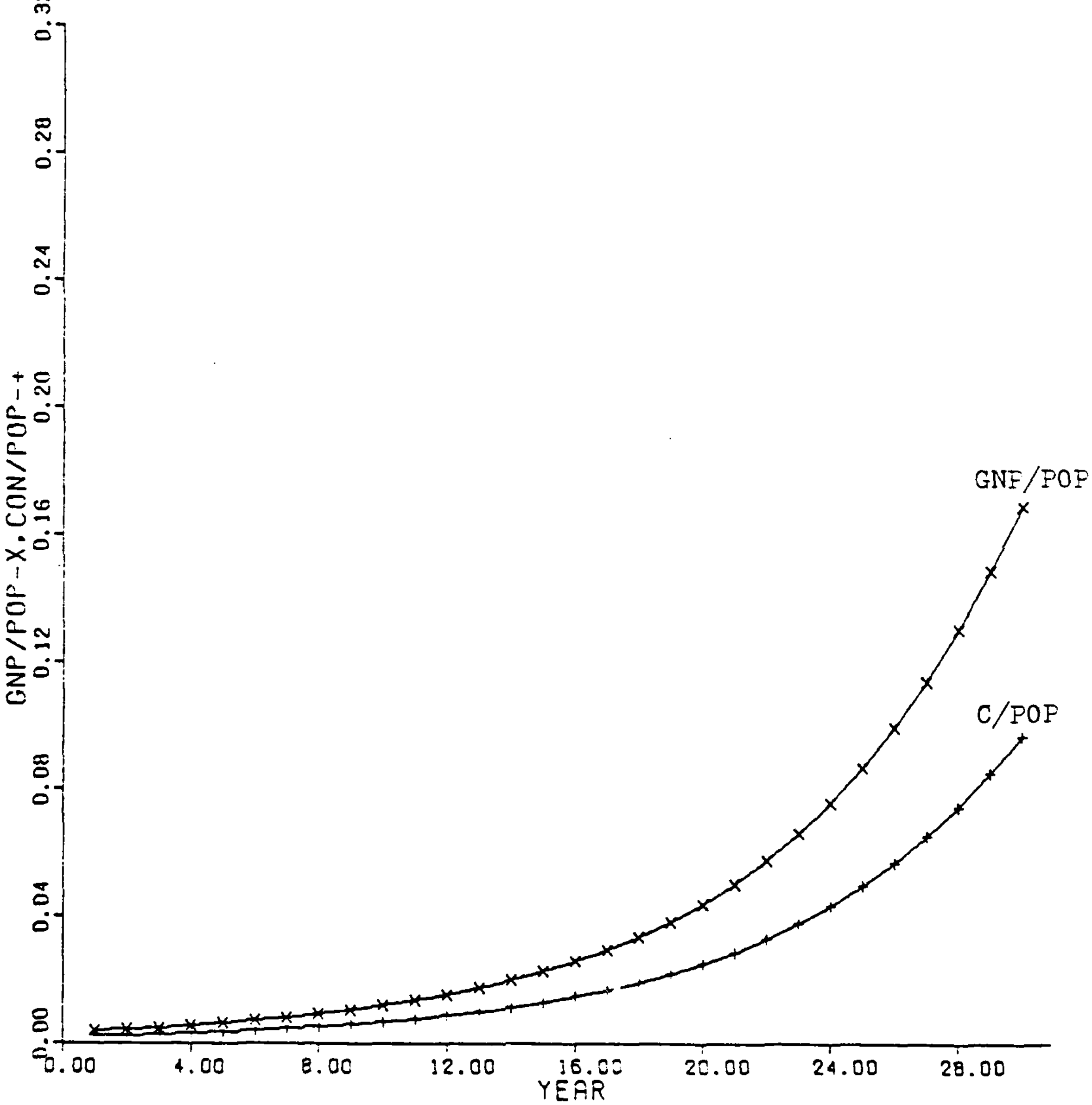

Figure B-13. Growth in GNP per Capita and Consumption per Capita (10% Growth in Net Investment - Base Case)

Vita

Edward Joseph Perry II was born in Southbridge, Massachusetts, on October 25, 1954. He graduated from Marianhill Central Catholic High School in Massachusetts in 1972 and attended Worcester Polytechnic Institute from which he graduated in 1976. He entered the Air Force in October 1976 and was assigned to Robins AFB, Georgia, as a plans and programming officer in the Data Automation Branch. In 1978 he was assigned to the Foreign Technology Division at Wright-Patterson AFB, Ohio, as a computer systems analyst and entered the Air Force Institute of Technology in June 1980.

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